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Pricing of Mobile Telephony Services in India

Ajit Shankar[1] and Kishore Kumar Morya[2]
[1]Research Scholar, School of Management, G.D. Goenka University, Sohna-Gurgaon (Haryana), India.
[2]Associate Professor, School of Management, G.D. Goenka University, Sohna-Gurgaon (Haryana), India.

(Corresponding author: Ajit Shankar)
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ABSTRACT: A study of the pricing of mobile telephony is essentially an analysis of elements driving survival of business in hyper competitive, capex intensive, technology centric businesses. Pricing is an essential ingredient of the strategy for growth and survival of operators at individual level as well as for the overall sectoral growth. Under perfect competition, the prices tend to move towards marginal costs. However, facing an exceptionally fierce competition, Indian mobile telephony service providers are driven by a long-term survival strategy of customer acquisition & increasing market share; and the services are being offered at significant discount to marginal costs leading to huge losses to operators. In this paper, quarterly data on price and demand have been used to regress two types of demand functions- a quadratic polynomial function and an exponential function with pricing as an independent variable. Further, the operators are assumed to follow revenue maximization (RM) strategy and price point leading to revenue maxima for the regressed demand function is predicted as the service price in the following time period. It is noted that from March 2008 to Sept 2016, the revenue maximization assumption yields service price close to the actuals. However, in subsequent quarters (after the entry of Reliance Jio in market), the prices were not driven by RM strategy but by the survival need of operators. As a result, the mobile telephony service prices in this period are not just lower than marginal costs but also lower than what is required for revenue maximization.

Keywords: Mobile Telephony, Price optimization, Business survival, Price elasticity of Demand, Regression.

Abbreviations: RM, revenue maximization; ARPU, average revenue per user; AGR, adjusted gross revenue; INR, Indian rupees; RPM, rate per minute; MOU, minutes of usage; GDP, gross domestic product; EBITDA, earnings before interest tax depreciation and amortization; GMOU, gross minutes of usage; PCMOU, per capita minutes of usage; PCGDP, per capita gross domestic product.

I. INTRODUCTION

The mobile telephony service usage rate in India is one of the lowest in the world. It has come down from Rupees thirty per minute at the time of commencement of service to around ten paise per minute. Service pricing in the dynamically evolving business environment with changing competitive intensity is an intriguing study and this paper strives to put forward a rational of the mobile telephony service rates at different points of time from Jan 2008 to Sep 2019.

Mobile telephony service rate has decreased from INR 0.52 per minute in March 2008 to INR 0.11 in Sep 2019 (Fig. 1) sector leading to declining Average Revenue Per User (ARPU) which has come down from INR 331 to an abysmally low INR 74.38 (Fig. 2) and also declining Adjusted Gross Revenue (AGR) despite increase in subscribers (Fig. 3). Hence, while the subscribers grew from 262.07 million in March 2008 to 1173.75 million in September 2019 showing a 350% increase, the quarterly adjusted gross revenue (AGR) has grew from 278.45 billion to 373.38 billion only showing a mere 34% increase. The revenue growth will be still lower if we consider inflation and the AGR is rationalized using a price index. It is observed that between December 2009 to December 2016 the service rates have been in the range of Rs. 0.28 to Rs. 0.34 and incidentally, during this period reasonably healthy growth in subscribers has also happened. Subsequently the service usage rates per minute (RPM) has been declining and subscriber growth appears to have stopped. It appears that the service pricing is largely being governed by the customer retention and acquisition target and it is difficult to econometrically model the same.

II. RESEARCH SIGNIFICANCE

This paper indicates that under a very high intensity of competition, three out of four Indian mobile telephony service operators (considering public sector enterprises BSNL & MTNL as one entity, as their merger is already

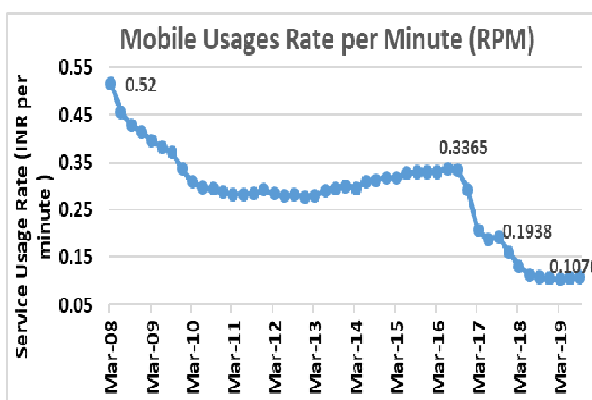

Fig. 1. Mobile service usage rate across last few years.

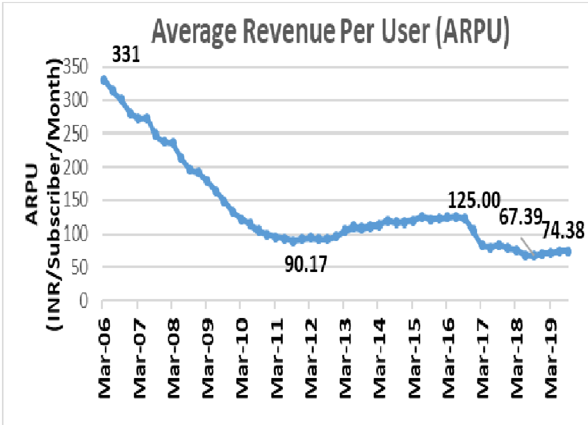

Fig. 2. Declining ARPU across last few years.

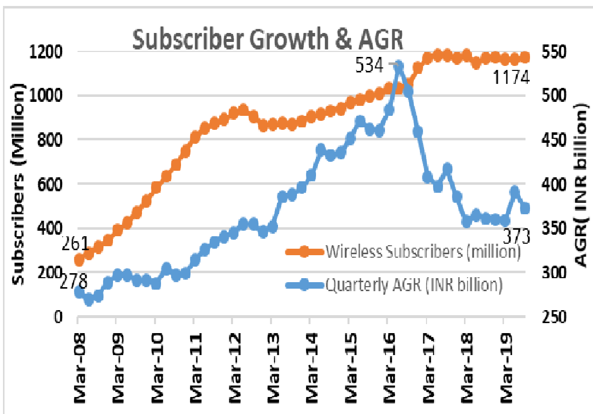

Fig. 3. Subscriber growth & AGR.

in pipeline) are following survival strategy using revenue maximization approach. Typically, companies following RM Strategy also fix a profitability threshold for themselves. Indian Telcom Companies, in their zeal to survive, have accepted a negative profitability threshold thereby making the whole business unsustainable in the long run. This research tries to establish that present service pricing of mobile telephony in India after September 2016 is below marginal costs of production of these services. Accordingly, subsequent to some more collaborative and adjacent research, the Government of India may intervene positively in this regulated industry to avoid monopolies in the long run. Further, the price elasticity of demand has been calculated in a unique way in this research paper .The price elasticity study can be used by operators to design an attractive tariff plan and by the Government to effectively fix up taxes, license and spectrum fee so as to achieve a balance between maximizing its revenue or increasing customer welfare. Quantitative analysis contained in this research can facilitate positive intervention in pricing of mobile telephony services thereby increasing consumer welfare and/or accelerate the mobile telephony penetration in the country.

