Modeling Growth of Cellular Services in India: A Systems Dynamics Approach

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Abstract

The cellular industry all over the world has been witnessing very high growth rates in subscriber base in recent years. For developing countries in particular, cellular services are becoming a very significant proportion of the overall telecom infrastructure. The mechanics of competition within this market involve complex feedback effects between individual service providers and with their operating environment, and these forces play an important role in governing the growth of this industry. In this paper, we use the systems dynamics methodology to develop an initial model of cellular service provision within the duopoly market structure. We report preliminary tests with the model using subscriber growth data for the Indian cellular industry over a period of twenty-one quarters. Sensitivity analysis test demonstrate the model's potential as a decision support tool for service providers and policy makers.

1. Introduction

With the steep fall in the cost of providing cellular services, and increasing deregulation and competition, developing countries are witnessing rapid growth in cellular subscriber base. Indian cellular industry has been witnessing a Compounded Annual Growth Rate of about 105.2%. It is a $5 billion industry today, and the cellular subscriber base in the country has increased to 6.4 million from a mere 28,550 in 1996 [10]. According to reports, Indian mobile subscriber base is expected to grow to 15.68 million by 2003 [6]. However, the penetration rate of cellular services is very poor in developing countries. In India, the cellular density is 0.56 per 100 population compared to 77.84 in Finland [10].

Economic conditions, market structure, policies regarding tariffs and interconnect agreements, and customer characteristics are some of the significant forces affecting the growth of cellular services. Since it takes about 3-4 years for cellular operators to attain financial payback on their projects, estimates of market size can be useful for network and investment planning. Qualitative narratives and descriptive statistics of the cellular sector for many countries are available from a variety of industry sources (e.g. [8], [9]). However, rigorous empirically based studies of cellular market growth are much more limited in number (e.g. [14], [15], [18]). Moreover, these studies do not provide much insight into the mechanics of growth in cellular markets. Such insights can inform policymakers about the process by which growth occurs and help develop policies that can improve cellular penetration in developing countries. They are also useful to service providers in planning their network roll-outs and services in the face of market competition.

In this paper, we report on our initial efforts to develop a causal model of cellular market growth using the systems dynamics (SD) methodology [7]. The Indian cellular market is used as the specific modeling context, but many other developing countries share the same market characteristics. In addition to its potential use for forecasting, the modeling approach gives insights into the mechanics of growth, since its basic construct is the feedback loop. Section 2 provides a brief narrative on the evolution of India's cellular industry. Section 3 describes our causal model of cellular growth and justifies its structural components. Section 4 presents results showing the model's ability to replicate cellular growth patterns in India. Following that, some sensitivity analysis results are presented in Section 5 to demonstrate the model's ability to chart the dynamics of growth under different competitive scenarios and hence, it's potential as a decision support tool. In conclusion, we mention some of the planned extensions to the model that would enable it to capture market characteristics at a finer level of detail and make it more useful for planning purposes.

2. Cellular Market Structure in India

As in other countries, in India, the Cellular Mobile Service Providers (CMSPs) are licensed to operate in designated geographical operating areas. The service areas include four metro areas and 18 circles categorized as A, B and C. The categorization is based on the revenue

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potential with category C circles in the lower end of the scale. For example the metros account for 40% of the subscriber population, with Category-A, B and C accounting for 33%, 23% and 4% respectively.

As in most of the other countries, Indian cellular market adopted a duopoly market with licenses given to two Cellular Mobile Service Providers (CMSPs). The first digital cellular service started in the metros in 1995. A year later, licenses were awarded to two CMSPs in each of the 18 circles. The third and fourth operator licenses have been issued recently and the license holders are expected to commence their services soon [12]. Currently, only 900 MHz of the Global Systems for Mobile (GSM) band has been allocated for cellular services, though the government is considering the release of 1800 MHz band for cellular operations soon.

The CMSPs had to pay an entry fee and subsequently annual license fee as a percentage of their revenue to the Department of Telecommunications. The entry and license fees varied according to the service area, highest for metros and lowest for Category-C circles. Some of the CMSPs could not fulfill their licensing obligations and their licenses were revoked leading to a monopoly situation in certain areas. Apart from these charges, each CMSP has to share the revenue with the long distance operators for carrying inter-service area calls.

In profitable metros and circles, the competition is severe and the market is split between the two operators. In a price-cap regulated market, the operators use appropriate pricing strategy to win customers and win market share. In highly price-elastic markets, such as in India, as the service provider reduces the price, the subscriber base increases considerably, and so is the network traffic. The increased network traffic decreases the performance and the quality of service, inviting customers to switch [3]. Recently being a new entrant in a metro area, the government operator reduced the airtime charges to such an extent that the subscriber base increased suddenly leading to poor network performance. The operator did not have enough network capacity to handle calls leading to blocking of calls, with frustrated customers switching over immediately to competitors.

