Association for Information Systems
AIS Electronic Library (AISeL)

ICIS 2001 Proceedings

International Conference on Information Systems (ICIS)

December 2001

The Mechanics of Internet Diffusion in India: Lessons for Developing Countries

Amitava Dutta
George Mason Unviersity

Rahul Roy
University of Northern Iowa

THE MECHANICS OF INTERNET DIFFUSION IN INDIA: LESSONS FOR DEVELOPING COUNTRIES

Amitava Dutta
School of Management
George Mason University
adutta@gmu.edu

Rahul Roy[1]
College of Business Administration
University of Northern Iowa
Rahul.roy@uni.edu

Abstract

The issue of Internet diffusion in an economy over time is of interest to several stakeholders, including policy makers, regulators, investors, and businesses. It is particularly important in developing countries, which see the Internet as a major driver in achieving social and developmental goals. Concerns about the so-called "digital divide" also lend some urgency to the issue. However, Internet diffusion is driven by social as well as technical factors, and developing countries have distinctive characteristics that make their adoption process different from that in industrialized countries. This paper develops a causal model of Internet diffusion in developing countries, using the systems dynamics methodology. The modeling approach allows us to combine standard contagion mechanisms inherent in diffusion, such as innovators and imitators, with the distinctive regulatory, economic, and social circumstances in developing countries. The structure of the model is first justified using India as a specific developing country context. Next, the simulated values generated by this structural model are compared against actual values for Internet adoption in India for the period 1996–2001, and the fit is found to be reasonably good. These initial findings support model validity. Using a technique called dominant loop analysis the model suggests that, among all the different drivers, poor telecommunications infrastructure and high telephone charges are the major barriers to diffusion. In conclusion, we discuss the issues to be addressed in the remainder of this ongoing work.

Keywords: Technology diffusion, developing economies, systems dynamics, feedback models.

INTRODUCTION

The ability of the Internet to significantly impact social and economic activity is well established. It has spawned inquiry into a host of issues to understand and manage this impact. This research examines the issue of Internet diffusion in developing countries. We wish to capture the relationship among drivers of diffusion through a causal model, thereby gaining a better understanding of the mechanics of Internet diffusion in these countries. The research is motivated by the following observations.

Internet diffusion is of interest to a variety of stakeholders, regardless of country type. They include regulators (Taylor 1999), telecommunications service providers (Pert 2000), investors (Ybarra 2000), and business organizations (Ulfedar 2000). However, interest is especially strong in developing countries seeking to meet various developmental goals (Sprano and Zakak 2000; Woodall 2000). There is a sense of urgency in improving their infrastructure, stemming from concern that disparities between the world's haves and have-nots may increase in the Internet enabled economy (Luff 2000; Persaud 2000). However, their socioeconomic characteristics make the diffusion process different from that in industrialized countries (Peha 1999). The distinctiveness and urgency of Internet diffusion in the developing country context is, therefore, one motivation for this research.

[1]On leave from the Indian Institute of Management, Calcutta.

A second motivation is the modeling approach to be used. For developing countries, with their desire to expand and leverage nascent Internet sectors, it is desirable that the chosen modeling approach yields insights into the mechanics of diffusion in this distinctive context. We, therefore, propose to develop a causal model of the diffusion process using the systems dynamics (SD) methodology, which has seen infrequent application in the IS literature.

The paper is organized as follows. The next section summarizes Internet growth in India, using it to illustrate typical characteristics of developing countries relevant to Internet diffusion. The case for the SD approach is made in the following section. The model itself is presented and initial validity tests are shown using data for India. Tentative conclusions are offered.

INTERNET GROWTH IN INDIA: AN OVERVIEW

Internet service in India started in 1994 with government being the monopoly provider. Service was costly and unreliable and by 1996 there were only 4,000 subscribers nationwide. In 1998, the ISP market was deregulated. By 2000, there were 225 ISPs (India Infoline 2001) and prices had dropped 60%. PC prices also dropped significantly owing to lowering of import duties. The subscriber base then grew rapidly, reaching 1.8 million in January 2001. E-mail and chat are the most popular applications (Natarajan 1999). E-commerce is yet to find wide acceptance but is expected to touch $2.3 billion by 2002 (Pai 2000a). PC penetration in urban middle class households has increased in recent times (Dataquest 2000; Pai 2000b), and has led to an increase in Internet subscribers. The popularity of the Internet has also had a feedback effect on PC sales (Dataquest 2000).