III. METHODOLOGY

This study is a part of an overall research on Pricing imperatives of evolving mobile telephony services in India. Initially, a literature review on possible general pricing strategies under hyper competition as well as on price elasticity of demand of mobile telephony services has been done. Subsequently, the sensitivity of demand to price movements has been established and then demand has been modelled in terms of prevailing price using the quarterly price and demand data. Collecting operator level reliable long-term demand, ARPU or MOU data was found to be challenging in view of the time limitations. Further, a lot of new operator entries & exits and mergers & acquisitions enhance the fuzziness of information and make determination of price elasticity at an individual level pretty cumbersome. However, in view of almost similar tariffs land price levels fixed by all the operators, the price & demand relationships and price elasticity of demand study at an aggregate level also gives a lot of insights in the market. This study uses the aggregate level data on price and demand. Two relationships- demand as a quadratic polynomial function of price and as an exponential function, have been explored based on high coefficient of determination obtained in these relationships while regressing as well as simplicity of use of these functions in finding maxima and point price elasticity of demand. Minutes of Usage (MOU) expressed in terms of gross minutes of mobile usage per month and mobile service usage rate per minute (RPM) expressed in terms of INR per minute have, initially been considered as representatives of demand and price respectively. Later, to take care of the impact of increase in population as well as increase in purchasing power of the consumers during the period of study (Jan 2006 to Sep 2019), two variations for representation of demand and price have been explored- firstly, by substituting aggregate or gross MOU by per capita MOU and secondly by substituting RPM in Rupees per minute by RPM expressed in terms of a multiple of ten millionth part of prevailing per capita GDP. The MOU & RPM data pertaining to the quarter ending March 2006 to the quarter ending September 2019, as published by Telecom Regulatory Authority of India (TRAI) in its quarterly performance reports has been used. Per Capita GDP at current prices as published on http://statisticstimes.com/economy/gdp-capita-of-india.php for a financial year has been considered at midpoint of the financial year. For example, published Per capita GDP for the financial year 2011-12 has been assumed to exist on 30th September 2011, for the financial year 2012-13 on 30th September 2012 and so on. Per capita GDP for other points of time (quarter ends) have been found using linear interpolation from these available points. Prediction of optimal price for a quarter is based on historical data up to immediately preceding quarter. Available data as above is used to regress a possible function expressing demand in terms of price.

It has been assumed that under hyper competition, operators want to maximize revenue rather than profits in view of overall strategy of long-term survival and business leadership. Hence, using the function generated as above through regression, the price point for maximization of revenue and the price elasticity of demand are predicted. Finally, the predicted prices are compared with actual prices to evaluate the validity of our Revenue Maximization hypothesis.

IV. LITERATURE REVIEW

Study of pricing of mobile telephony services for the purposes of the subject covered in this paper can be categorized in two parts-(a) Studies related to price elasticity of demand of telephony services; and (b) studies related to general pricing strategies of organizations under different levels of competition.

A. Elasticity of Demand

Mitchell *et al.*, (1991) had empirically analyze the US telecom scenario and they did not consider it to be relevant to include service price as a meaningful variable for determination and growth of telecom demand [1]. In stark contrast, Hakim & Neaime (2014) [2] have argued that the elasticity study is extremely important as it provides prediction of the impact of price changes on sales and on overall revenue, setting in turn, the unit rates for mobile communications keeping in view the affordability (determined by per capita income and likely changes in it in near future). It also gives inputs for optimization of the taxes (directly on telecom revenue or through spectrum costs) to be imposed on mobile telephony services; and for computation of welfare gains by expanding the reach of mobile services and making it more inclusive. Hakim & Neaime have also asserted through their study of Middle east & North African countries during 1995-2007 that a 10% increase in mobile subscription leads to a 6.9% increase in minutes of usage.

There is a lack of consensus on the value of elasticity of demand- both price elasticity as well as income elasticity. A list of studies pertaining to price elasticity of demand is summarized in Table 1. It may be seen that an elasticity measure of even 3.963 -one of the highest in available literature was reported by Okada & Hatta (1999) [3]. They have attributed this large elasticity to the fact that the mobile telephone was at the diffusing stage during their period of study and accordingly certain factors like reduction in price of mobile handsets, introductory pricing by operators, volume discounts etc. may have given an upward bias to own-price elasticity determined by them. Additionally, they have asserted that use of less noisy short run annual data or negligence of categorization of demand (personal or business, local & long distance etc.) may also have led to higher values of elasticity.

Okada & Hatta have also found the cross-price elasticities between fixed-line and mobile telephones as positive implying that their study supports the assertion that these services are substitutes of each other [3]. Interestingly they have found significant asymmetry between the two cross elasticities and that the price change of wireline network is found to have greater impact on mobiles than vice versa. (η_{21} = 0.866 against η_{12} = 0.276). In India, between March 2003 to March 2018, while the wireless subscribers grew from 13 million to 1183.41 million, the wireline subscribers have reduced from 41.48 million to 22.81 million clearly establishing the fact that even in India, there is a definite decrease in fixed line subscriptions with increasing mobile subscriptions. However, increase in fixed line connections decelerating the mobile subscriber growth cannot be established for Indian market and may not be actually be true.

Ingraham & Sidak (2004) [4] have studied the impact of taxation on mobile services in USA. However, to exactly compute the impact of taxation and the resultant inefficiencies, they have used the price elasticity of demand. They have formulated a consumption model and considered both the elasticities of demand- firstly the own price elasticity of demand for mobile services and secondly the cross-price elasticity of demand for mobile services with respect to fixed line long distance telephony. The demand of wireless services by a consumer has been modelled as under:

$$Q_{\text{wireless}\,i} = \alpha_0 + \alpha_1 P_{\text{wireless}\,i} + \alpha_2 P_{\text{long-distance}\,i} + \alpha_3 t_i + \sum_{j=4}^{M} \alpha_j X_j + e_i$$

where Q_{wireless} = $\log_e$ (mobile minutes)

P_{wireless}= $\log_e$ (rate per minute of mobile service)

$P_{\text{long-distance}}$= $\log_e$ (rate per minute of fixed line long distance service)

α_1 and α_2 are own elasticity of demand and cross elasticity of demand respectively and *e* is a random error term with constant variance and zero mean.

$\sum_{j=4}^{M} \alpha_j X_j$ takes care of demographic variables wherein numbers have been assigned to parameters like single, married, occupation type, household size, age, income etc. Subsequently, regression analysis has been used to record decline in consumption with increased price due to taxation. If we disconnect the study by Ingraham & Sidak to its taxation aspect, they have, concluded that the demand (in USA) for mobile telephony service has become more elastic and hence, price increase (due to increased taxation in his studies) has resulted in inefficiencies.

Similar price elasticity studies with respect to Indian market and more specifically different telecom circles should, ideally give significant insights on subscriber behaviour and his price sensitivity and the telecom service providers can use the same in offering various tariff packages to optimize their revenue and/or profitability, in accordance with the strategy being followed by them. Moreover, due to prevalence of large low-income group subscribers in India- the business models should necessarily involve innovations leading to profitably capturing this subscriber segment. While price elasticity of demand, being an established market influencing parameter is typically talked about by most of the people- Miravete (2002) [5] made a study of local telephone service demand by consumers having optional calling plans. His basic assumption is information asymmetry and he compared the revenues in case of a monopolist offering a mandatory non-linear tariff and that in case of the same monopolist offering a choice to be exercised in advance - of optional two-part tariffs. Miravete has used rigorous regression and correlation techniques using linear and non-linear pricing models in his econometric analysis to estimate the welfare parameters. Christopher (2007) [6] has concluded after his study of various developing countries that the residential monthly price elasticity is insignificant- however, connection elasticity is higher than that normally found in available research literature.

Table 1: Summary of a few price elasticity studies for mobile telephony available in literature [2, 3, 7-27].

