Internet Diffusion in India and China – Comparison Based on Feedback Loop Dominance

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Abstract

Many developing countries have recognized the need to enhance their Internet infrastructure to participate competitively in the global economy. However, these countries have distinctive socioeconomic characteristics that impact the assimilation of any new technology, including the Internet. Their interactions are complex, making it difficult to deduce the underlying mechanics informally. This, in turn, makes it hard to assess the impact of efforts to stimulate Internet diffusion. To get more formally grounded insights, this paper compares the mechanics of Internet diffusion in two developing countries – India and China – using the system dynamics methodology. The results show a basic similarity in the underlying mechanics, in that the behavior of major feedback loops is similar in the two cases. Specifically, infrastructure capacity shortage and absorption of the technology in different industry sectors drive two counteracting diffusion mechanisms in both countries. However, it also appears that policy actions can impact the timing and duration of dominant behavior. Based on this comparison, we surmise that developing countries, despite the different specific circumstances, do share some common mechanics for Internet diffusion. Moreover, policy actions need to be designed to stimulate sectoral absorption of the technology in parallel with expansion of the physical network infrastructure.

1. Introduction

It is well known that there are major disparities, both in quality and quantity, in the Internet infrastructure of different countries. The disparities have the potential to reinforce social and economic inequalities and are of particular concern in developing countries [1], [2]. Many of them are, therefore, moving aggressively to expand their Internet infrastructure. On the 'supply' side, one major hurdle has been that of financing the buildup, especially in light of foreign exchange constraints. However, the problem of expanding Internet infrastructure, and benefiting from it, is substantially more complex. One also has to consider the 'demand' side – the economy and society's ability to leverage the Internet for core activities. In the developing country context, chronic deficiencies in transportation and energy infrastructure, low literacy levels, insufficient experience with technology, inadequate regulatory structures etc., produce complex interactions between the forces of supply and demand that make it difficult to informally deduce the likely consequences of different actions being considered to stimulate Internet diffusion. To obtain more formally grounded insights, in this paper we use the system dynamics methodology to compare the mechanics of Internet diffusion in two developing countries – India and China. Any similarities that are revealed would suggest the presence of generic forces that may be applicable in other developing country settings as well. Analysis of differences in the mechanics can help point out the reasons behind the effectiveness, or lack thereof, of alternate policy actions.

In both China and India, the Internet was introduced on a commercial basis roughly around 1995. By June 2002, the total number of Internet hosts in China grew to 13 million. In contrast during the same period the total number of hosts in India grew to only about 1.8 million. Figures 1 and 2 show the patterns of growth and growth rate, respectively, in

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these two countries between 1996 – 2002 (a host here refers to a computer having a IP address) exhibits a similar pattern, but the two growth patterns diverge significantly towards the latter quarters.

The appreciable difference in growth appears

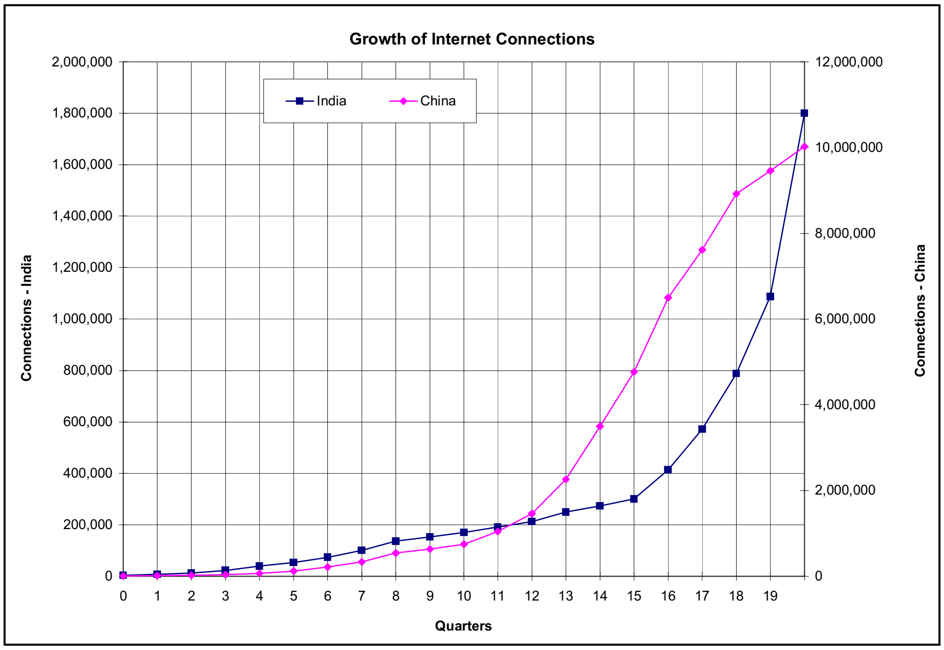

Figure 1: Growth of Internet Connections - China & India (1996-2002)