The operators also have to resort to non-pricing competition strategies to win customers. In India, CMSPs offer a variety of service plans as a means to attract new customers. Different service plans include: pre-paid calling card schemes, discounted airtime rates for evening and night time calls, discounted roaming charges, no or minimum activation fees, and reduced mobile to mobile long distance call rates. The service providers incur additional advertising and infrastructure cost for implementing these plans. Short Message Service (SMS) and Wireless Application Protocol (WAP) service are fast catching up. For example, in India, about 500,000 SMS messages are being carried by a service provider in one metro area alone.

When the sector moves over to an oligopoly market, the operators have to provide improved quality of service and value added services in order to survive and gain market share. Larger operators who have experience and infrastructure may be able to provide a higher quality of service and other value-added service at a lower price. They also have access to larger project financing for enlarging their networks and services. For example, a single large operator now has license to operate in 14 service areas in the country with the largest footprint to cover most of the areas of the country. Mergers and acquisitions are commonplace as the operators are consolidating their revenues to survive in the market places [5].

3. A Causal Model of Cellular Market Growth

There are different approaches to representing dynamic processes, each with its own strengths and weaknesses. We have used the well-known finite difference equation methodology of System Dynamics (SD) [7] to develop a model of the mechanics of growth in the cellular services market. SD has been used successfully to study process structure in a wide variety of application areas [18] including online service provision [3] and Internet diffusion [4]. The basic construct of an SD model is the feedback loop. A feedback loop is simply a closed sequence of cause-effect relationships. Developing an SD model of system behavior consists essentially of identifying the feedback loop structure of the system and validating it by comparing the model behavior to actual observed behavior. By simulating the SD models, it is possible to study 'what-if' scenarios. In order to build feedback loops, SD uses four structural elements – (a) stocks, which are accumulations of some quantity such as labor or capacity (b) flows, which are rates of change in accumulations (c) connectors, which represent information flows that regulate flows and (d) converters, which represent decision rules. It is this stock-flow structure that generates an underlying system of difference equations, which is then simulated to yield system behavior.

For visual simplicity however, feedback loops are often represented in the form of a causal loop diagram (CLD). Figure 1 shows the CLD for our basic model of cellular market growth. The fundamental element of a CLD is the causal link, which represents an elementary cause-effect relationship. A link is *positive* (or negative) if a change in the causal element produces a change in the *same* (or *opposite*) direction for the effect element. A double bar on a causal link indicates a delayed effect. A closed sequence of causal links represents a casual loop. An even/odd number of negative polarity links in a loop results in a positive/negative feedback.

Two major structural components can be seen in Figure 1. The first one Component A - reflects the mechanics of competition in a general duopoly market as developed in by Sice, et al in [17]. Here, perceived quality has been taken as the key determinant of competitive advantage. It is considered as a holistic characteristic of the product/service - cellular service in this case -reflecting features such as price, application variety, and quality of service. This aggregation introduces coarseness into our model, but will suffice as a first approximation, since it captures the mechanics of competition between the two providers.

