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W.P. No.2007-12-04
December 2007

INDIAN INSTITUTE OF MANAGEMENT
AHMEDABAD-380 015
INDIA

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Introduction

Natural monopolies arising out of sub-additivity costs on the supply side are well known. Recently the consumer side has been emphasized especially in industries like telecom and IT/software industries. As per Shapiro and Varian (1999), network industries are characterized by strong super additivity of benefits on the consumption side. In the IT and related industries, Morris (2002) explores the detailed exposition on consumer side economies of scale and scope and its regulatory implications. Demand side economies of scale accrue from increased utility to a potential subscriber from a larger network. Hence, size itself becomes a factor in driving demand and has implications for a firm and its associated industry's growth prospects. We review the economic literature for demand side economies of scale.

Rohfls (1974) models demand for a telecommunication service by explicitly incorporating incremental utility for a user that accrues from increase in size of the network of users. The basic model models a user i's incremental utility for the service as:

$U_i = \sum_{j \neq i} v_{ij} q_j - p$

Where q_j is a user's demand state (binary variable), p is price of service

Under the simplifying scenario of a user's utility not being dependant on a specific user, we have

$U_i = \sum_{j \neq i} w_i q_j - p$, with w_i being a user's marginal utility due to increase in network size.

The user's demand state is set to 1 if the user's incremental utility is positive. An equilibrium set is defined as a user state, where every user's demand state matches his/her subscription state. The paper then characterizes various equilibrium states depending on initial conditions and additional simplifying assumptions of the base case model. An interesting result is the uniform calling model where w_i is assumed to vary uniformly across the population. This leads to an interesting result: for a given price level, there are two equilibrium states (one stable and the other unstable). The paper discusses convergence to equilibrium for varying initial conditions.

Oren and Smith (1981) expand on this framework and analyze the role of the tariff structure in attaining equilibrium. Katz and Shapiro (1985) develop a simple, static model of oligopoly to analyze markets in which consumption externalities are present. The point of departure in this work is that incremental utility is a function of expected size of network rather than the current size.

Katz and Shapiro (1986) analyze technology adoption in industries where network externalities are significant. All of these focus on equilibrium states.

Our work builds on the notion of increased utility due to increasing network size. However, we focus on dynamics of attaining equilibrium as characterized in the literature. Traditional temporal growth models for new product introduction are based on the diffusion model presented in Bass (1967). The central feature of this model is the segmentation of users into innovators and imitators. Imitators are induced into buying the product because of more users buying it. This is captured by the equation:

$$P(T) = p + (q/m) Y(T)$$

P(T) is the probability at time T of making a first time purchase given that no purchase has been made earlier, Y(T) is the quantum of sales at time T.

However, the model does not explicitly capture the increased preference for subscribing to a network size on account of increased network size. Our work attempts to explicitly incorporate network externalities based on demand into a dynamic growth model. We build on the uniform growth model presented in Rohfls (1974) and focus on the dynamics of attaining equilibrium. We assume supply will always meet increase in demand. The rationale for this assumption is presented in the section on supply side analysis.

The Indian Telecom Sector

We have used growth data from the Indian Telecom industry from the 2000-2005 periods for our investigations. The Indian Telecom industry was de-tariffed in 2000 and has since been marked by high subscriber growth, decreasing tariff structures across range of service providers, and granting of additional licenses. An investigation of the cost structure of Indian telecom providers reveals decreasing costs (both fixed and variable) with growth of subscribers. Interestingly, variable cost per user shows a downward trend with increase in network size. We attribute this to strong learning curve effect. From our study of costs in Indian telecom, we infer that the current scale of operations is one of diminishing marginal cost of adding additional subscribers. Hence, growth will be purely determined by additional demand. Hence, we can assume that supply is essentially horizontally sloped viz. prize and the analysis can be confined to the demand side.

We seek to examine the presence of network economies in the Indian telecom industry and give it a concrete functional structure. This could serve as a valuable component in the valuation models in the telecom sector. We start by trying to characterize the nature of demand side network economies in the Indian telecom industry.