S. No.	Researcher	Year of Publica-tion	Region/Market studied	Period pertaining to the Data/Study	Result	Remarks
1.	Ahn & Lee [7]	1999	64 different countries	Data obtained from ITU's World Telecommunication Development Report, 1998	$\eta_{connection\ fee}$ = -0.25 η_{usage} = -6.1 $\eta_{mobile\ originated\ calls}$ = -30.62	Elasticity of demand calculated at an aggregate country level.
2.	Okada & Hatta [3]	1999	Japan	1992-96	η= -3.963	
3.	Hausman [8-10]	1997, 1999 & 2002	30 Metropolitan Statistical Areas (MSAs) of USA	1989-1993	η= -0.51	Estimation through a log linear demand curve. Least expensive plan for 160 minutes of usage as a measure of price.
4.	Chris	2003	UK	Q3-1996 to Q1-1999	η= -0.49	as reported by Afridi *et al.*, [16]
5.	Grzybowski [11]	2004	EU Countries	1998 to 2002	η for mobile demand varying from -0.2 to -0.9.	
6.	Growitsch et al [12]	2010	61 EU member states	2003 to 2008	Short run & long run η = -0.097 & -0.608 respectively.	Using Dynamic Generalized Method of Moments (GMM) Panel
7.	Access Economics [13]	1998	Australia		η= -0.80	
8.	Dewenter & Haucap [14]	2004	Austria	Jan 1998 to March 2002	η for business & private Consumers at -0.33 and -0.14 respectively. η for postpaid and prepaid is -0.22 and ~0 respectively.	Using Dynamic Panel Regression
9.	Haucap, Heimeshoff and Karacuka [15]	2010	Turkey	Jan 2002-Dec 2006	Long run η : Postpaid=-0.72, Prepaid=-0.33, blended=-0.45 Short run η : Postpaid=-0.20, Prepaid=-0.36, blended=-0.28	Firm specific data for five firms used.Demand= total outgoing minutes of the respective mobile network, Price=ARPU /outgoing minutes for the whole market
10.	Afridi et al [16]	2010	UK	Q2 1999-Q4 2008	η= -0.52	
11.	Genakos & Valletti [17]	2009	20 countries	Six Years	Magnitude of Waterbed effect > 1	
12.	Competition Commission of UK [18]	2003	UK		η for mobile subscriptions= -0.08 to -0.54 η for mobile calls= -0.48 to -0.62	Studies by DotEcon, Frontier Economics & Holden Pearmain
13.	Hakim & Neaime [2]	2013	MENA Countries	1995 to 2007	η = ~ -1	
14	Madden & Coble-Neal [19]	2004	56 Countries	1995 to 2000	η = -3.09	
15	Ogut *et al.*, [20]	2015	Turkey	Jan 2009 onwards	For operators, own η =-1.73 to -2.4 Cross price elasticity=0.63 to 1.75	
16	Hausman & Ros [21]	2012	17 countries i/c Mexico, Russia, Turkey etc.	Q2-2004 to Q3-2011	η for mobile services=-0.524, GDP-per capita η=-0.425	Demand = Tele-density Price= Voice Revenue per minute
17	Hausman & Sidak [22]	2007	Ireland	2004	η =-0.84	Proxy for Demand=ARPU, Price= log of average price per minute
18	Ward & Waroch [23]	2009	U.S. Households across 48 states	Q3 1999 to Q4 2001	η for mobile subscriptions= -0.75 to -0.81 η for fixed lines= -0.23 to -0.26 cross price elasticity between fixed & mobile =0.25 to 0.31.	
19	Parker & Roller [24]	1997	USA	1984 to 1988	η =-2.5	
20	Rodini, Ward & Woroch [25]	2002		Jan 2000 to Dec 2001	η =-0.43 for mobile subscriptions, η =-0.60 for mobile access and usage	
21	Danaher [26]	2002	New Zealand	Oct 1994-Oct 1995	η =-0.06,-0.10,-0.20 & -0.35 for (access price, usage price) of (10,0.1),(15,0.15), (25,0.3) & (35,0.6) respectively.	
22	Tishler, Ventura & Watters[27]	2001	Israel		η =-0.22 (phone purchase), η =-0.42 (monthly charges)	

B. General Pricing Strategies under Competition

The rational for profit maximization assumption is provided by "Market Selection Hypothesis" for which Friedman (1953) [28] had said that entities that fail to Maximize profits fail in competitive markets since competitive environments are similar to Darwin's natural-selection- like forces or "the survival of the fittest: theory of Biology. In contrast, Baumol (1958) [29] propounded a revenue maximization hypothesis followed by large oligopolistic firms with significantmarket power subject to a minimum profit constraint. They adopt this price strategy to eliminate competition or part thereof. Amihud & Kamin (1979) [30] through their study of behaviour of various firms supported Baumol's hypothesis and stated that revenue maximizing behaviour is more prevalent among management controlled oligopolistic firms.

Opera (2014) [31] has studied various organizations and concluded that high rates of survival are, in many cases, achieved by moving away from profit optimization. He has further elaborated that in many cases, wealth maximization (implying profit maximization and consequent value creation for the company) and high rates of survival are incompatible in which case the companies tend to hoard excessive cash to improve their survival probability. In the case of mobile telephony in India, for most of the firms the deviation is so high that cash accretion is negative. However, Opera has reserved his comments in the case of competitive credit markets and enlisted it as an area of future research. The Indian mobile telephony market shows that in absence of hoarded cash, the companies have gone for multiple rounds of fund raise to ensure maximization of survival probability.

C. Gaps in available literature

A lot of informative papers are available on price elasticity studies as well on pricing strategies under fierce competition. However, not much was found on these studies in specific reference to Indian mobile telephony space. Further, subjective theories have been proposed connecting regulatory policies and competition to the low mobile telephony tariffs in India. This paper strives to commence quantitative analysis of prevailing pricing and demand modelling of wireless telecommunications demand in India which, in turn, provides inputs for strategic decisions to operators as well as the regulator.

V. DETAILS OF PRESENT STUDY

A. Mobile Telephony Service Pricing in India

Price of mobile services is conventionally represented by Revenue Per Minute (RPM) and the usage is represented by minutes of usage (MOU). The product of the average MOU reported and average subscribers (arithmetic mean of subscribers at the start of the quarter and those at the end of the quarter) can be considered a good approximation of the gross MOU of the quarter. The basis of this assumption is that subscriber acquisition or separation for the whole quarter can be considered as happening with uniform pace without large spikes. Incidentally, the mobile telephony demand in India is extremely price sensitive and exhibits the law of price and demand as shown in Fig. 4. Chabossom *et al.*, (2008) [32] indicated that demand of mobile telephony services and PCGDP have a positive correlation. However, after a study of articles by various researchers like Mitchell and Vogelsang, Hakim & Neaime and others, one tends to conclude that there is no unanimity on this issue. Hence, it is proposed to test the following hypothesis regarding the mobile usage demand in India being impacted by service price-

Null hypothesisH_0: The mobile telephony demand (gross MOU) is not impacted by service price (RPM).

Alternative Hypothesis H_1: The mobile telephony demand (gross MOU) is a function of service price (RPM).

Using the two-tail student - t test for the same, the t statistic value obtained =11.9428 which is higher than $t_{critical}$= 2.6776 obtained for a degree of freedom = 52 and level of significance=0.001.Hence at 99.9% confidence level, the null hypothesis is rejected, and it can be concluded that the mobile telephony demand (Gross MOU) is a function of service price (RPM). Through regression, we have evaluated both- (a) a quadratic polynomial demand function; and (b) an exponential function as these two were exhibiting high coefficient of correlation.

(i) Demand function as a quadratic polynomial of Price: Expressing the price demand relationship as under:

$$D = AP^2+BP+C \quad (1)$$

where D= Gross Mobile telephony service demand expressed in minutes of usage per month; P= Service Rate per minute (RPM); and A, B & C are constants. Demand is dependent on various factors besides price and the constant C is expected to represent all such factors which are impacting demand levels but are independent of Price. Such demand function regressed for the quarter ending March 2006 to the quarter ending September 2019 is shown in Fig. 5.

Multiplying both sides of (i) above by P we get Revenue (R).

$$R= D*P = AP^3+BP^2+CP \quad (2)$$

Under hyper competition, it is expected that the competing operators shall fix their service price for revenue maximization rather than profit maximization. We shall simply use the optimization theory to arrive at the rate per minute for revenue maximization:

i.e. $$\partial R/\partial P = 3\,AP^2+2BP+C \quad (3)$$

& $$\partial^2 R/\partial P^2 = 6AP+2B \quad (4)$$

For Maxima- Minima, $\partial R/\partial P = 0$ i.e. $3\,AP^2+2BP+C =0$ which has following roots:

$$\text{Root 1} = (-B+ (B^2-3AC)^{0.5}) / (3A) \quad (5)$$

and $$\text{Root 2} = (-B - (B^2-3AC)^{0.5}) / (3A) \quad (6)$$

and the root satisfying $d^2R/dP^2 <0$ or $P< -B/3A$ shall yield maximum revenue. In this case, $(B^2 – 3AC)^{0.5}$ being a positive number, Root 2 shall always meet this criterion and provide maxima. Accordingly, in our analysis Root 2 is the service rate which operator shall charge to maximize its revenue.

We assume that there is no information asymmetry with operators about customer response to pricing in terms of availability of historical MOU at different prices and that the operators use the same to maximize their revenue. Using the quarterly data available for actual MOU & RPM for the period of March 2006 to December 2008 (Table 5A), the coefficients A, B & C are determined for the quadratic equation representing the demand through regression. This is used to determine the RPM for the subsequent quarter January-March 2009 in a way that R= R_{max} in accordance with equations developed above. The price and demand representing the relationship between the RPM and gross MOU for the period March 2006 to September 2019 is shown in Fig. 5. Similar regressions are carried out for each quarter end from December 2008 onwards and is used for determination of RPM in the following quarters. Such predicted RPM is compared with the actual RPM observed and the comparison is shown in Figs. 6 and 7. The detailed tabulation for different periods is given in Table 5B of the Appendix to this paper.