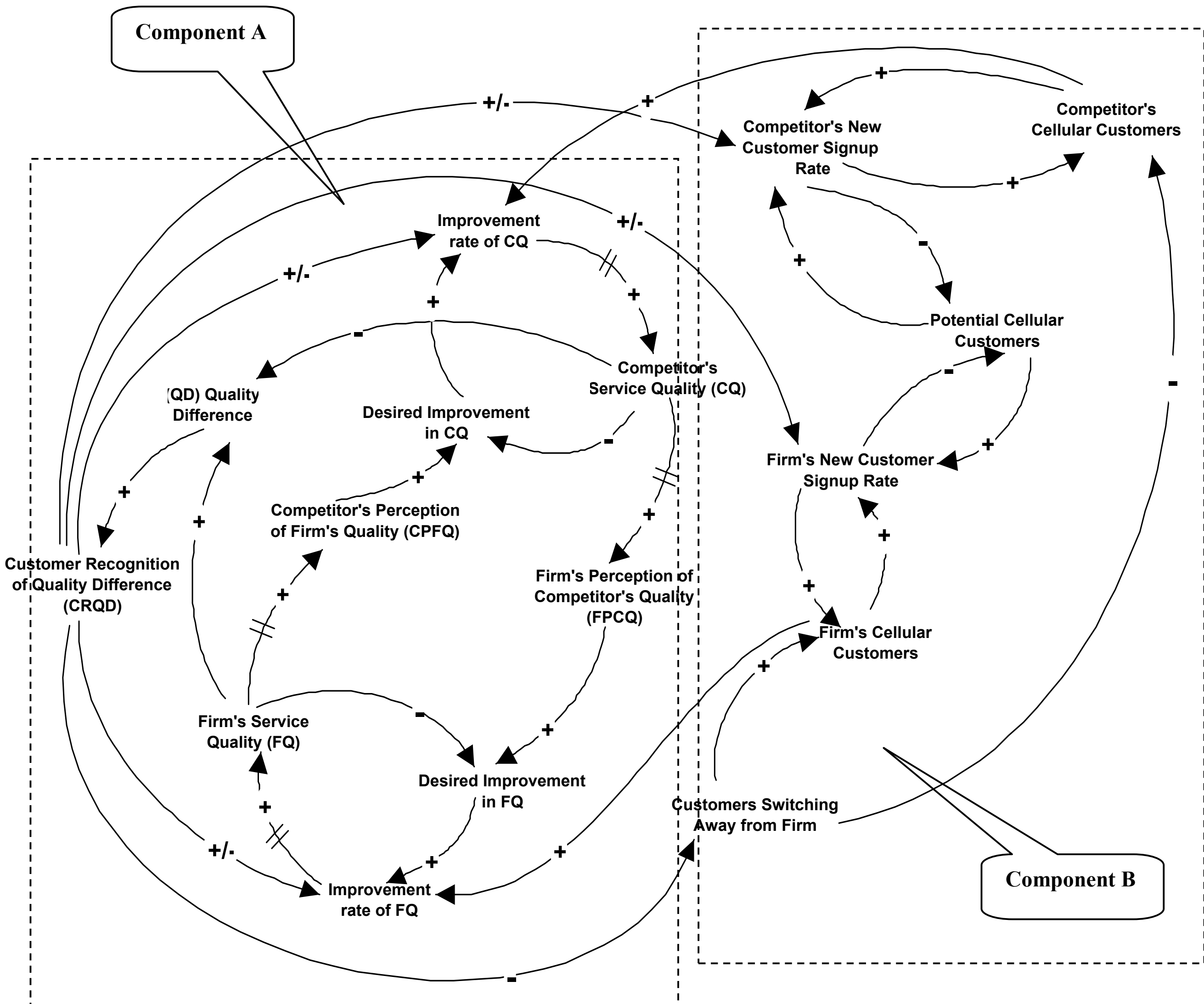

Figure 1. Causal model of cellular duopoly market

The two competing organizations are referred to as the Firm and the Competitor. As Firm Quality (FQ) increases, competitor's perception of firm quality (CPFQ) increases after some delay. Notice the positive polarity causal link from FQ to CPFQ with the double bar across it. After a materialization delay, which represents the internal workings of the company, the desire to improve quality generates actual improvement in Competitor's Quality (CQ). At the same time, as the firm is watching the competitor's quality, a similar cycle happens at the firm leading to increase in the quality level of the products by both the firm and the competitor. However, the lag in generating an actual improvement in quality is considered to be a function of the current quality level. This implies that it becomes increasingly difficult to improve the quality as the overall level of quality becomes higher [17]. The positive feedback loop results in exponential growth in both of the quality variables.

Customers are assumed to recognize a difference in quality between the two products and to react to such a difference by shifting their demand. This results in a negative feedback loop, the impact of which is determined by the time delay in customer's perception of the quality difference. This time delay is assumed to increase with increasing quality difference since increase in quality of the firm (competitor) increases the relative advantage of the firm (competitor), resulting in increase in market share of the firm (competitor) and consequently no immediate improvement is required. For both the materialization delay and customer's perception delay, we use the sigmoid functions given in [17] for our simulation. For instance the following equation defines the functional form of the customer's perception delay τ_i.

$$\tau_i = m_0 + m_1\left(0.5\pi + \tan^{-1}\left(aCRQD\right)\right)$$

where m_0 is the minimum value of the perception delay constant in quarters and m_1 and a define the span and transition rate of the sigmoid function, respectively.