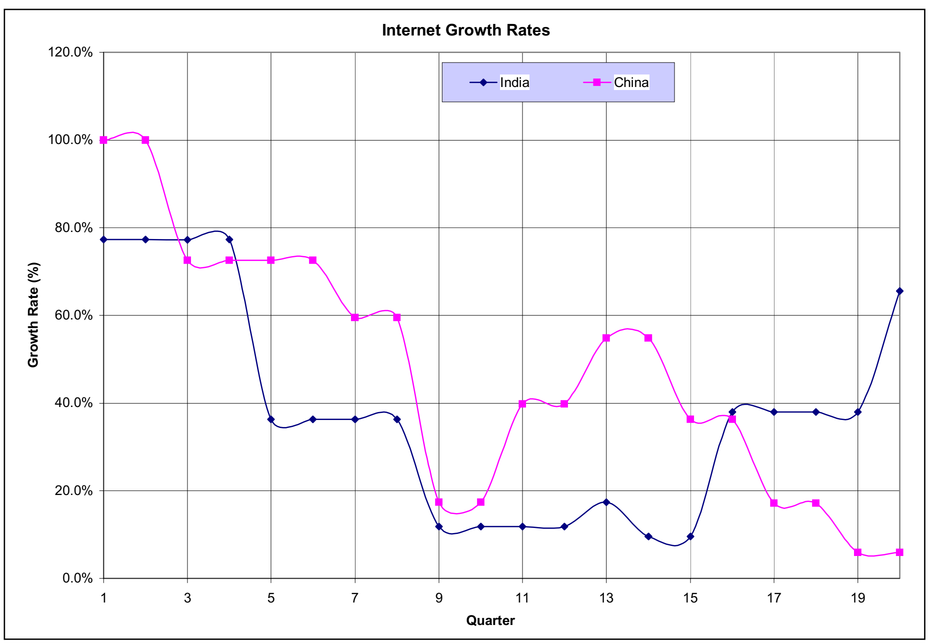

Figure 2: Growth Rates of Internet Connections - China & India (1996-2002)

The figures show that the pattern of growth in the two countries has varied both in absolute numbers and rate. In China, for example, the absolute number was lower than in India initially, but picked up significantly during later periods and exceeded that of India. In terms of growth rate (see Figure 2) the first few quarters were strong in India, but that was followed by a long period of stagnation. China counterintuitive at first glance because the two environments possess many similarities. Both have large rural populations, a handful of densely populated urban centers, low literacy levels and inadequate levels of physical infrastructure such as energy, transport and clean water. In other words, both environments lack important characteristics that support the ability to effectively leverage Internet capabilities for social and economic benefit. However, both India & China have a sizeable and growing middle class population, the likely adopters of Internet. In China, the middle class population size was 100 million in 2001 and the number is expected to double in ten years[1,2]. As of 2000, India had about 100 million people living in 4.5 million households living in 8 major cities and enjoying a comfortable standard of living[3]. That number was growing at an annual rate of 10%. In spite of their different political and economic systems, both governments have assigned high priority to information technology and the Internet, seeing these as a major instrument for economic development. In both countries, Internet services were initially introduced under government-controlled monopolies.

That said, there are also some significant differences in the two environments, particularly in the way the telecommunications sector is organized. In China, Internet usage is, to a large extent, still government controlled. Competition is encouraged among government owned agencies but government regulates access price. The government is the primary entity that invests in network backbone facilities and content is strictly monitored. In India on the other hand, the Internet service sector has been completely deregulated, although the government owned agency still remains the largest provider. Nevertheless, private players have the freedom to enhance infrastructure and compete under competitive market conditions. Part of the access price (telephone charges) is under government control. Therefore, in India, the expansion of network infrastructure is determined by market forces, while in China, that expansion is insulated from market forces to a substantial degree. It is not clear if these differences between the two countries are strong enough to make their Internet diffusion mechanics substantially different, or whether their common characteristics will override these differences to reveal similar underlying mechanics.
Therefore, we intend to use system dynamics to compare the mechanics of Internet adoption in terms of the causal structure of each setting. System dynamics is well suited to the task because it attributes the difference in system behavior to the underlying system structures. Our analysis focuses on identifying the dominant feedback loops at various phases of growth. The paper is organized as follows. Section 2 presents models of Internet diffusion for India and China and briefly explains their structural components. Section 3 discusses the results of dominant loop analysis and its implications for the underlying mechanics. Section 4 concludes with remarks about generalizing these findings to other developing countries.

[1] http://www.newsday.com/ny-chinagallery.storygallery
[2] http://fpeng.peopledaily.com.cn/200107/20/eng20010720_75468.html
[3] http://www.aceglobalonline.com/MarketProfile.html

2. Causal Models of Internet Diffusion

Internet diffusion is a dynamic process, and a variety of methods are available for representing dynamic processes. We have chosen system dynamics (SD) [3],[4] 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. 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 is needed to represent certain social mechanisms. Moreover, SD models can be simulated, providing a platform on which to test scenarios for policy analysis.