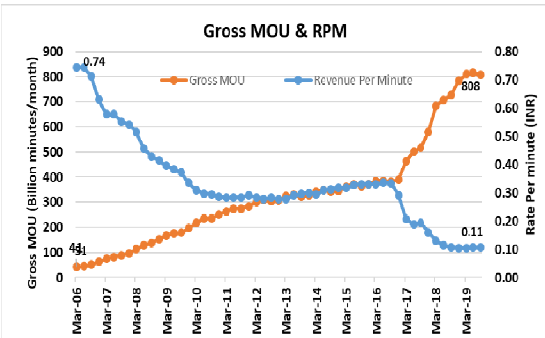

Fig. 4. Mobile Telephony price and demand (in terms of gross MOU).

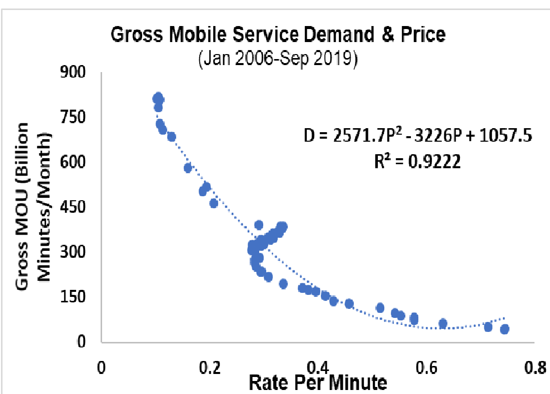

Fig. 5. Gross MOU & RPM relationship in terms of a quadratic polynomial.

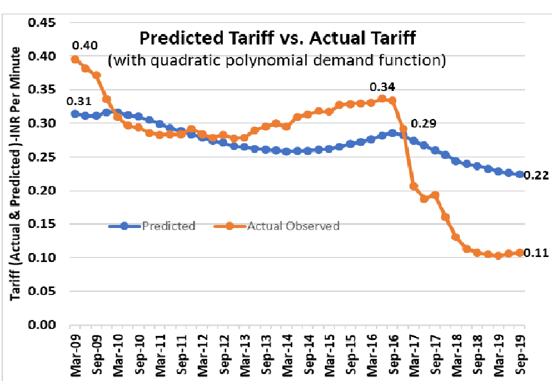

Fig. 6. Predicted vs actual tariff with quadratic demand function & gross MOU as a measure of demand.

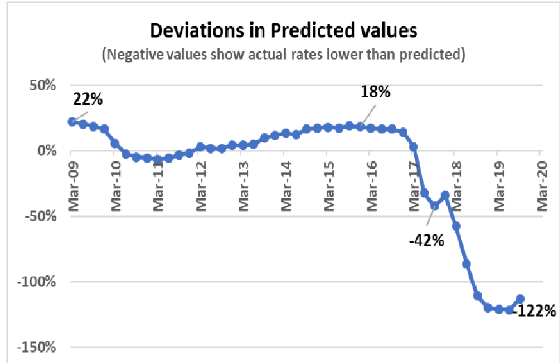

Fig. 7. Deviations in predicted rates- quadratic demand function & gross MOU case.

(ii) Demand function as an exponential function in terms of Price: Expressing the price demand relationship as under:

$$D = \alpha e^{-\beta P} \quad (7)$$

where D= Gross Mobile telephony service demand expressed in minutes;

P = Service Rate per minute (RPM); and α & β are positive constants. The constant β is expected to represent all non-price variables impacting demand levels.

Multiplying both sides by P we get Revenue (R).

$$R = D^*P = \alpha P e^{-\beta P} \quad (8)$$

Using the optimization theory to arrive at the rate per minute for revenue maximization:

i.e. $\partial R/\partial P = R(1/P - \beta$ (9)

& $\partial^2 R/\partial P^2 = R\beta(\beta\text{-}2/P$ (10)

For Maxima- Minima, $\partial R/\partial P = 0$ i.e $(1/P - \beta) = 0$ implying $P = 1/\beta$.

At this Price $\partial^2 R/\partial P^2 = -\beta.R^2$ which is negative implying that $P = 1/\beta$ shall yield maximum revenue.

The price and demand representing the relationship between the RPM and gross MOU for the period March 2006 to September 2019 is shown in Fig. 8. Similar regressions are carried out for each quarter end from December 2008 onwards in the same manner as in para 4.1.1 above. Comparison of such predicted RPM with observed RPM is shown in Fig. 9 and 10. The detailed tabulation for different periods is given in Table 5B of the Appendix to this paper.

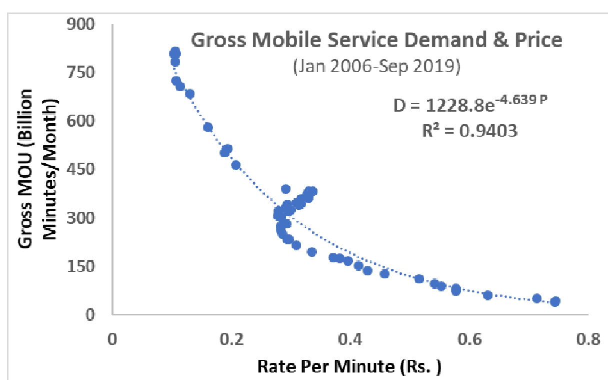

Fig. 8. Gross MOU & RPM relationship in terms of an exponential function.

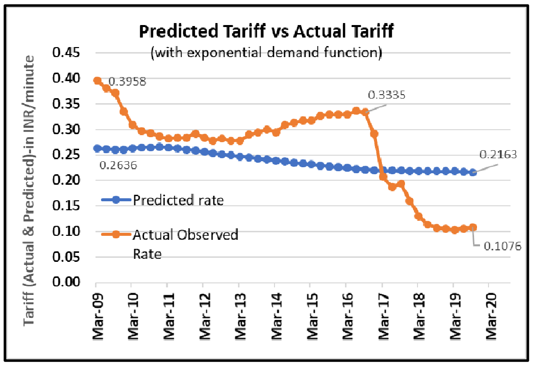

Fig. 9. Predicted vs actual tariff - exponential demand function & gross MOU.

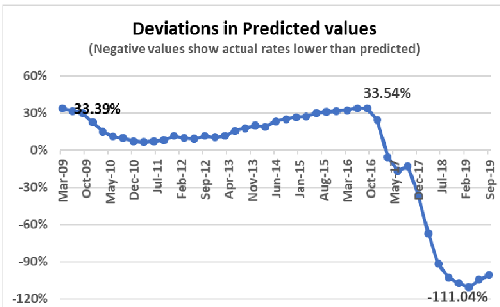

Fig. 10. Deviations in predicted rates- exponential demand function & gross MOU case.

The aforesaid analysis suffers from a few limitations viz: it does not consider the growth in demand due to increased population. It does not also consider the increase in per capita income during the period under analysis. The increase in per capita income is important as the data of price and demand is at different times which is not the case in conventional studies of price elasticity. Further, there has been changes in lifestyle, educational level, occupational pattern etc. which also impact demand although to a significantly lower level than the two issues enumerated earlier. If there were no capacity constraints in the period under analysis- both these factors could have substantially impacted demand.

To nullify the effect of increasing population on the demand, per capita MOU was used instead of gross MOU in the same models- per capita MOU being the product of wireless tele-density and MOU and the result is tabulated in Table 9 of Appendix. The price and demand graph, in this case shall be modified to Fig. 16. If we follow the quadratic polynomial demand function and exponential in P, then the price & demand relationship and the comparison of predicted & actually observed service rate are shown in Fig. 17 and 18 of Appendix. Corresponding figures for an exponential demand function are given in Fig. 19 and 20 of Appendix.