The demand for bandwidth outstrips supply thirty-fold (Desai 2001). As of December 2000, there were only 28 million telephone lines—equal to a tele-density of 3.5/100 persons. Alternatives to analog modems, such as ISDN lines or cable modems, are limited. Regulations have also stifled Internet growth. The ban on Internet telephony and the requirement to obtain security clearance before setting up an international gateway are two examples. In short, Internet diffusion in India started very recently and is characterized by high telephone charges, limited customer acceptance of E-commerce applications, limited telecommunications infrastructure, and restrictive regulations. These characteristics are prevalent in many other developing countries as well.

MODELING INTERNET GROWTH

Earlier work (Gurbaxani 1990; Rai et al. 1998) on modeling Internet growth has been based on contagion effects from diffusion of innovation theories (Rogers 1995). Clearly, contagion is a core mechanism underlying diffusion. Interestingly however, Rai et al., using data from 1980 through 1997, found that the logistic and Gompertz models had poorer predictive validity compared to the exponential model. The first two models are based on contagion mechanics but the last is not. The authors surmise that contagion alone may not provide adequate understanding of Internet growth since it "ignores external factors such as government policy and sponsorship….and technological developments" (Rai et al. 1998). A model that combines contagion effects and their interaction with external factors may yield a more complete understanding of the mechanics of Internet diffusion in developing countries.

A variety of methods are available for representing dynamic processes. We have chosen SD (Sterman 2000) for the following reasons. The main structural element in an SD model is the feedback loop, making it well suited for capturing the interaction among different drivers of diffusion over time. SD can represent quantifiable as well as "soft" variables, which is useful since the diffusion context has both social and technical aspects. Delays can also be modeled, and this feature is needed to represent certain social mechanisms. Moreover, SD models can be simulated, providing a platform on which to test scenarios for policy analysis. SD models can also be used for forecasting (Lyenis 2000).

The basic premise in SD is that system behavior results from interaction among its feedback loops. Model building begins with development of a causal loop graph that consists of a collection causal links, each having a certain polarity. A positive (negative) link implies a reinforcing (balancing) relation where a positive change in the cause results in a positive (negative) change in the effect. A small line intersecting the causal link represents delays in an effect. A causal loop is formed by a closed sequence of causal links, and loop polarity can be easily determined from individual link polarities. The causal loop graph leads to a mathematical model wherein relationships are depicted by means of time varying difference equations (Sterman 2000). What-if analysis is carried out by simulating the mathematical model under different parametric and structural alternatives.

AN SD MODEL OF INTERNET GROWTH IN DEVELOPING COUNTRIES

Figure 1 shows the causal loop diagram for our diffusion model. The first step in validation is to justify each of its structural components. Due to space constraints, we will not discuss the basis for each and every causal link in Figure 1. Instead, we discuss the foundation for its core component, followed by selected components that capture external factors typical of developing countries. At its core lies contagion-based Internet Adoption by which PC Owners become Internet Subscribers. Contagion is driven by the Innovation Coefficient and Imitation Coefficient in the same manner as in (Bass 1969). If the model did not have any other structural components, the causal loop structure consisting of the above five variables would yield the familiar S-shaped diffusion curve.

However, as discussed earlier, it is necessary to augment the basic contagion mechanism with external factors typical of developing countries. In Figure 1, this is achieved by having contagion parameters be driven by external factors such as PC price, tele-density, and the level of competition allowed by regulation. We now discuss the basis for selected structural components linking external factors to the core contagion structure.