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 diagram 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 double line intersecting a link represents delays in an effect. A causal loop is formed by a closed sequence of causal links. A negative feedback loop has an odd number of negative polarity links, while a positive loop has an even number of negative links. The causal loop graph can be mapped to a mathematical model consisting of a system of difference equations, which can be simulated under different parametric conditions.

System dynamics literature reports modeling of diffusion in the context of medical technologies [5]. In previous work, we have developed a system dynamics model of Internet diffusion and have tested that model with data from the Indian context [6]. Since our interest in this paper is to compare and contrast the underlying diffusion mechanics in two developing countries, the model was then adapted and tested on data for China. Subsequently, the underlying mechanics in the two contexts were compared by studying the similarities and differences in the dominant loops for the two models, respectively. Therefore, to provide a foundation for the comparison, we briefly review the model developed earlier for India. Its causal loop diagram (CLD) appears in Figure 3.

For brevity, only the major effects will be discussed. For ease of identification, variables from Figure 3 will appear in italics in the narrative that follows. The core structure in Figure 3 is the contagion effect that is widely used in the diffusion of innovations literature [7]. So called innovators start the adoption process and then, by a communication process – the contagion effect – adopters spread the word to the remaining population and the adoption process gradually gets taken over by imitators. Ultimately, there are no new customers left, and the adoption tapers off, resulting in market saturation. This mechanism results in the well-known S-shaped diffusion curve. In Figure 3, this basic contagion mechanism is captured by two feedback loops: a positive one, *Adoption Rate* $\Rightarrow^{+}$ *Internet Users* $\Rightarrow^{+}$ *Adoption Rate*, and a negative loop: *Potential Users* $\Rightarrow^{+}$ *Adoption Rate* $\Rightarrow^{-}$ *Potential Users*. The strength of the loops is driven by two parameters – the *innovation* and *imitation coefficient*, respectively. The remainder of the structure in Figure 3 represents feedback effects from the environment to this core contagion mechanism. After all, as the Internet diffuses, people's familiarity with the technology, their ability to leverage it for various activities etc., will increase. This, in turn, will affect the innovation and imitation coefficients, altering the adoption rate. Note that feedback effects need not all be positive. For instance, as the Internet diffuses, people's awareness of, and concern about, security issues increases, and this has the effect of slowing down adoption rates. In other words, feedback into the contagion mechanism from the environment consists of both positive and negative forces. Thus the dynamics of Internet diffusion depends on the balance between these opposing mechanics. We now identify a few key variables in the environment and their feedback effects on the contagion mechanism.