To eliminate the impact of increased income, the service rate was expressed as a multiple of per capita GDP and similar optimization principles were applied. Instead of raw price as a variable impacting demand, we express the service rate per minute as a multiple of ten millionth part of the per capita GDP. The modified numbers yield Fig. 21 to 23 (in Appendix). Incidentally, as also shown in Table 10 (in Appendix), the deviations from actual in this case are significantly higher and this model does not appear to be valid. The reason for the same have not been explored in detail in this paper- however, one obvious reason appears to be the fact that per capita GDP in India may not be a true representative of purchasing capacity because of huge inequalities of income, insignificance of the service price vis a vis the per capita income, operators moving in lower income groups in their effort to capture new subscribers etc. Without going into the explanation of the same- it is interesting to note for pure numerical analytic satisfaction that if we modify the service rates P so arrived in the case of quadratic polynomial & exponential demand functions using the Eqns. (11) & (12) below respectively, then in both cases, we get a very good fit with the actual observed price as shown in Fig. 11 & 12:

$$P_{modified} = 0.6254\, e^{0.0499\, P} \quad (11)$$

$$P_{modified} = 0.0092\, P^2 - 0.4265\, P + 6.929 \quad (12)$$

Going back to our original revenue maximization theory, it may be noted that the actual observed RPM is equal to or slightly higher during quarter ending March-09 to quarter ending March-10 and subsequently from quarter ending Dec-11-16 which is expected as in this period the service providers exhibited positive EBIDTAs and the strategy being followed was a hybrid of profit maximization to revenue maximization rather than purely revenue maximization. During the quarter ending June 10 to the quarter ending Sep-11, the rates are even lower than what is expected for revenue maximization. This may be because of sudden overcrowding of operators in this period due to a number of licenses awarded in 2008. However, the point worthwhile to note is the increased variation of actual observed tariffs vis a vis the predicted tariff from Dec16 onwards- after entry of Reliance Jio as an operator in the mobile telephony arena. During this period- the model seems to have failed comprehensively clearly signifying that in this period the competition has pushed operators beyond revenue maximization, and they are willing to take short term hit on the top line for enhancing the probability of their survival.

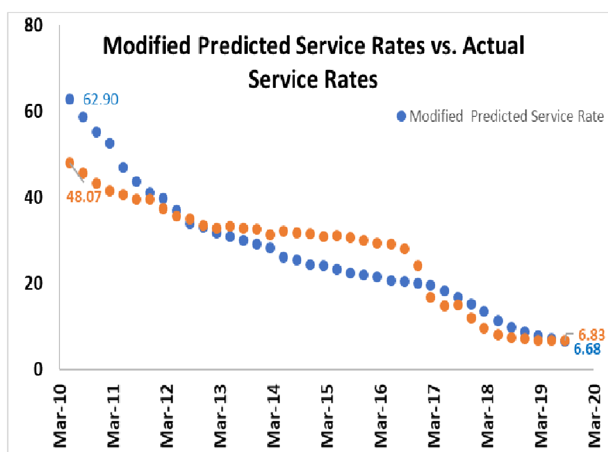

Fig. 11. Predicted and actual price, using quadratic polynomial demand function modified by applying an exponential function.

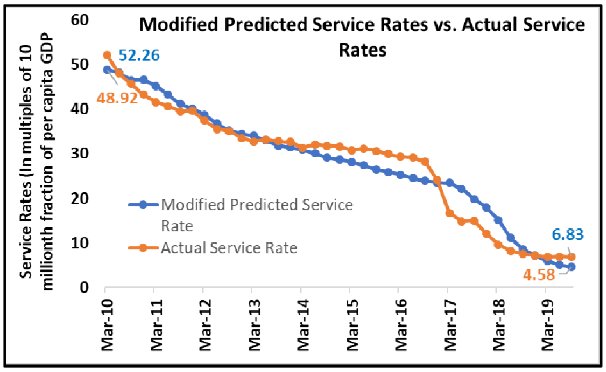

Fig. 12. Predicted and actual price, using exponentialdemand function modified by applying a quadratic polynomial function.

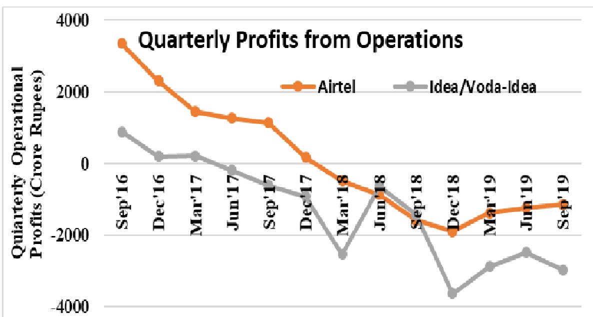

Fig. 13. Quarterly Operational profits of two major operators.

Significantly lower actual RPM compared to the predicted RPM to maximize revenues is because the challenger new entrant is willing to offer predatory rates (including free services for an introductory period) to acquire new subscribers and the incumbent service providers had to almost match the service rates for subscriber retention- even at the cost of reducing overall revenues. This is reflected in abysmal operating margins exhibited by all the operators (excluding Reliance Jio) in this period (Fig. 13.) and continuous southward movement of mobile telephony AGR as shown in Fig. 14. Clearly the profitability threshold discussed by Baumol (1958) is negative in the case of Indian mobile telephony operators.

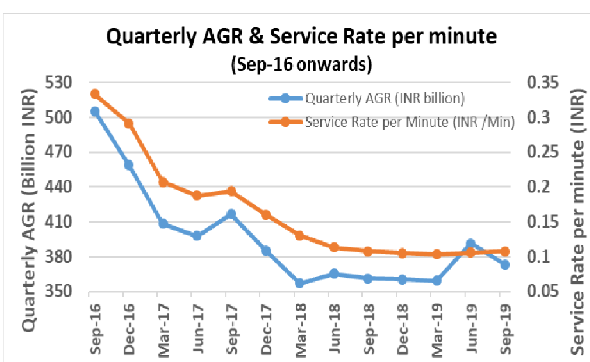

Fig. 14. Declining AGR of mobile telephony triggered by declining tariffs.

Further, while hoarding excessive cash has not been possible operationally, operators have been using competitive equity as well as credit markets to accumulate cash to ensure survival. It is worthwhile to point out that Vodafone Idea arranged for cash through rights issue while Bharti Airtel has accumulated a war chest of US$ 3 Billion through a mix of sale of convertible bonds outside India and private placement of shares.

B. Price Elasticity of Mobile Telephony Service Pricing in India

Having constructed the demand function as a function of price, we can calculate the elasticity of demand-

$$\eta_t = -(P/D) * (dD/dP) \quad (13)$$

yields $\eta_t = -P*(2AP+B)/D$ (for $D=AP^2+BP+C$) (14)

and $\eta_t = \beta P$ (for $D=\alpha e^{-\beta P}$) (15)

At any given point of time, the value of coefficients A & B as above, actual MOU observed and actual rates per minute may be substituted in the aforesaid equation to obtain the value of elasticity. So, a close estimate of actual elasticity is given for quadratic demand function and for exponential demand function respectively by

$$\eta_t = -P_{act}*(2AP_{act}+B)/D_{act} \quad (16)$$

and $\eta_t = \beta * P_{act}$ (17)

P_{act} & D_{act} being actual service price and demand observed in the quarter.

The price elasticities of demand so calculated for different periods for both types of demand functions considered in this paper and for Gross MOU as well as per capita MOU have been tabulated in Table 5 of the Appendix and depicted in Fig. 15. It is noted that the general trend of change in elasticity has been almost the same in all the four cases considered. Further, the elasticity appears to be higher in the case of exponential demand function than in case of quadratic polynomial demand function. It is also noted that, in case of exponential demand function- the elasticity has been consistently more than unity till quarter ending September 2016 after which the elasticity has been consistently declining - dropping to ~0.4 by September 2019. Not surprisingly quarter ending Sep 2016 marks the beginning of commercial operations by the new entrant Reliance Jio as an operator.

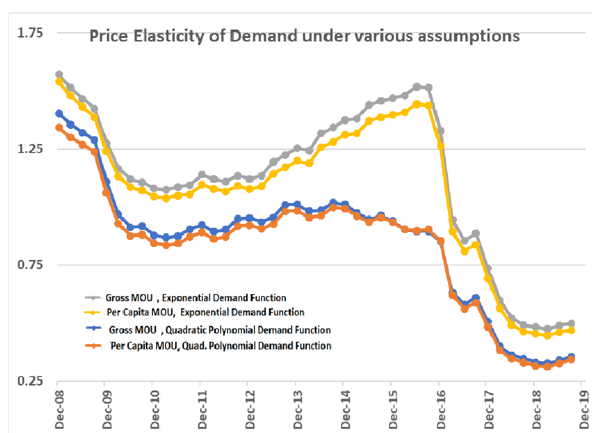

Fig. 15. Price elasticity of mobile telephony demand over time under different assumptions.