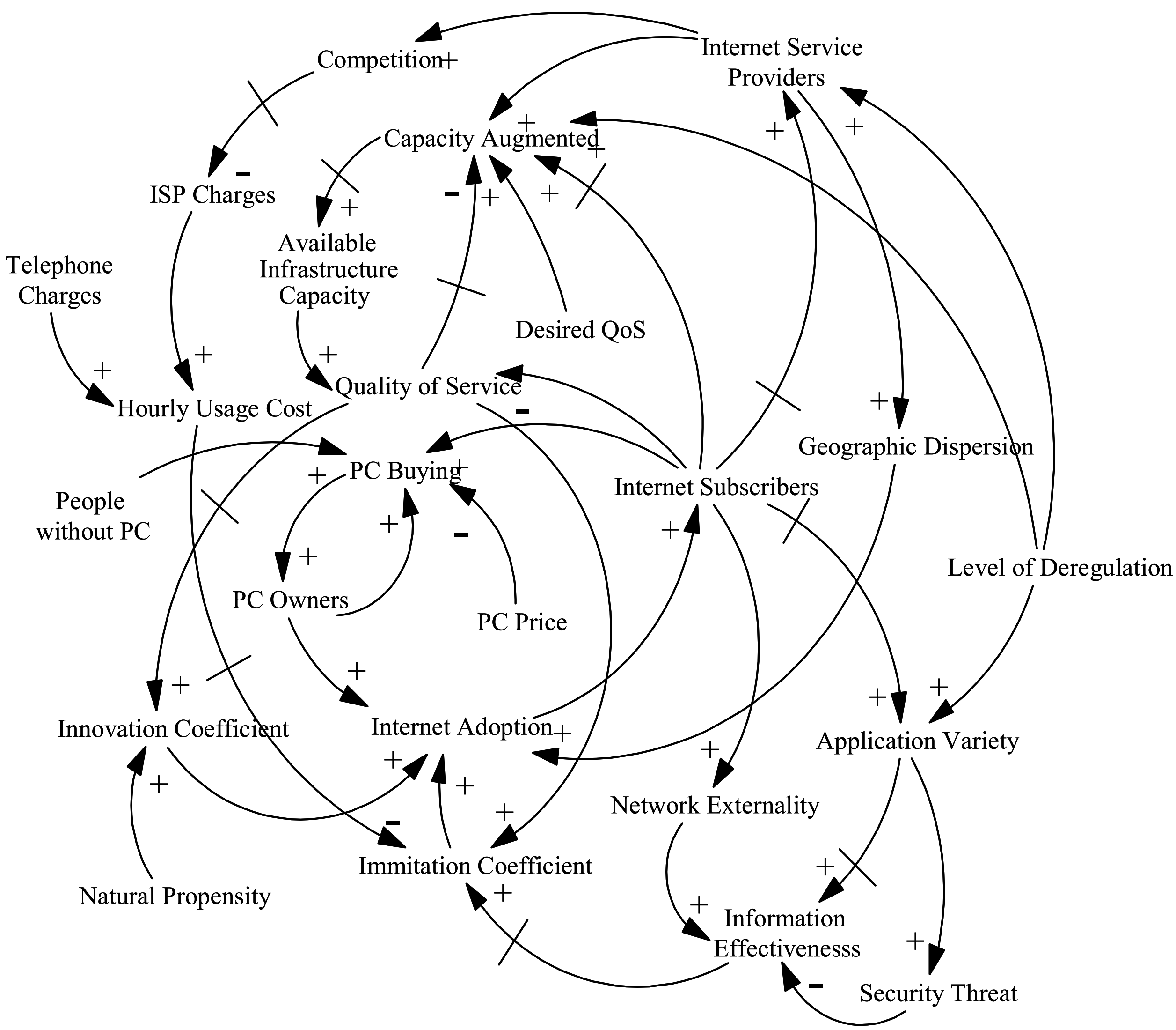

Figure1. Causal Loop Diagram for Internet Adoption in Developing Countries

The causal chain connecting Internet Subscribers, PC Buying, PC Owners, and PC Price captures the observation made earlier that increased Internet diffusion is having a feedback effect on PC Buying. The contagion parameter Imitation Coefficient has a positive link from Application Variety, which in turn has a positive link from Internet Subscribers. It was noted that application variety is currently limited among developing country users, but is expected to pick up with wider diffusion of the Internet. In many developing countries, customers face usage-based call charges in addition to ISP charges. Typically, ISP charges have dropped drastically due to competition, but monopoly telephone charges have not. Accordingly, Figure 1 shows two separate price components: ISP Charges and Telephone Charges. There is a negative polarity chain from Internet Service Providers to ISP Charges (via Competition), which causes access charges to drop with competition. Next, note the positive link from Level of Deregulation to Internet Service Providers, and the positive link from the former to Application Variety. Recall the restrictive regulations reported earlier. As they are eased, we can expect application variety and competition to increase. The two links just noted capture this causal mechanism.

Another typical characteristic of developing countries noted earlier was the disparity between bandwidth demand and supply. Figure 1 shows a negative link from Internet Subscribers to Quality of Service, while there is a positive link from Available Infrastructure Capacity to the latter. In turn Quality of Service is linked to Capacity Augmentations as is Level of Deregulation. By following the polarity of these links, it is not hard to see how Figure 1 captures the impact of regulation on this disparity. In short, the causal loop diagram in Figure 1 structurally integrates many factors typical of developing countries with the basic contagion mechanism that underlies Internet diffusion. We expect to refine this structural model in the course of completing the research.

MODEL VALIDATION: REPLICATING OBSERVED BEHAVIOR

The second stage in validating an SD model is to see if it can replicate observed behavior. The model in Figure 1 was converted into the corresponding difference equations (Sterman 2000), and then implemented using the iThink® package. Figures 2 and 3 compare simulated and observed behavior, of subscriber base and growth rates respectively, using quarterly data for India from 1996 to January 2001 (21 data points). The goodness of fit results shown in Table 1 are quite reasonable, although tentative given the limited data. They offer initial support for model validity. Additional tests are planned using data from more developing countries.