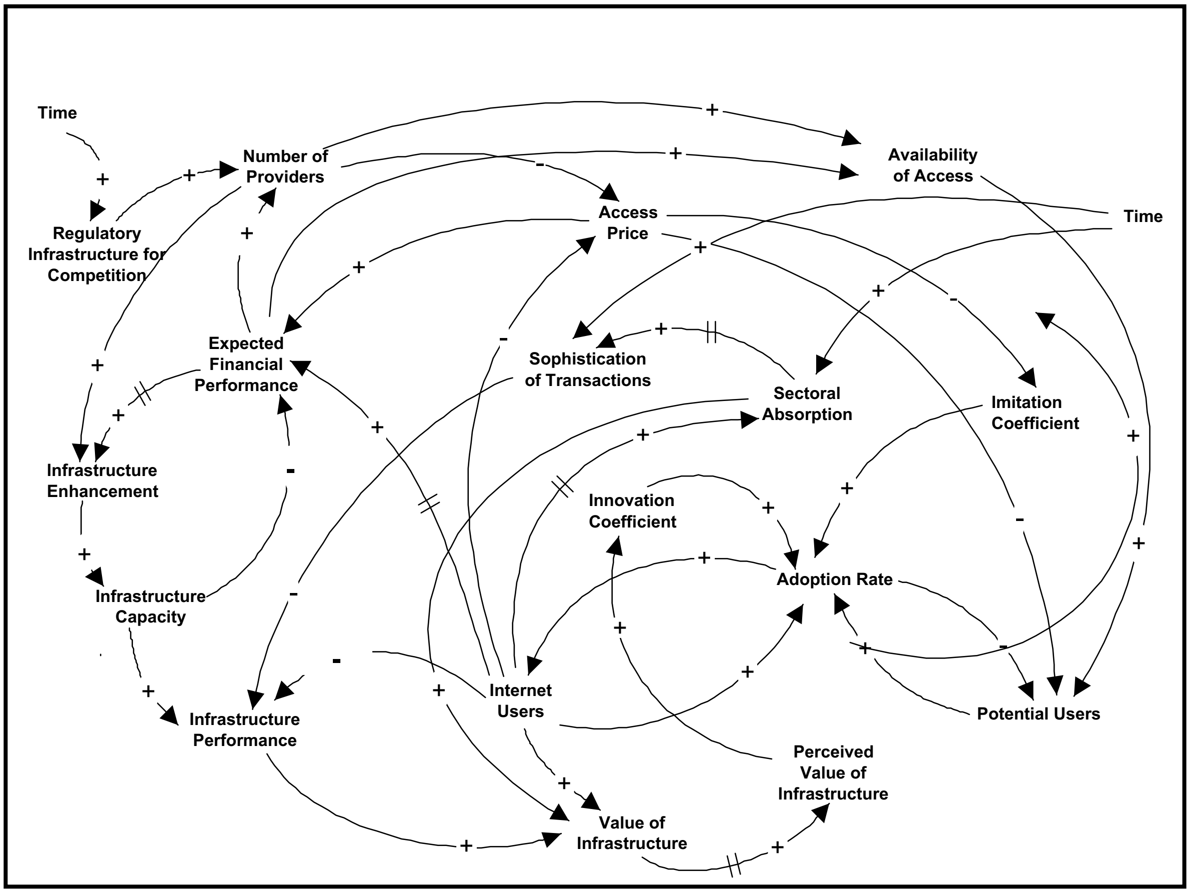

Figure 3: Causal Loop Diagram of Internet Diffusion in India

In Figure 3, the variable *sectoral absorption* has been adapted from [8] and reflects the extent to which different sectors of a developing economy, such as education, health, public administration etc, have adopted the Internet. Higher sectoral absorption means adoption across a broader spectrum of activities. *Access price* and *availability of access* are also important variables for developing countries. The latter refers to the uneven spatial distribution of Internet access in these countries, which limits the number of potential users. Among the other variables in Figure 3, *infrastructure performance* is an aggregate performance indicator that includes transmission speed, capacity and reliability. Since infrastructure expansion is capital intensive [9], the variable *expected financial performance* mediates the investment in infrastructure expansion by service providers. *Regulatory infrastructure for competition* captures the climate for competition in the telecommunications sector. It includes the level of competition permitted by law, and the infrastructure that enforces the laws and implements policy. It is common for developing countries to privatize telecommunications without simultaneously building the appropriate regulatory agencies and policy-making apparatus [10].

Having identified key variables, we next point out some of their feedback effect on the core contagion mechanism. The positive links from *infrastructure performance*, *sectoral absorption* and *internet users* to *value of infrastructure* are easy to understand. Each of the three variables increases the value of the infrastructure to potential adopters. Hence the positive link from *value of infrastructure* back to *imitation coefficient*. However, as number of Internet users increases, this increases network load, resulting in degradation of network performance. Hence the negative link from *internet users* to *infrastructure performance*. Increased competition usually results in price reductions. Hence the negative link from *number of providers* to *access price*. Other links in Figure 3 and their polarities can all be justified in like manner. Details may be found in [6], which also reports the good fit between simulated and actual Internet growth in the case of India using the model of Figure 3.