The second component – Component B – is based on basic mechanics of diffusion well documented in the diffusion of innovations literature [16]. The mechanism posits that there are two types of adopters – innovators and imitators. Imitators adopt based on word of mouth influences from current adopters, while innovators need no such special impetus. The proportion of innovators and imitators is represented by two fractions – innovator and imitator fractions - respectively. Notice that the diffusion mechanism is replicated for both the firm and the competitor in Component B. The imitator component is captured by the causal links from firm's (competitor's) cellular customers to firm's (competitor's) new customer signup rate as these new customers imitate the behavior of the existing customers and subscribe to the firm (competitor). The other causal links ending up at the firm's (competitor's) new customer sign up rate capture the innovative behavior of customers.

Finally, notice the feedback effects between component A and B. First, the customer's recognition of quality difference (CRQD), from component A, has causal links to the new customer signup rate for the firm and its competitor in component B. Note that the polarity of each of these two causal links could be either positive or negative, depending on the sign of CRQD. If CRQD is positive, the link to the firm (competitor) has a positive (negative) polarity. The opposite is true when CRQD is negative. Similarly, there is feedback from component B back to component A.

Note the causal link from the firm's cellular customers (competitor's cellular customers) in component B to improvement rate of FQ (improvement rate of CQ) in component A. These links reflect the fact that the firm with the larger customer base will have greater revenues to apply to improve internal efficiencies.

The above causal diagram explicitly integrates the generic forces in a duopoly market with the specifics of cellular service provisioning into an integrated feedback model of cellular subscriber growth using the formalisation of SD. The CLD was then implemented using the stock-and-flow constructs of SD [1], mentioned earlier, and the resulting system of difference equations was simulated using empirical data from Indian cellular industry to calibrate the model. Predictive validity was then tested as explained in the following sections.

4. Simulation Results and Discussions

The stock-and-flow model was simulated for 21 quarters. The cellular subscriber base for Delhi metro area for the two service providers, namely Bharti and Sterling were obtained from [2]. The plot of actual subscriber base versus the simulated results from the first quarter of 1996 up to the first quarter of 2002 are shown for Bharti and Sterling in the following Figures 2 and 3 respectively. The graphs show that the simulated results fit the later stages of observed growth rather well, but not the initial stages. There is a very reasonable explanation for this difference based on the specific circumstances of the Indian telecommunications market. The sharp increase in subscriber base during the initial three to four quarters can be attributed to pent-up demand. When the digital subscriber service was introduced in India in 1996, the existing land-line telephony for both the local and long distance services were operated by the government owned monopoly operator. In 1996, the number of land-line telephone lines in the country was 14.582 million and the number of applications in waiting line for telephone service was around 2.894 million [11]. This huge pent up demand was sharply concentrated in the metro areas like Delhi.