Demand Side Network Economies of Scale:

As per Metcalfe's law, the total value of a network to the network's users is proportional to n^2 where n is the number of subscribers within the existing network. Given a competitive market and the standardized nature of cellular services, companies will not be able to capture this value in the form of price premiums. However, new users will be more inclined to join larger existing networks, other things being equal. Large companies will therefore accrue benefits from their networks in the form of larger additions to their networks.

Regression I

We have tried to examine the existence of such a relationship by regressing subscriber size growth as a polynomial function of n, adjusting for other significant drivers such as real tariff changes, real income changes and absolute value of market size.

Therefore, we ran the following regressions:

Subscriber growth addition = $k_1 * n^2 + k_2 * (\alpha) + k_3 * (\beta) + k_4 * (\gamma)$

- **n** : Total subscriber base in the December of previous year for a company (Number of Subscribers)
- **Subscriber growth addition** measured as new subscribers for a company's service in the current year (Subscribers/Year)
- **α**: change in per capita NDP (Net Domestic Product) @ factor cost from December of current year to December of previous year (Rupees/Year)

- **β**: change in ARPU (Average Revenue per User) /WPI (Wholesale Price Index) (/year)

  Explanation

  ARPU is average revenue per user for in the Indian Telecom sector (unit: Rupees) at any given point, WPI is the price level of workers in the Indian economy at any given point (in Rupees). ARPU/WPI therefore proxies for the real price level for mobile services at a given point in time. **β** = ARPU/WPI (December of current year) - ARPU/WPI (December of previous year)
- **γ**: Additional telecom subscribers (across all services) in current year (Unit: Subscribers/Year)

The results show that annual subscriber growth is a statistically significant relationship of n^2, where n is the subscriber base of a company in the previous year. Subscriber growth is also found to be a positive function of per capita NDP @ factor cost increase and negative function of increase in ARPU/WPI (albeit not statistically significant).

Regression Results

The output of the regression comes out as given in Table 1:

Variable	Coefficient	t-Statistic
n^2	2.01E-05	5.09
α	0.31	0.32
β	-12.19	-0.037
γ	0.20	4.77E-10

Coefficient of Regression R^2	0.98
F-Statistic	321.22

Table 1: Results of Regression I

The first row consists of the coefficients of regression. The level of significance comes out to be 0.98 (row 3 – r^2) indicating a significant relationship between the output and the input variables.

Regression II

Pursuing the logic of demand economies, we bring in an additional variable: the subscriber base of competitors in the circles a company operates in.

We ran the following regression with statistically significant results:

Subscriber growth addition = $k_1 * n^2 + k_2 * m + k_3 * (\alpha) + k_4 * (\beta)$ + constant

Where m now is: Total subscriber base of competitors in company's operating circles during previous year's December (Subscribers)

Regression results

A Regression with all 4 variables

Variable	Coefficient	t-Statistic
n^2	1.75E-05	4.39
m	0.23	7.63
β	-17.18	-1.17
α	0.034	0.22
Constant	-16.59	-0.074

Coefficient of Regression R^2	0.98
F-Statistic	304.39

Table 2A

B Regression with only m, n^2

Variable	Coefficient	t-Statistic
Constant	192.45	1.37
m	0.23	7.62
n^2	1.82E-05	4.67

Coefficient of Regression R^2	0.98
F-Statistic	619.61

Table 2B

The results indicate that external market size could be a significant driver of company growth. This is consistent with the theory of demand economies if we assume seamless connectivity across networks. This holds true for the Indian telecom sector.

Interestingly, we don't get a statistically meaningful relationship when we regress growth against m^2 and n^2, indicating that demand economies are more strongly exhibited within the company's network.

Demand Side Economies at the Aggregate Level

We then tried to take a look at the network effects on a circle level if any. We looked at overall growth in terms of subscribers in a circle and then looked at the relation of that with the number of subscribers in that circle. This was in continuing with the earlier result that growth for the company was a statistically significant function of n^2 with the other factors being not so relevant. In that case overall growth in a circle we believed would be a strong function of the number of subscribers which are already there in the circle. The rationale for this again was that in a given circle the market would grow faster if the existing base was large at least in the growth phase since the benefits to be gained from people having a mobile if people in the vicinity have a mobile are quite high.