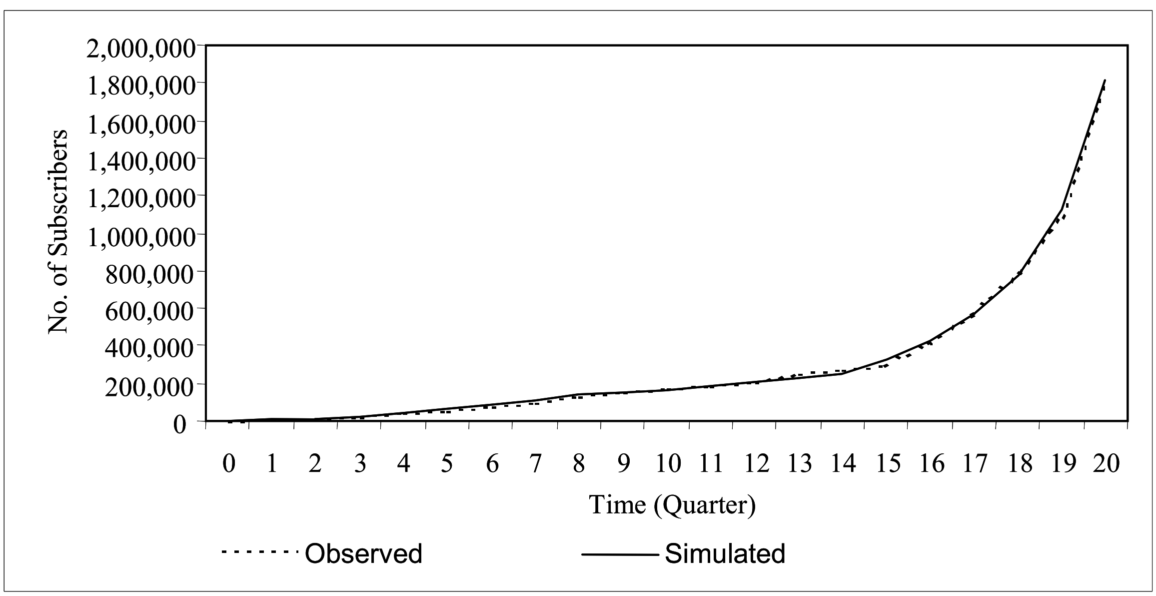

Figure 2. Number of Subscribers—Simulated versus Observed

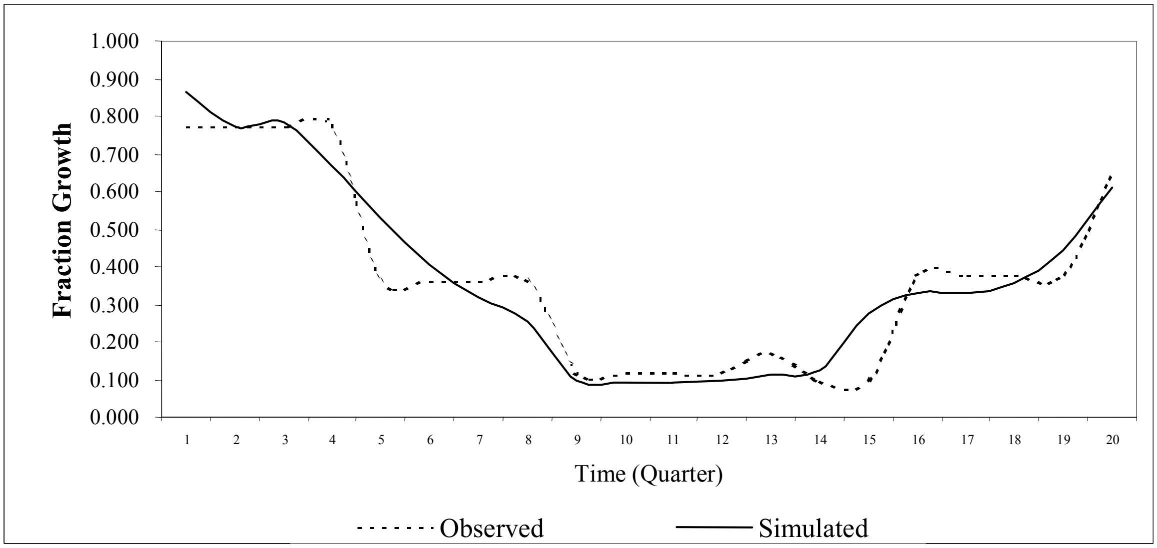

Figure 3. Subscriber Growth Rate—Simulated versus Observed

Table 1. Goodness of Fit India Growth Data (1996–2001)
Number of Subscribers

Number of observations = 21
Mean Absolute Percentage Error or MAPE = $\{\sum_{\#obs} \frac{\lvert simulated - observed \rvert}{observed}\}/\{\#Observations\} = 4.95\%$
Logarithm(observed number of subscribers) vs. Logarithm(simulated number of subscribers).
Correlation: 0.9993
Linear Regression analysis: R^2 = .9986, Slope = 0.9893, t-statistic= 117.51, P= 0.0000

The validated model provides a synthetic environment in which to analyze the effect of different external factors. We used a method known as loop dominance analysis (LDA) in SD parlance (Ford 1999; Kampmann 1996;Kim 1995) for this purpose. A dominant loop is one "that is primarily responsible for model behavior over some time interval" (Richardson 1995). LDA is relevant since it helps identify which loops to strengthen and/or weaken, through policy actions, in order to achieve more desirable behavior. Two sample findings from our model, using LDA, are noted below:

- Low infrastructure capacity, high hourly usage cost and low geographic dispersion dominate the diffusion process during the last six quarters of simulations runs. Clearly, regulatory policy will play a key role in weakening these variables and, hence, their dominance over the diffusion process in the future.

- Security threat is yet to play a dominant role. This finding was somewhat surprising, but one possible explanation is that e-commerce is yet to take hold in developing countries. Hence, security concerns have not reached significant levels as compared to industrialized countries.