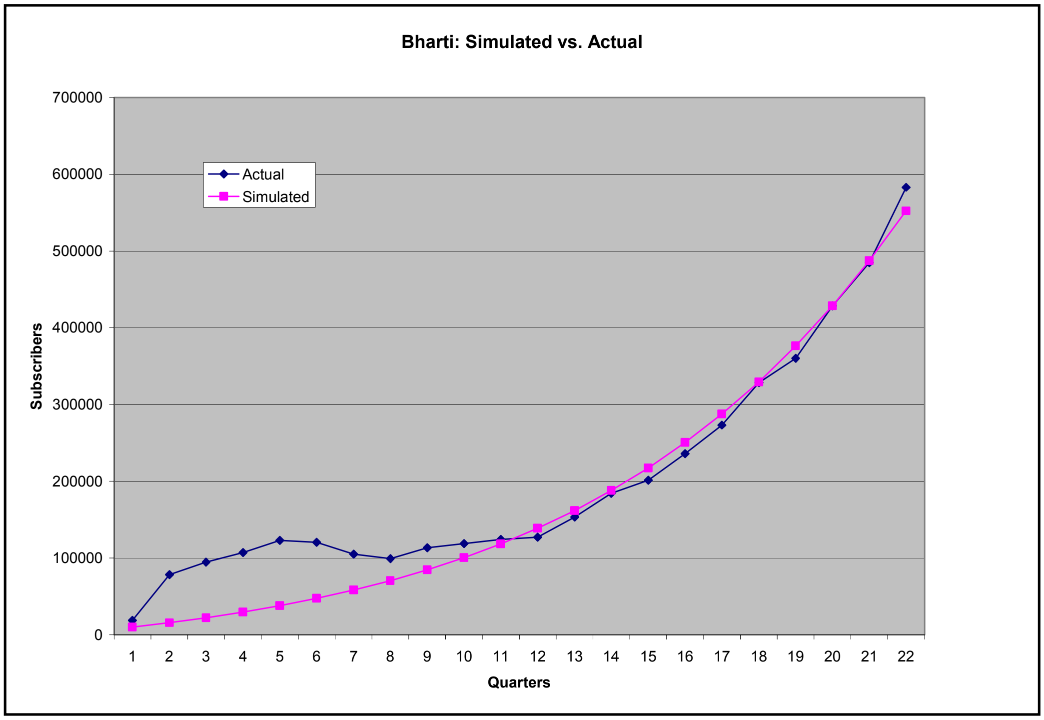

Figure 2. Simulated vs. actual growth of Bharti subscriber base

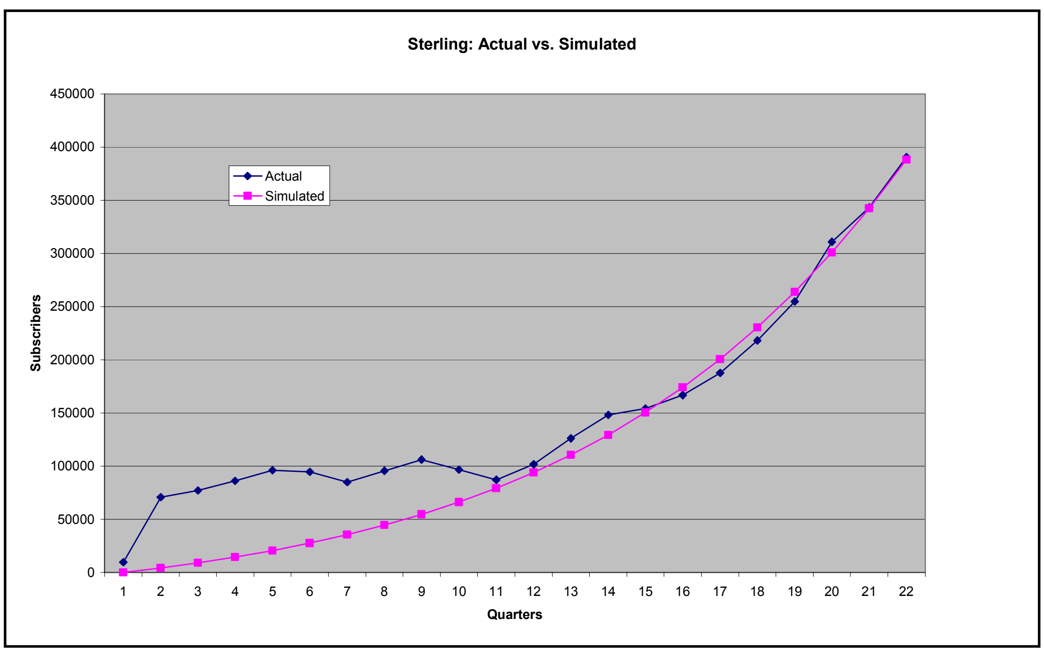

Figure 3. Simulated vs. actual growth of Sterling subscriber base

When cellular service was introduced in the metro areas in 1996, it is possible that many of the applicants waiting for land-line connections, particularly affluent ones, subscribed to cellular service resulting in abrupt growth. But the growth stabilizes after the fifth quarter and from the tenth quarter onwards coincides with the simulated results. After this pent up demand is met, the simulated and observed values track rather well. The fact that this pattern is observed for both Sterling and Bharti reassures us of the above explanation. Hence we suggest that the model captures the major mechanisms underlying growth in the Indian cellular market.

4.1. Sensitivity Analysis Results

Having presented initial evidence of model validity in the form of replicating observed growth patterns, we now turn our attention to demonstrating the model's ability to serve as a decision support tool for planning purposes. The plot of the quality variables: Firm's Quality (FQ), Competitor's Quality (CQ) and the Customer's Recognition of Quality Difference (CRQD) are shown in Figure 4.

The specific input parameters, which generated this behavior, are not significant for the ensuing discussion, but they are the same values, which enabled the model to replicate observed growth patterns in Figures 2 and 3. Notice the duopoly competition in Figure 4. At the start, FQ>CQ. The competitor does not remain passive. Rather, through the mechanism represented by component A in Figure 1, it responds by trying to improve its quality, and it does so aggressively. The firm, on the other hand, does not see any need to improve quality since FQ>CQ. This is reflected in the flat shape of FQ. However, after CQ becomes greater than FQ, the firm realizes it has to improve its own quality to keep from losing customers. This response can be observed in the gradual upward shift in FQ towards the latter quarters. Figure 4 also demonstrates the models ability to capture delays in how customers perceive this quality difference. For instance, FQ-CQ is zero at about quarter 2, but CRQD is still positive. CRQD becomes zero only after an additional quarter or so. In general, CRQD lags the actual quality difference.