In case of quadratic polynomial demand function, the elasticity determined based on Gross MOUs has been higher than 1 till Dec 2009, hovered between 0.8 to 1 between March 2010 to December 2016 and subsequently reduced further. Since the Quarter ending Dec 2017, the point elasticity of demand is even lower than 0.50 and came down to as low as 0.225 in the quarter ending March 2019. In case of price elasticity determined based on per capita MOUs- the elasticity has been lower by 0.09 to 0.26 as shown in the figure but the trend on changes in elasticity has been the same. It is apparent that service providers do not have any immediate incentive in lowering the prices anymore and the price war between the competing service providers is to retain the customers in the long run. The situation is somewhat like the e-commerce business, where it is alleged that a few large players are indulging in selling goods at loss to create a loyal customer base for the long run. One explanation is that, in view of the large size of Indian mobile telephony market and interest by large global players like AT&T, Singtel, NTT, Softbank etc., the service providers are driven by Company valuation and creation of shareholder value rather than EBIDTA or short-term profits. Incidentally, valuation in a few recent M & A transactions including Hutchison-Vodafone deal and Spice acquisition by Idea are reported to have been impacted more by lifetime subscriber value rather than EBIDTA multiples or returns on capital employed.

VI. LIMITATIONS OF THIS STUDY AND SCOPE OF FUTURE RESEARCH

This study does not consider the cost data for mobile telephony business and limits itself to price optimization to ensure revenue maximization. Hence, the aggregate analysis cannot provide a path to second optimal price (Ramsey–Boiteux pricing) and is limited to price demand interdependencies. Further, studies pertaining to complementarities or substitution effects and cross elasticity with internet telephony, video calls from computer, google applications and whatsapp on mobile voice demand will also be important. Additionally, in view of multiple technologies and multiple generations of same technology being simultaneously deployed in the network by various operators– the impact of their interplay and of convergence of all services- cable TV, gaming, fixed line telephony, broadband internet services and mobile telephony on consumer behaviour, service demand and pricing (through bundled service offerings) will also form an interesting study. Finally, a study to determine possibility of dynamically adjusting the taxation (in terms of revenue share) as well as the spectrum costs to maximize consumer welfare and ensure avoidance of monopoly creation will be quite interesting and rewarding. Elasticity studies using panel data for various states as well as for rural and urban regions separately shall also be meaningful.

Table 2: Summary of Price prediction studies (Quarter ending March 2009 to Quarter ending Sep-2019).

S.No.	Type of Demand function Used	Variables representing Demand & Price	Range of Errors exhibited by the predicted values	Mean of Error percentages	Standard Deviation of the Errors
1.	Quadratic	GMOU, RPM	0.00%-125.18%	30.83%	39.81%
2.	Exponential	GMOU, RPM	5.81%-111.04%	32.36%	31.19%
3.	Exponential	PCMOU, RPM	3.18%-134.12%	32.58%	36.43%
4.	Quadratic	PCMOU, RPM	0.18%-136.24%	32.45%	44.03%
5.	Quadratic	PCMOU, RPM/x.PCGDP	28.09%-636.01%	220.04%	190.42%

Table 3: Summary of Price prediction (Quarter ending March 2009 to Quarter ending September 2016).

S. No.	Type of Demand function Used	Variables representing Demand & Price	Range of Errors exhibited by the predicted values	Mean of absolute value of Errors	Standard Deviation of the absolute value of Errors
1.	Quadratic	GMOU, RPM	0.00%-20.06%	10.64%	6.83%
2.	Quadratic	GMOU, RPM	6.33%-33.72%	19.16%	9.59%
3.	Exponential	PCMOU, RPM	3.18%-31.99%	16.01%	9.77%
4.	Exponential	PCMOU, RPM	0.18%-17.40%	9.85%	5.49%
5.	Quadratic	PCMOU, RPM/x.PCGDP	28.09%-143.59%	114.26%	33.49%
6.	Exponential	PCMOU, RPM/x.PCGDP	23.41%-153%	121.06%	38.21%

VII. CONCLUSION

There are various factors which impact the demand of mobile telephony services- viz: the pricing of services, the income level of users, economic activities in the area, educational level of users, access to electricity and transport infrastructure, cultural factors and other sociodemographic parameters. Price is the only factor which can be directly controlled by the service provider- all other factors constitute the ecosystem and changes in them are gradual. These factors appear to have been captured by the changes in the coefficients of the two demand functions considered in this paper. While the approach of this paper is distinctly different from various studies, which have focused on building a demand function for utility maximization- it appears to reasonably predict the service rates in the study period except the period of December 2016 onwards, when hyper-competition has pushed the service providers to artificially lower the rates, even while incurring losses and even lowering the top line.

The summary of the performance of these price predictions is given in Table 2 & 3. It is noted that the reliability of predictions, if the whole period up to Sep 2019 is considered is not acceptable. However, if the period up to September 2016 only is considered then Quadratic polynomial and exponential-both type of demand functions gives quite good predictions of the mobile telephony service prices under revenue maximization assumption. This also proves that directly or indirectly the companies prior to September 2016 were following the revenue maximization strategy. After Sep 2016, the decline in service prices defies logic and in absence of any known technological breakthrough reducing the input costs- the possibility of predatory prices being adopted by one operator which is imitated by other competitors purely as a survival strategy cannot be ruled out.

It also goes on to prove that the subscriber retention and growth is not aligned with the changes in telecom revenue. It has already led to various operators either shutting down business or getting amalgamated with each other. Since such pricing is not viable for long periods, strategic interventions to modify service pricing and value offering are imminent for the mobile telephony business to be sustainable. The summary of price elasticity studies is given in the Table 4. Price elasticity studies of Mobile telephone usage should be used by operators to optimize its revenue and/or profitability objectives. The taxation structure should, ideally be balanced between long term and short-term goals since a push in tele-density due to reduction in taxation may increase GDP growth rate. Similarly, regulations should not just ensure best prices for customers but also work for avoidance of monopoly creation.

Table 4: Summary of Price elasticity studies.

S.No.	Demand function	MOU used	QE Mar ‘09 to QE Sep’11	QE Sep ‘11 to QE Sep ‘16	QE Sep ‘16 to QE Sep ‘19
			Decrease in η.	Gradual increase in η.	Sharp decline in η.
1.	Expo	GMOU	1.08-1.47	1.08-1.51	0.50-1.51
2.	Expo	PCMOU	1.02-1.40	1.02-1.37	0.43-1.36
3.	Quad	GMOU	0.89-1.30	0.86-1.02	0.35-0.90
4.	Quad	PCMOU	0.72-1.10	0.68-0.75	0.23-0.70

VIII. ANNEXURES

A. Fig. 16 to 24

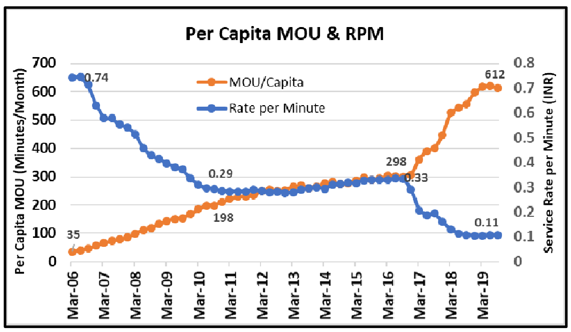

Fig. 16. Price (RPM) and demand (PCMOU).

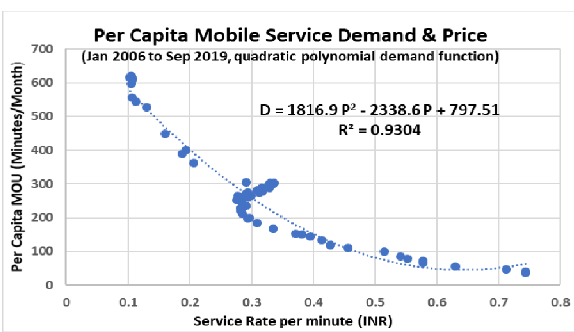

Fig. 17. PCMOU & RPM as a quadratic polynomial.