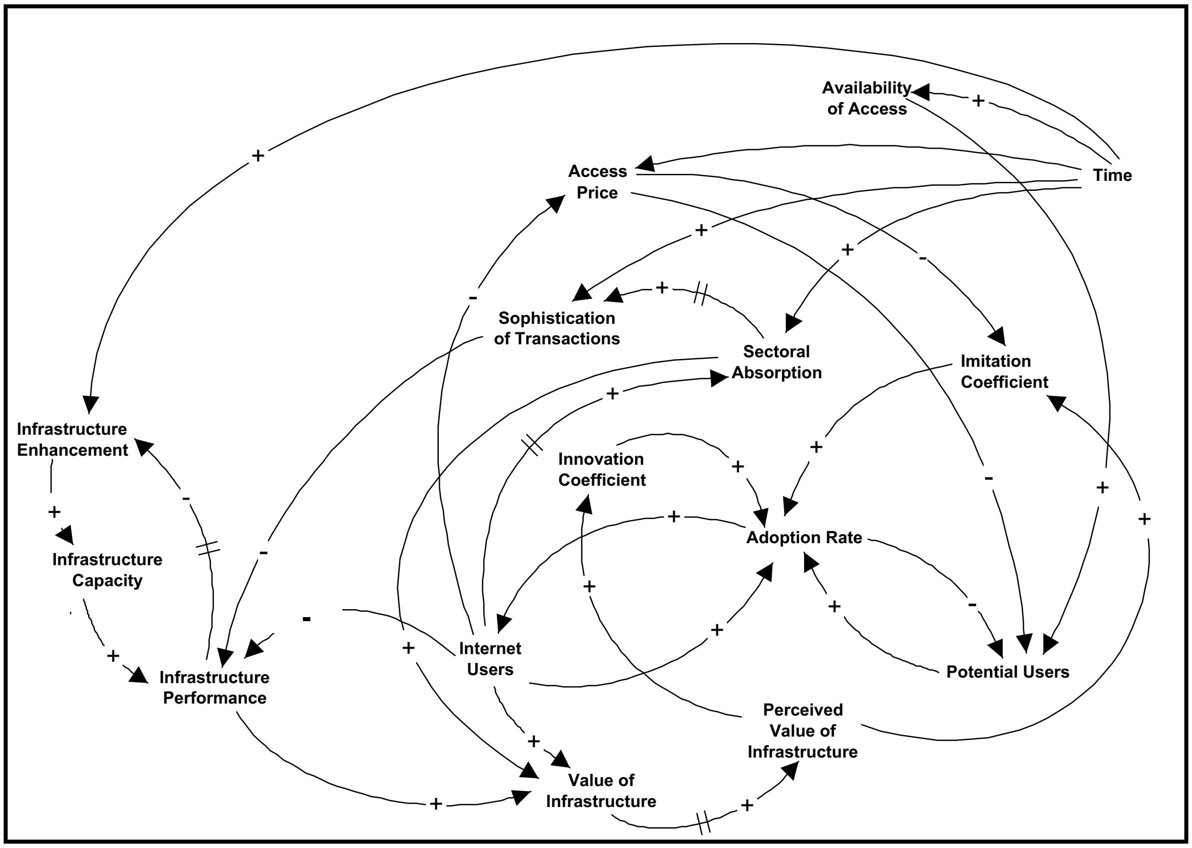

Figure 4: Causal Loop Diagram of Internet Diffusion in China

To answer the research question posed earlier – viz. do developing countries share common mechanisms for Internet diffusion - the model in Figure 3 was adapted to the Chinese environment as shown in Figure 4. Obviously, certain structural components, such as the basic contagion mechanism, remain the same. Also, variables such as *sectoral absorption* and *availability of access*, need to remain since China shares many of the same developing country traits as India.

However, as noted earlier in the introduction, there are aspects of the network services industry in China which are significantly different from that in India. In India, providers are free to enter the market, and market forces determine which ones survive. In China, there are also multiple Internet service providers, which compete in some sense. However, since the government has assigned a high priority to enhancing the Internet infrastructure, these service providers enjoy a level of funding and support that is not entirely correlated to how well they are doing in terms of revenue. Hence, Figure 4 has been obtained from Figure 3 by eliminating variables that reflect the impact of market forces on service provision, and their associated causal links. For instance, the variable *expected financial performance* in Figure 3 has been removed in Figure 4. Thus, other than the difference in sector organization, the two causal loop diagrams have the same structure. This model was fitted to Internet growth data for China. Figure 5 compares the actual and simulated values and the fit can be seen to be quite reasonable.

that a system variable x, over an appropriately defined time interval, demonstrates one of the three '*atomic behaviors*' namely - **linear** (when the rate of change remains constant over time), **exponential** (when the absolute value of the rate of change increases over time), **logarithmic** (when the absolute value of the rate of change decreases over time).

Observed behavior can be reconstructed using combinations of these three atomic behaviors. Therefore, if a feedback loop dominates the behavior of a variable over a given time interval, deactivating the loop should cause the atomic behavioral pattern of the variable to change during that interval. In Figures 3 and 4, the variable of interest is 'Internet Users'. Of course, one can enumerate a large number of feedback loops in Figures 3 and 4, all of which could, in principle, dominate the behavior of our variable of interest over certain periods of time. However, based on the literature documenting Internet diffusion efforts in developing countries [8], we have selected a more modest but realistic set of feedback loops to be tested for dominance patterns in the two countries.