Using Figure 4 as a base reference case, Figures 5 and 6 show the sensitivity of subscriber growth to variation in customer's inclination to switch providers due to quality problems. This switching propensity is an important marketing variable for all cellular providers. Recall that Bharti is the firm while Sterling is the competitor. The propensity to switch is represented by the variable Xferratio. With increase in Xferratio, the subscriber base of Bharti, the Firm, decreases while that of Sterling, the Competitor, increases after the initial 3-4 quarters. This can be attributed to switching of subscribers from the Firm to the Competitor due to the behavior of CRQD – customer recognition of quality difference – shown earlier in Figure 4. It is interesting to see that when customers are highly quality conscious (plot no. 3 in Figures 5 and 6), the aggressive move of the competitor to improve its quality can actually result in its gaining market share over Bharti. This kind of analysis can help the firms plan their internal activities in a competitive environment.

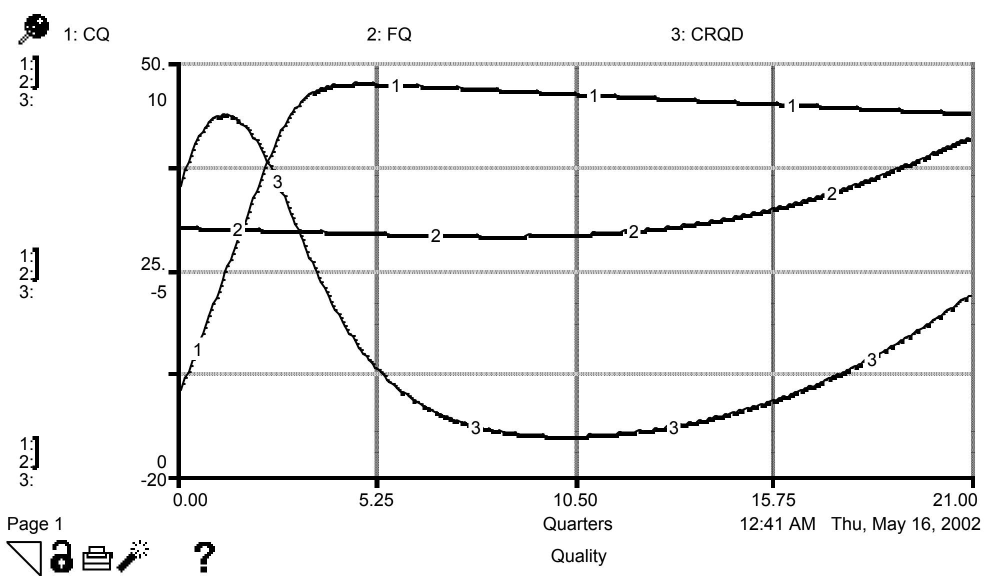

Figure 4. Behavior of FQ, CQ and CRQD

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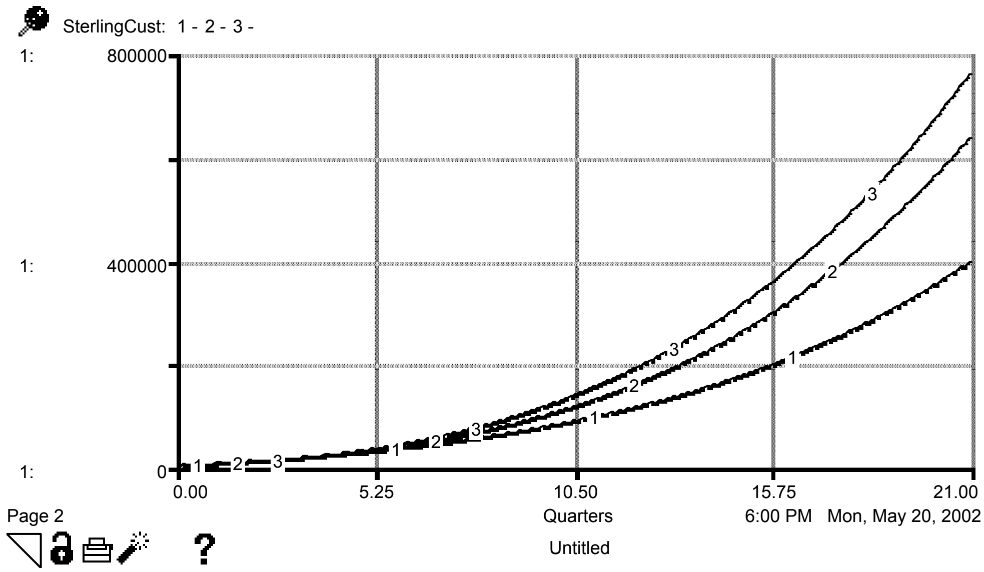