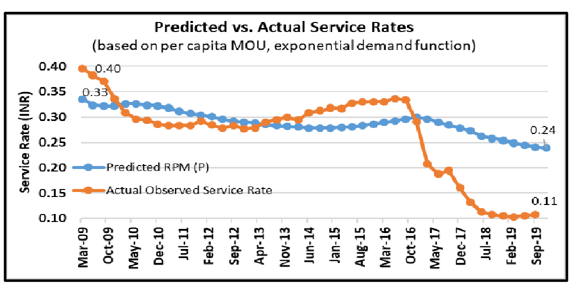

Fig. 18. Predicted vs actual tariff - quadratic demand function & PCMOU case.

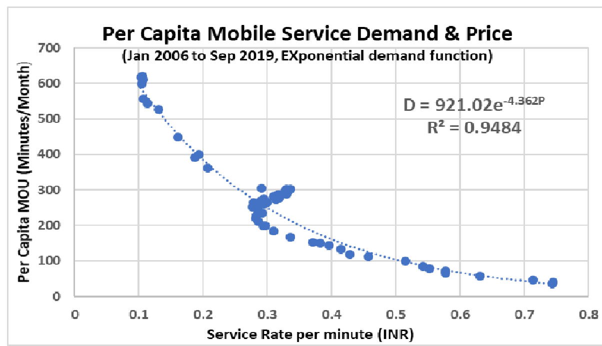

Fig. 19. Per Capita MOU & RPM relationship in terms ofan exponential function.

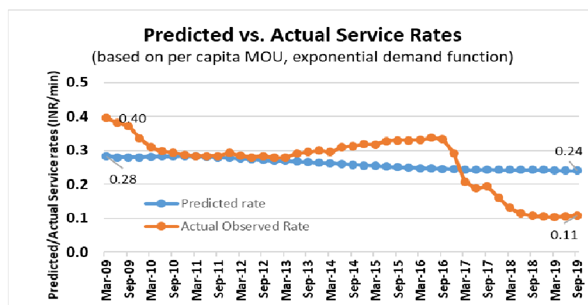

Fig. 20. Predicted vs actual tariff - exponential demand function & PCMOU case.

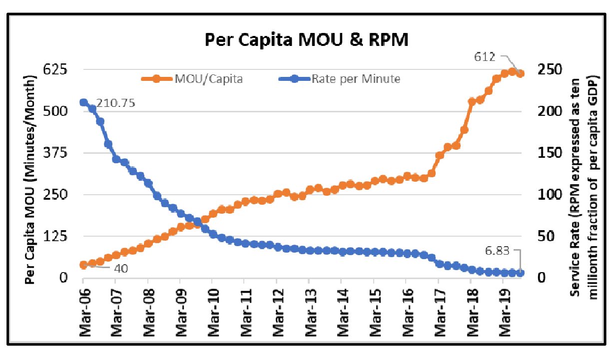

Fig. 21. PCMOU & Price as multiple of PCGDP/10^7.

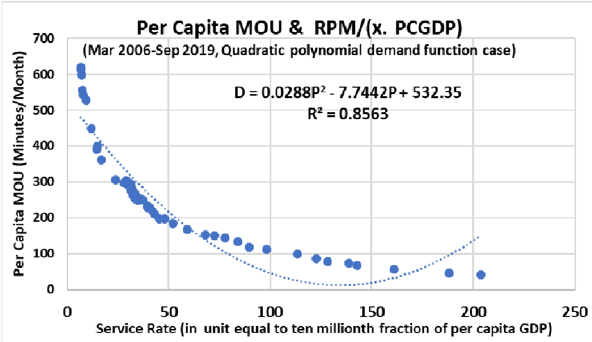

Fig. 22. PCMOU and Priceas a quadratic polynomial.

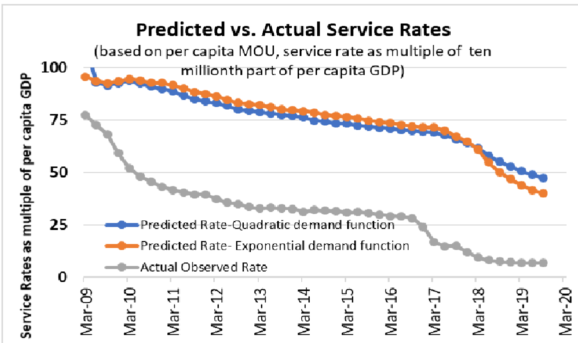

Fig. 23. Predicted vs. Actual tariffs- RPM/(x.PCGDP) & PCMOU case.

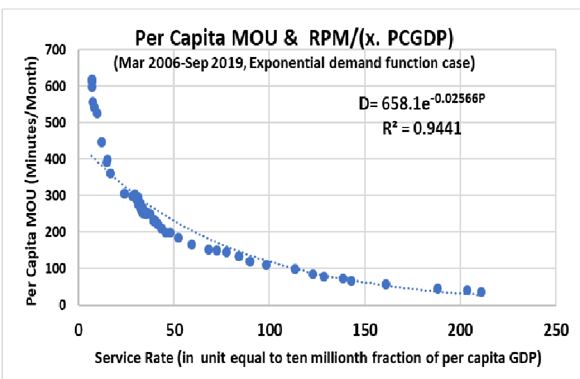

Fig. 24. PCMOU and Price expressed as ten millionth of the PCGDP- regressing a exponential polynomial.

Table 5: Price Elasticity of Demand in Various Periods.

Quarter ending	Demand Function=Quadratic Polynomial in P		Demand Function= Exponential function in P	
	Based on GMOUs	Based on PCMOUs	Based on GMOUs	Based on PCMOUs
	$\eta = -P_{act}(2AP_{act}+B)/D_{act}$		$\eta = -\beta.P_{act}$	
Dec-08	1.404	1.342	1.571	1.539
Mar-09	1.355	1.300	1.513	1.479
Jun-09	1.321	1.270	1.466	1.431
Sep-09	1.288	1.236	1.424	1.387
Dec-09	1.108	1.061	1.275	1.239
Mar-10	0.968	0.928	1.167	1.133
Jun-10	0.912	0.876	1.119	1.085
Sep-10	0.917	0.881	1.106	1.071
Dec-10	0.878	0.844	1.080	1.045
Mar-11	0.868	0.835	1.074	1.038
Jun-11	0.875	0.843	1.086	1.049
Sep-11	0.904	0.872	1.095	1.056
Dec-11	0.922	0.891	1.139	1.097
Mar-12	0.894	0.863	1.120	1.078
Jun-12	0.902	0.872	1.109	1.067
Sep-12	0.950	0.919	1.135	1.091
Dec-12	0.953	0.921	1.121	1.076
Mar-13	0.935	0.905	1.135	1.089
Jun-13	0.956	0.927	1.194	1.144
Sep-13	1.010	0.981	1.223	1.171
Dec-13	1.011	0.984	1.254	1.199
Mar-14	0.982	0.956	1.243	1.188
Jun-14	0.986	0.962	1.316	1.257
Sep-14	1.019	0.998	1.342	1.281
Dec-14	1.011	0.993	1.374	1.311
Mar-15	0.976	0.961	1.381	1.316
Jun-15	0.946	0.936	1.439	1.371
Sep-15	0.963	0.956	1.456	1.386
Dec-15	0.939	0.935	1.468	1.397
Mar-16	0.903	0.902	1.481	1.408
Jun-16	0.895	0.898	1.518	1.443
Sep-16	0.895	0.902	1.513	1.437
Dec-16	0.852	0.855	1.330	1.262
Mar-17	0.633	0.622	0.945	0.896
Jun-17	0.580	0.562	0.856	0.810
Sep-17	0.610	0.587	0.886	0.838
Dec-17	0.506	0.484	0.734	0.693
Mar-18	0.401	0.383	0.599	0.565
Jun-18	0.362	0.346	0.521	0.491
Sep-18	0.347	0.331	0.492	0.464
Dec-18	0.330	0.316	0.483	0.455
Mar-19	0.326	0.313	0.475	0.447
Jun-19	0.341	0.327	0.490	0.461
Sep-19	0.356	0.343	0.499	0.470

B. Table 5 to 10

Table 6: Basic MOU & RPM Data.