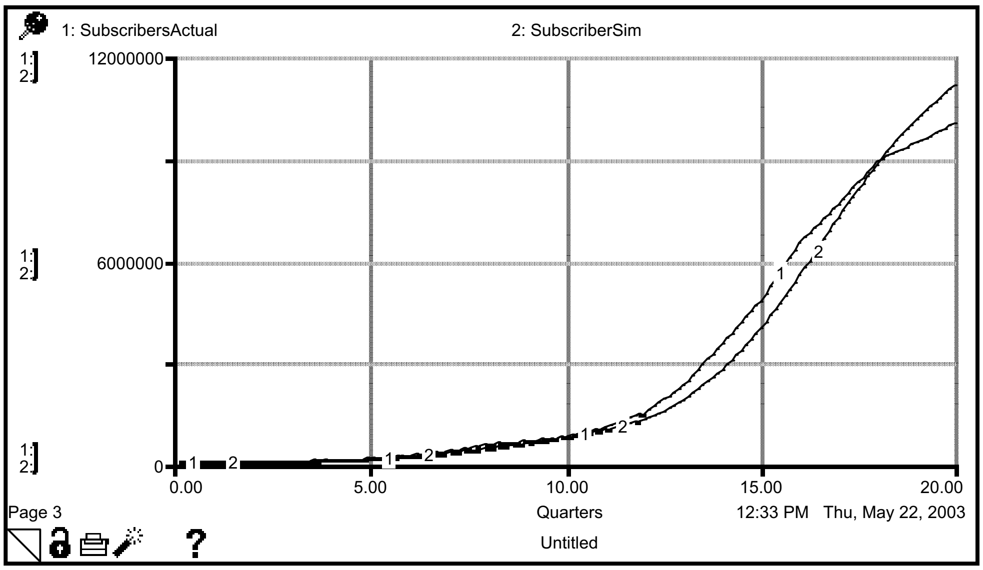

Figure 5: Simulated vs Observed Values of Internet Adopters in China

3. Dominant Loop Analysis

The preceding section has established causal models of Internet growth for India and China. The links in each model can be mapped to the characteristics of each country, and the models appear to replicate observed growth behavior of the two countries reasonably well. If we therefore take the two models to be acceptable representations of the underlying mechanics in their respective countries, we are now in a position to compare their mechanics more formally. This will be done by carrying out loop dominance analysis on the two models.

Loop dominance analysis identifies which feedback loops dominate the dynamic behavior of a system over some period of interest under given structural and parametric conditions [11]. We use a method suggested by [12] for its ease of implementation. The method is based on the premise

The selected loops, their polarities, and reasons for being selected, are noted below:

- Infrastructure Performance (Negative loop) :- *Infrastructure Performance* $\Rightarrow^{+}$ *Value of Infrastructure* $\Rightarrow^{+}$ *Imitation Coefficient* $\Rightarrow^{+}$ *Adoption Rate* $\Rightarrow^{+}$ *Internet users* $\Rightarrow^{-}$ *Infrastructure Performance*. Since developing countries suffer from chronic and acute shortage in Internet infrastructure, it is important to examine the feedback impact of this shortage on adoption. In particular, we are interested in knowing if this shortage constrains

Internet diffusion in a significant way, despite efforts to expand infrastructure.

- Network Externality (Positive loop):- *Internet users* $\Rightarrow^{+}$ *Value of Infrastructure* $\Rightarrow^{+}$ *Imitation coefficient* $\Rightarrow^{+}$ *Adoption rate* $\Rightarrow^{+}$ *Internet users.* As more entities, be they individuals or organizations, adopt the Internet, the value of the infrastructure to both potential and existing adopters increases. In other words, Internet diffusion has positive network externality [13], not unlike the adoption of the telephone in its early days. We want to see if this powerful force feeds back to speed up the diffusion process in a significant way.
- Sectoral Absorption (Positive loop) :- *Sectoral Absorption* $\Rightarrow^{+}$ *Value of Infrastructure* $\Rightarrow^{+}$ *Imitation coefficient* $\Rightarrow^{+}$ *Adoption rate* $\Rightarrow^{+}$ *Internet users* $\Rightarrow^{+}$ *Sectoral Absorption.* The literature points to the lack of sectoral absorption as one impediment to Internet diffusion in developing countries [8]. Therefore, we wish to examine the feedback effect of sectoral absorption, see if it dominates diffusion behavior in any way, and compare the dominance patterns between China and India.
- Price-Adoption (Positive loop) :- *Access Price* $\Rightarrow^{-}$ *Imitation coefficient* $\Rightarrow^{+}$ *Adoption rate* $\Rightarrow^{+}$ *Internet Users* $\Rightarrow^{-}$ *Access Price.* Unlike innovators, imitators usually give more serious consideration to the price parameter when making an adoption decision. Due to low income levels, imitators in developing countries are likely to be even more price sensitive. Given the recent trend towards competition in Internet service provision, it is expected that access prices will fall in developing countries. Thus we are interested in seeing the feedback impact of this variable on the imitation coefficient and hence, on adoption.
- Price-Potential User (Positive loop):- *Access Price* $\Rightarrow^{-}$ *Potential users* $\Rightarrow^{+}$ *Adoption rate* $\Rightarrow^{+}$ *Internet users* $\Rightarrow^{-}$ *Access Price.* Apart from its likely impact on the imitation coefficient, price changes also impact the pool of potential users. As price drops, Internet service becomes affordable to a larger segment of the population. By examining this feedback loop, we wish to see if this feedback effect of price dominates diffusion patterns in either of the two countries.

Table 1 compares the loop dominance results for India and China. Row numbers in Table 1 refer to quarters, starting with 1996. The five column headings are abbreviations for the five feedback loops discussed above. To facilitate comparison, dominance patterns for India and China are shown together in Table 1, using 'In' and 'Ch' to represent the two countries, respectively. Thus, each column has two halves, the left showing the dominance pattern of the associated feedback loop for China, and the right showing that for India.