We ran a regression of growth in a year with existing subscriber base squared in the previous year (n^2).

Circle Growth = $k\ n^2 + c$

- **n**: Total subscriber base in the December of previous year in an operating circle (Subscribers)
- **Circle Growth**: measured as new subscribers in an operating circle in the current year (Subscribers/Year)

With one degree of freedom, we were able to obtain a 62% goodness of fit.

The results of the regression are stated below:

Variable	Coefficient	t-Statistic
Constant	318.79	7.45
n^2	0.00013	16.59

Coefficient of Regression R^2	0.62
F-Statistic	275.11

Table 3

The relevance of the n^2 term is also visible from the results.

We believe these results, in keeping with the earlier ones, confirm to the fact that Network Economies are a major factor when it comes to subscriber growth.

However, we believe that on an aggregate level, taking all companies in a circle, the demand side economies will drive growth. Earlier, the results obtained on a company level suggested a relation to the existing subscriber base for a company to the extent of n^2 and to the external market to the extent of m.

We ran a regression of overall growth in number of subscribers with n. The results were better than the earlier regression with the regression coefficient coming out as 76.4%.This suggests a stronger prevalence of demand side economies on the aggregate level.

The results are as shown

Circle Growth = k n + c

Variable	Coefficient	t-Statistic
Constant	86.71	2.27
n	0.60	23.23

Coefficient of Regression R^2	0.76
F-Statistic	539.74

Table 4

Implications of our findings

Our results have profound consequences for telecom sector valuation models. During the growth phase of any sunrise industry, market size growth resides in the steep portion of the S-curve. This can be attributed to a) supply side economies bringing down prices b) change in real income of consumers making the products more affordable c) greater product awareness. This is in contrast to the findings by Jain (2006) which imply that drop in ARPU is the primary driver of growth.

In case of telecom, we assert that demand side network economies contribute an additional factor. From the perspective of a potential customer, the subscription becomes more valuable if there is larger cellular network to tap into. This induces exponential growth during the initial stage.

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APPENDIX

Growth	α	β	n	m	γ
39.0	-196.1	-17.9	47.0	85.3	2853.7
46.0	-372.5	-16.8	86.0	150.8	7427.9
125.0	633.0	-22.2	132.0	114.4	20408.9
248.0	-854.1	-8.0	257.0	353.9	17952.4
559.6	1632.6	-3.4	505.0	699.2	38754.7
90.6	576.8	-8.4	171.4	404.5	2853.7
138.5	825.4	-12.8	262.1	588.8	7427.9
389.8	-540.3	-14.6	400.6	664.6	20408.9
895.6	218.3	-4.1	790.4	1822.9	17952.4
594.2	279.8	-0.4	1686.0	2732.8	38754.7
261.3	-18.4	-6.6	838.4	2413.3	7427.9
549.7	6.5	-9.6	1099.7	2864.8	20408.9
845.7	76.9	-2.6	1649.3	6409.8	17952.4
373.3	-1074.1	-9.0	286.3	746.9	2853.7
560.5	-344.6	-21.2	659.6	1722.4	7427.9
1224.0	72.6	-14.7	1220.0	1708.5	20408.9
2435.7	447.1	-9.3	2444.0	7914.5	17952.4
1852.9	-1491.6	-2.5	4879.7	9765.3	38754.7
658.0	871.7	-29.1	595.0	758.4	2853.7
1626.0	-1264.3	2.6	1253.0	2378.9	7427.9
3625.0	206.1	-21.3	2879.0	8703.5	20408.9
4480.0	330.3	-8.4	6504.0	17000.8	17952.4
8595.0	-429.4	-10.1	10984.0	25980.6	38754.7
17562.0	624.4	-6.1	19579.0	45690.8	70288.3

Raw Data for Regressions I, II (Source: CMIE Telecom)

Growth	131	224	335	515	202	293	165	18	85	79	127	116	55	9	100	144	160	188
n	296	487	920	1707	3092	1561	2622	51	103	238	430	826	70	158	246	469	824	890

Raw Data for Regression III (Source: CMIE Telecom)