Figure 5. Sensitivity of Sterling's growth pattern with varying Xferratio (1=low, 3=high)

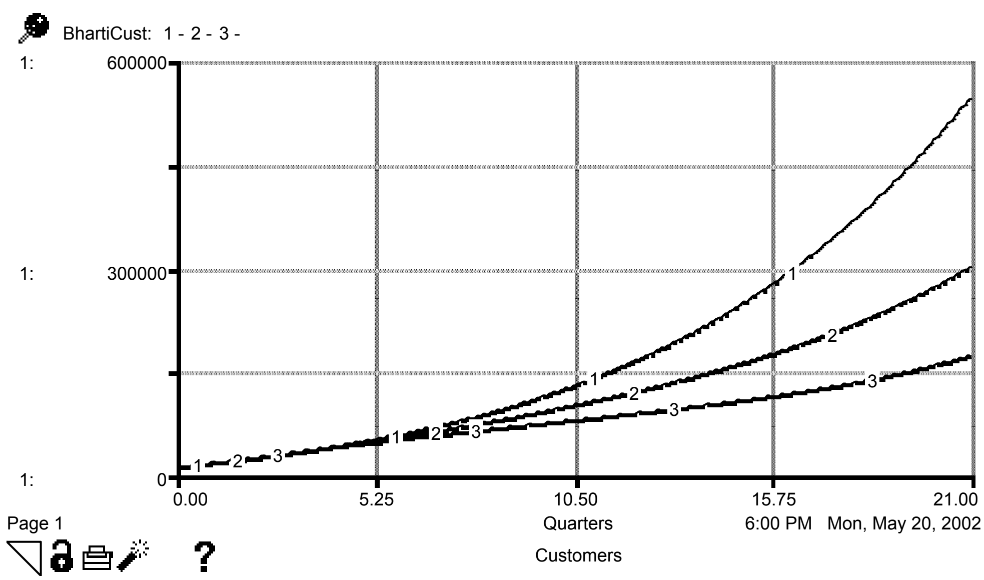

Figure 6. Sensitivity of Bharti's growth pattern with varying Xferratio (1=low, 3=high)

Figures 7 and 8 show the sensitivity analysis performed by varying the materialization delay of the competitor (Sterling). Materialization delay, as discussed earlier in the paper, refers to the time constant associated with the internal workings of the company in its efforts to improving the quality of its product offerings. After all, organizational change is not instantaneous, and some firms are more agile than others. We have used the following sigmoid functional representation for this time constant τ_m as discussed in [17].

$$\tau_m = n_0 + n_1\left(0.5\pi + \tan^{-1}\left(c(30 - FQ)\right)\right)$$

In the above equation, n_0 is the minimum value of the material response lag time constant in quarters and n_1 and c define the span and transition rate of the sigmoid function, respectively.

By increasing the span and gradient of the sigmoid function for the competitor, we have simulated conditions in which the competitor (Sterling) is assumed to be more agile in responding to quality improvements (referred to as the Agility of the Competitor (AC) in Figures 7 and 8) than the firm (Bharti).

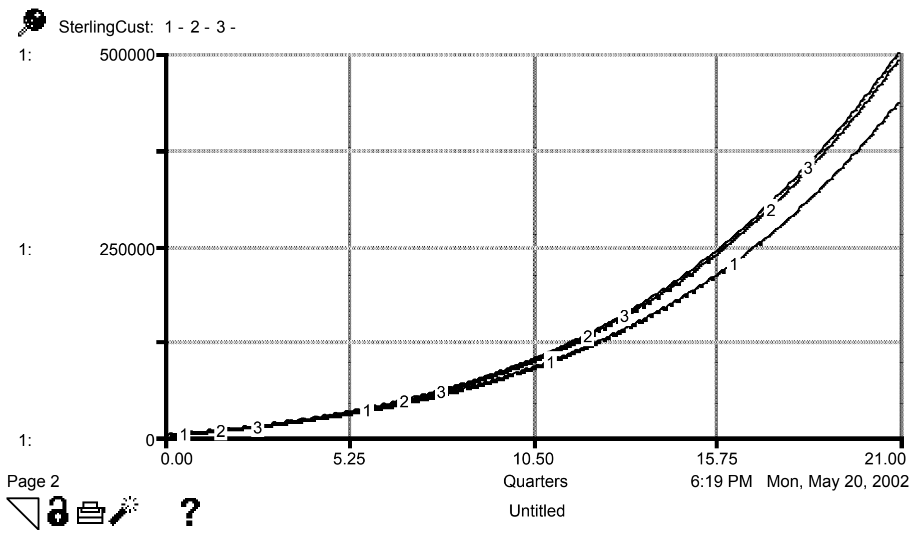

Figure 7. Sensitivity of Sterling's growth pattern for varying AC (1=low, 3=high)