Qrt.	Infra-structure Perfor-mance		Network Extern-ality		Sectoral Absorp-tion		Price Adop-tion		Price-Potential User Growth	
0										
1										
2										
3										
4										
5						In				
6				In		In				
7				In		In				
8		In	Ch		Ch					
9		In	Ch		Ch					
10		In	Ch		Ch					
11		In								
12	Ch	In								
13	Ch	In								
14	Ch	In								
15	Ch		Ch		Ch		Ch			In
16	Ch		Ch		Ch		Ch			In
17	Ch		Ch		Ch		Ch			In
18	Ch		Ch		Ch		Ch			In
19				In		In	Ch			
20				In		In				

Table 1. Feedback Loop Dominance Analysis
In = India, Ch = China

To understand the patterns of dominance in Table 1, consider the first column and focus only on the cells marked by "Ch" – i.e. quarters 12 through 18. This pattern was obtained as follows. The China model was first run from quarter 0 to 20 with all feedback loops active. By taking the first derivative of the growth pattern for *Internet Users* generated by the model, we obtain the atomic behavior pattern of our variable of interest. In other words, for each quarter, we note whether the first derivative is zero, positive or negative – call this Pattern-1. The China model is then run again, but this time the Infrastructure Performance loop is deactivated. As before, we take the second derivative of *Internet Users* and, for each quarter, note whether it is zero, positive or negative. This gives us the atomic behavior of *Internet Users* with the infrastructure performance loop deactivated – call this Pattern-2. Comparing Pattern-1 and Pattern-2, we can note the quarters for which the sign of the derivative differed between the two patterns. The Infrastructure Performance loop would be considered to be dominant in those quarters since its absence resulted in change in atomic behavior. For instance if Patterns 1 and 2 for infrastructure performance in China are as shown in the first two rows of Table 2, the dominance pattern would be as shown in the third row (Y indicates dominance of the loop).

Qrt	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Pattern 1	0	0	0	+	+	+	+	+	+	+	-	-	-	-	-	+	+	+	+	+	+
Pattern 2	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Dominance				Y	Y						Y	Y	Y	Y	Y						

Table 2. Determining Dominance Pattern for a Feedback Loop

In Table 1, the first column for China indicates that the Infrastructure performance loop was dominant from quarters 12 through 18. By comparison, the right half of column one shows that the same feedback loop was dominant in India from quarters 8 through 14. Note that the duration of dominance is about two years (seven quarters) in each case, although the onset of dominance occurs earlier in India compared to China. From the sustained duration of dominance in both countries, one is inclined to conjecture that infrastructure capacity is a common factor inhibiting adoption of the Internet in developing countries during the earlier stages of diffusion. In other words, the diffusion process tends to choke on its own growth in the initial stages. The difference in onset of dominance – eighth quarter for India versus twelfth for China – can be explained by two factors that differentiate the two environments. Firstly the infrastructure in China, under the exclusive control of the government, which realized the potential of Internet quite early on, has been growing at a rate commensurate with the growth of user base. The infrastructure in India has however been partly by government but majorly by ISPs. The second factor is how competition was introduced in the two countries. In India, when Internet service was made completely competitive in 1998, there were many new entrants (more than 200 by year 2000) and prices fell sharply due to competition. There was rapid surge in Internet adoption, which strained network capacity and impeded adoption. This date – 1998 – coincides approximately with the onset of dominance for infrastructure performance in the case of India (the eight quarter corresponds to about 1998). In the case of China however, competition was more controlled. There were four backbone service providers in year 2000, all of them state owned. Also, there were controls on content. Thus, the forces of supply and demand in China did not result in the sudden surge in adoption witnessed in India [14]. Adoption was slower but it was steady. This is consistent with the onset of dominance for the infrastructure performance feedback loop occurring much later in China compared to India.

Moving on to the next two feedback loops, network externality and sectoral absorption, Table 1 shows that they also exhibit dominance patterns in both countries. It is interesting to observe the relative timing of the dominance patterns. In India, for instance, network externality as well as sectoral absorption begins dominance around the fifth quarter. However, this dominance ceases in the eight quarter when infrastructure performance begins its dominance. Only after infrastructure performance ceases dominance in quarter 14 do the two regain their dominance. A similar pattern is evident in China in that sectoral absorption and network externality begin dominance in the eighth quarter, but cease to do so as infrastructure performance begins its dominance in quarter 12. Only after a break of four quarters, during which infrastructure performance continues its dominance, do these two loops resume their dominance. Unlike the case for India however, this resumption occurs before infrastructure performance ceases its dominance. These differences in timing notwithstanding, the common pattern in both countries appears to be the following: sectoral absorption and network externality have powerful positive feedback effects on the basic contagion mechanism that drives Internet diffusion. In China for example s dominant sectoral absorption loop drives growth of Internet users. However, a mismatch between the supply of network capacity by service providers and demand for capacity from Internet adopters is what leads to degradation of infrastructure performance. As we saw in Table 1, this variable has a powerful negative feedback effect on adoption and stifles the beneficial impact of the other two forces. This is evident from the pattern of dominance exhibited by the first three feedback loops.