CONCLUSIONS

The model is being refined and will be tested with data from more developing countries. The following observations are offered as tentative conclusions. The reasonable fit between simulated and observed data suggests some degree of model validity, and confirms that social and regulatory factors have indeed had significant effect on Internet growth in developing countries. Loop dominance analysis corroborates popular thinking that slow speed of deregulation and lack of infrastructure are key inhibitors of Internet growth. While these findings are based on only one country, India, they probably apply to other developing countries as well due to their common socioeconomic characteristics. This conjecture will be explored through additional testing.

References

Bass, F. "A New Product Growth Model for Consumer Durables," *Management Science* (15:1), 1969, pp. 215-227

Dataquest. "Indian PC Market," May 15, 2000 (http://www.indiainfoline.com/cyva/repo/pcmk/).

Desai, S. V. "Bandwidth Challenges," March 10, 2001 (http://www.siliconindia.com/tech/tech_pgtwo.asp?newsno=8258&newscat=Analysis).

Ford, D. N. "A Behavioral Approach to Feedback Loop Dominance Analysis," *System Dynamics Review* (15:1), 1999, pp. 3-36.

Gurbaxani, V. "Diffusion of Computing Networks: The Case of Bitnet," *Communications of the ACM* (33:12), 1990, pp. 65-75.

India Infoline. "Sector Reports: Internet Service Providers," *Annexure 4*, February 15, 2001 (http://www.indiainfoline.com/sect/itsp/ann4.html).

Kampmann, C. E. "Feedback Loop Gains and System Behavior," in *Proceedings of the 1996 International System Dynamics Conference*, System Dynamics Society, Cambridge, MA, 1996.

Kim, D. H. "A New Approach to Finding Dominant Feedback Loops: Loop-by-Loop Simulations for Tracking Feedback Loop Gains," *System Dynamics: An International Journal of Policy Modeling* (7:2), 1995, pp. 1-15.

Luff, D. "E-merging Markets," *Global Finance* (14:2), 2000, pp. 54-56.

Lyenis, J. M. "System Dynamics for Market Forecasting and Structural Analysis," *System Dynamics Review* (16:1), 2000, pp. 3-25.

Natarajan, A. "CricInfo: Growing with the Web," May 21, 1999 (http://www.indialine.com/net.columns/column72.html).

Pai, U. L. "Indian E-Com Pegged at $2.3 B by 2002," January 12, 2000 (http://asia.internet.com).

Pai, U. L. "Forty Percent of Homes in India Will be Net-enabled," February 2, 2000 (http://asia.internet.com).

Peha, J. M. "Lessons from Haiti's Internet Development," *Communications of the ACM* (42:6), 1999, pg. 62.

Persaud, A. "The Knowledge Gap," *Foreign Affairs* (80:2), 2000, pg. 107

Pert, T. "Survival of the Fittest," *Telecommunications* (34:12), 2000, pp. 63-66.

Rai, A., Ravichandran T., and Samaddar, S. "How to Anticipate the Internet's Global Diffusion," *Communications of the ACM* (41:10), 1998, pp. 97-104.

Richardson, G. P. "Loop Polarity, Loop Dominance, and the Concept of Dominant Poliarity," *System Dynamics Review* (11:1), 1995, pp. 67-88.

Rogers, E. M. *Diffusion of Innovations*, Free Press, New York, 1995.

Sprano, E., and Zakak, A. "E-commerce Capable: Competitive Advantage for Countries in the New Economy," *Competitiveness Review* (10:2), 2000, pp. 114-131.

Sterman, J. D. *Business Dynamics: Systems Thinking and Modeling for a Complex World*, Irwin McGraw-Hill, New York, 2000.

Taylor, J. "Absence of Intervention," *Telephony* (236:22), 1999, pg. 48.

Ulfelder, S. "All the Web's a Stage," *CIO* (14:1), 2000, pg. 132.

Woodall, P. "Survey: The New Economy—Falling through the Net," *The Economist* (356:8189), 2000, pg. S34.

Ybarra, M .J. "Internet Fever," *Upside* (12:9), 2000, pg. 134.