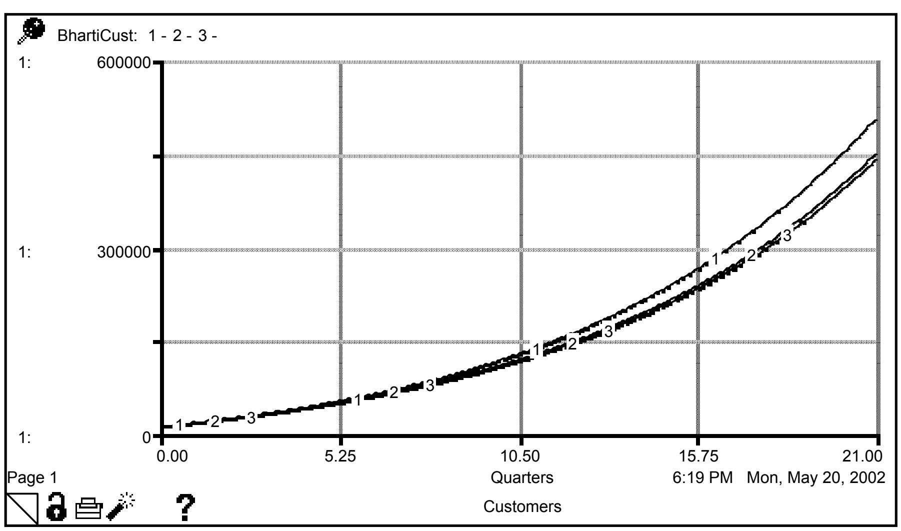

Figure 8. Sensitivity of Bharti's growth pattern for varying AC (1=low, 3=high)

The effect of increased agility of the competitor is shown as the increase in the subscriber base of the competitor as compared to the firm. Note however, that the improvement is nonlinear. The gap between plot 1 and plot 2 is significantly larger than that between plot 2 and plot 3. Hence there are diminishing returns for investments in improving internal efficiencies

5. Concluding Remarks

The preceding results indicate how a systems dynamics based modeling approach can yield insights into the mechanics of growth in the cellular market. Moreover, these simulation models can serve as decision support tools for planning purposes since they also inform us about the dynamics of growth under different operating assumptions. We view the model presented here as a first step towards a more comprehensive model of growth in the cellular market. Clearly, the model presented here is coarse. Hence, the first direction for model enhancement will be to disaggregate the concept of quality into its component parts specific to cellular service, and then capture the mechanics driving these individual components. These components include price, network capacity and variety of cellular services as mentioned at the start of the paper.

The second dimension for model enhancement is the inclusion of a third and fourth operator as is being contemplated in India and other developing countries. The viability of multiple service providers in an oligopoly market is an important issue, and one that is challenging to model. With the introduction of new providers, the incumbents face erosion of their subscriber base. They can take preemptive measures to improve the quality of their services offerings, reduce prices and increase the breadth of their service offerings. The new operators have to battle against the advantages of the incumbents such as existing subscriber base, economies of network operations, network infrastructure and their financial strength. There are other idiosyncrasies that may also need to be considered. In case of India for instance, some of the entities that have received licenses to operate as the fourth operator in metro areas, have prior cellular network provisioning experience in selected parts of the country. They can reduce the roaming charges when the subscriber roams in the operator's other areas. Further, the government owned third operator, was erstwhile monopoly operator in basic and domestic long distance services. This operator has extensive long distance network and a sound financial base that will enable them to cross-subsidize the cellular service and reduce prices. Moreover it is pointed out in [6] that the cost of networking equipment and license fees have come down from \$400 to \$100 per subscriber. This reduces cost of network set-up for the new entrants.

The following research questions are representative of those that can be analyzed based on the extensions just mentioned:

1. In the existing duopoly markets, what is the effect of price, quality of service and variety of services on the subscriber growth and market share for each of the service providers?
2. What is the transient behavior of the market when the third and fourth operators start providing service in their respective operating areas in the coming years?
3. What is the steady state subscriber base in an oligopoly market in each service area for the incumbent operators, and for the new operators?

The answer for the above questions can be very informative to the incumbents and new entrants as they plan their network rollout and service offerings.

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