Unlike the first three loops, which exhibited similar patterns for both countries, the last two feedback loops – both dealing with the feedback effects of access price – each behave differently for the two countries. Let us take the 'Price-adoption' loop first. It (fourth column in table 1) exhibits a dominance pattern in the case of China but not for India – at least for the twenty quarters being simulated. As noted earlier, the causal chain for this loop is: *Access Price* $\Rightarrow^{-}$ *Imitation coefficient* $\Rightarrow^{+}$ *Adoption rate* $\Rightarrow^{+}$ *Internet Users* $\Rightarrow^{-}$ *Access Price.* We surmise that the main reason for the difference in behavior of this loop between the two countries is the impact of effective price on the imitation coefficient in the two cases. We know that competition among service providers in India, which resulted in dramatic reductions in access price, did not ultimately benefit users due to high connectivity charges levied by the telephone companies. In other words, the effective price seen by users is the monthly access charge levied by Internet service providers plus the per minute telephone charges levied by the local telephone company. The latter is still a government owned monopoly and they have not taken any action to ease connectivity charges. Thus the price benefits of competition are reduced and the effective price drops were not significant enough to impact the imitation coefficient - and hence, adoption – in India. It appears though, that China took steps to not only reduce Internet access charges, but also the per minute telephony connectivity charges [15]. Thus, the effective prices seen by users were reduced by an appreciable amount. At least, the drop was significant enough to affect the imitation coefficient and enhance adoption. This would explain the appearance of the dominance pattern for the Price-adoption loop for China in Table 1.

On the other hand, the 'Price-potential user' feedback loop (fifth column in Table 1) exhibits a dominance pattern for India but not for China. Note from Figures 3 and 4, that there are two inbound causal links into the variable *Potential users*, one from *Access Price* and the other from *availability of access*. Therefore, from the difference in dominance patterns, one deduces that the influence of *availability of access* on *potential users*, masked that of *access price* in the case of China but not in the case of India. The operational interpretation of this insight from the model is that China appears to have had more success in achieving wide geographic coverage with its infrastructure expansion efforts compared to India. There is some evidence for this disparity in geographic coverage [16] at least during the earlier portion of the simulation.

The five feedback loops analyzed above illustrate how loop dominance analysis can provide insights into which of numerous feedback mechanisms really affect behavior in substantial ways. It can help focus attention on the 'mechanics that matter' when it comes to guiding Internet diffusion through appropriate policy actions.

4. Concluding Remarks

We conclude by attempting to generalize – cautiously – to other developing country settings. The major lesson we would draw from the preceding comparison of the two countries is that policies for stimulating Internet diffusion must address both infrastructure expansion as well as sectoral absorption in a balanced manner. For infrastructure expansion, this basically means that policies need to be crafted to stimulate private sector investment. This requires designing appropriate measures to mitigate financial risk for the new entrants, developing institutions that will craft clear 'rules of the game' to reduce business uncertainty, and creating viable means for resolving disputes. By and large, developing countries have recognized the need for these moves [10]. India, for example, has set up the Telecommunications Regulatory Authority of India (TRAI), whose function is roughly equivalent to that of the FCC in the United States. TRAI is busy crafting 'rules of the game' for telecommunications services in general [17]. In other words, India has separated the regulatory and operational role of government, when it comes to telecommunications services. That separation has also occurred in several other developing countries although not yet in China. In short, it appears that developing countries are devoting some attention and energy to expanding Internet infrastructure [18].

However, it is not clear that they either recognize the need, or are taking steps, to stimulate sectoral absorption of the Internet as our findings suggest needs to be done. For instance, sectoral absorption in both Turkey and Pakistan did not increase much from 1992-1999. During the same time frame, their Internet infrastructures expanded substantially [19]. In other words, current policy actions seem focused on the supply side of Internet diffusion more than on the demand side. In any event, stimulating sectoral absorption is a more complex proposition than stimulating infrastructure expansion. In simple terms, the problem is how best to incentivise the assimilation of Internet technologies by different sectors of the economy and individuals at large. Given the multitude of ills mentioned early in the paper - low literacy levels, poor transport and energy etc. – it is not clear how this is best done.

Four sectors that are commonly identified are academic, commercial, health and public. In many developing countries, universities and public sector administrative functions have taken the lead in assimilating Internet technologies because the institutions are either government entities or operated by it. However, given trends towards market economies in developing countries, until the commercial sector adopts Internet technologies in a substantial way, it is unlikely that the demand side will achieve sufficient strength to fuel Internet diffusion. It is not within the scope of this paper to address the issue of how best to guide development. Our analysis simply points out that attention devoted to Internet infrastructure expansion needs to be matched by efforts directed at stimulating sectoral absorption of the technology. We simply mention the relatively recent notion of 'sustainable development' [20], which appears to hold some promise in stimulating technology assimilation.

It is also appropriate to repeat the obvious – that two countries are not enough to make strong general statements about all developing countries. However, the characteristics of the two countries on which the analysis in this paper is based are shared by many other developing countries. Hence we are led to believe that the findings may apply more generally. Tests on additional developing countries will show if that belief holds.

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