QE	Wireless Subscribers (Million)	Wireless Tele-density	ARPU(Rs./ Month/Sub)	PCI (Rs. / Annum)	RPM (As a fraction of PCI)	MOU (per Sub per Month)	GMOU (Billion Minutes /Month	PCMOU (Minutes/ Month)
Mar-06	101.86	9.01	331	35289	210.75	445	41	35
Jun-06	112.15	10.2	315	36581	203.57	423	45	41
Sep-06	129.54	11.74	301	37920	188.17	421	51	46
Dec-06	149.62	13.52	281	39141	161.02	445	62	56
Mar-07	165.11	14.62	272	40402	142.96	471	74	66
Jun-07	184.92	16.32	273	41703	138.52	472	83	73
Sep-07	209.07	18.39	248	43046	128.35	449	88	78

Dec-07	233.62	20.44	239	44184	122.59	441	98	86
Mar-08	261.07	22.78	237	45353	113.56	459	114	99
Jun-08	286.87	24.95	213	46552	98.25	466	128	111
Sep-08	315.31	27.32	195	47783	89.71	456	137	119
Dec-08	346.89	29.96	192	49361	83.93	464	154	133
Mar-09	391.76	33.71	179	50991	77.62	453	167	144
Jun-09	427.29	36.64	164	52675	72.52	428	175	151
Sep-09	471.73	40.31	148	54414	68.24	398	179	153
Dec-09	525.09	44.72	132	56749	59.14	393	196	167
Mar-10	584.32	49.6	121	59184	52.26	391	217	185
Jun-10	635.51	53.77	114	61723	48.07	384	234	198
Sep-10	687.71	57.99	104	64372	45.63	355	235	198
Dec-10	752.19	63.22	100	66110	43.27	348	251	211
Mar-11	811.59	67.98	95	67894	41.63	337	263	221
Jun-11	851.70	71.11	93	69727	40.64	330	274	229
Sep-11	873.61	72.7	90	71609	39.60	318	274	229
Dec-11	893.84	74.15	93	73739	39.61	319	282	234
Mar-12	919.17	76	94	75933	37.41	333	302	250
Jun-12	934.09	76.99	93	78192	35.62	333	309	255
Sep-12	906.62	74.49	93	80518	35.13	329	303	249
Dec-12	864.72	70.82	96	82744	33.53	347	308	252
Mar-13	867.80	70.85	104	85031	32.77	374	324	265
Jun-13	873.36	71.08	110	87381	33.20	379	330	269
Sep-13	870.58	70.63	108	89796	32.85	367	320	260
Dec-13	886.3	71.69	111	91875	32.64	371	326	264
Mar-14	904.51	72.94	112	94002	31.34	382	342	276
Jun-14	914.92	73.55	119	96178	32.15	384	349	281
Sep-14	930.2	74.55	116	98405	31.79	370	341	274
Dec-14	943.97	75.43	117	100567	31.61	370	346	277
Mar-15	969.89	77.27	119	102776	30.83	377	360	288
Jun-15	980.81	77.9	125	105034	31.19	382	372	296
Sep-15	996.66	78.93	121	107341	30.66	368	364	289
Dec-15	1010.89	79.82	122	109973	29.98	370	372	294
Mar-16	1033.63	81.38	124	112670	29.31	376	384	303
Jun-16	1035.12	81.26	125	115432	29.15	371	384	302
Sep-16	1049.74	82.17	122	118263	28.20	364	380	298
Dec-16	1127.37	88	104	120907	24.10	359	390	305
Mar-17	1170.18	91.08	84	123611	16.75	403	463	361
Jun-17	1186.84	92.12	80	126375	14.84	426	502	391
Sep-17	1183.04	91.56	84	129201	15.00	435	516	400
Dec-17	1167.44	90.11	79	132455	12.11	493	580	448
Mar-18	1183.41	91.09	76	135792	9.62	584	684	527
Jun-18	1146.49	88	69	139212	8.16	606	706	543
Sep-18	1169.29	89.51	67	142719	7.53	627	726	556
Dec-18	1176	89.78	70	146314	7.19	667	782	598
Mar-19	1161.81	88.46	71	149999	6.88	692	809	617
Jun-19	1165.46	88.5	74	153778	6.89	701	816	620
Sep-19	1173.75	88.63	74	157651	6.83	691	808	612

Table 7: Predicted rates for Revenue Maximization using Gross MOUs.

Period used for regressing	Rate for QE	Actual RPM (INR/Min)	Quadratic Demand Function					Exponential Demand Function			
			$D=Ax^2+Bx+C$			R^2	Predicted RPM	$D=\alpha e^{-\beta P}$		R^2	Predicted RPM
			A	B	C			α	β		
Mar'06 - Dec'08	Mar-09	0.3958	594.34	-1012.7	468.04	0.9845	0.3228	727.6	3.793	0.9841	0.2636
Mar'06 –Mar'09	Jun-09	0.3820	662.02	-1097.3	493.81	0.9872	0.3146	741.9	3.824	0.9867	0.2615
Mar'06 – Jun'09	Sep-09	0.3713	694.23	-1137	505.75	0.9897	0.3110	748.89	3.838	0.9886	0.2606
Mar'06 - Sep'09	Dec-09	0.3356	692.95	-1135.5	505.28	0.9915	0.3111	747.04	3.834	0.99	0.2608
Mar'06 - Dec'09	Mar-10	0.3093	645.46	-1079.1	489.17	0.9924	0.3166	730.5	3.798	0.9906	0.2633
Mar'06 - Mar'10	Jun-10	0.2967	645.11	-1078.6	489.05	0.994	0.3167	719.68	3.773	0.9915	0.2650
Mar'06 - Jun'10	Sep-10	0.2937	687	-1127.1	502.44	0.9945	0.3117	718.75	3.771	0.9925	0.2652
Mar'06 - Sep'10	Dec-10	0.2860	702.4	-1144.9	507.33	0.9952	0.3100	716.19	3.765	0.9932	0.2656
Mar'06 - Dec'10	Mar-11	0.2827	748.2	-1197.3	521.59	0.9944	0.3050	721.21	3.777	0.9938	0.2648
Mar'06 - Mar'11	Jun-11	0.2833	808.54	-1266.1	540.2	0.9919	0.2989	731.43	3.801	0.9939	0.2631
Mar'06 - Jun'11	Sep-11	0.2835	876.36	-1343.5	561.17	0.9876	0.2926	746.05	3.834	0.9933	0.2608
Mar'06 - Sep'11	Dec-11	0.2920	925.76	-1399.9	576.46	0.9854	0.2884	758.19	3.861	0.9929	0.2590
Mar'06 - Dec'11	Mar-12	0.2841	980.17	-1463.4	594.12	0.9795	0.2841	775.68	3.9	0.9919	0.2564
Mar'06 - Mar'12	Jun-12	0.2785	1053.5	-1547	616.75	0.9717	0.2787	795.71	3.943	0.9892	0.2536
Mar'06 - Jun'12	Sep-12	0.2829	1123.2	-1625.5	637.63	0.9667	0.2739	813.78	3.981	0.9877	0.2512
Mar'06 - Sep'12	Dec-12	0.2774	1172.2	-1681.3	652.69	0.9639	0.2708	829.14	4.013	0.9866	0.2492
Mar'06 - Dec'12	Mar-13	0.2786	1217.5	-1732.1	663.13	0.9627	0.2661	842.31	4.04	0.986	0.2475
Mar'06 - Mar'13	Jun-13	0.2901	1276.6	-1798.6	683.8	0.9578	0.2647	859.68	4.075	0.9843	0.2454
Mar'06 - Jun'13	Sep-13	0.2950	1326.3	-1857.3	700.46	0.9481	0.2622	880.59	4.115	0.981	0.2430
Mar'06 - Sep'13	Dec-13	0.2999	1358.4	-1896.7	712.13	0.942	0.2608	898.26	4.147	0.9786	0.2411

Mar'06 - Dec'13	Mar-14	0.2946	1384.8	-1931.1	723.07	0.9335	0.2598	917.45	4.182	0.9754	0.2391
Mar'06 - Mar'14	Jun-14	0.3092	1423.8	-1978.6	737.06	0.924	0.2582	937.9	4.218	0.972	0.2371
Mar'06 - Jun'14	Sep-14	0.3129	1433.3	-1998.5	745.87	0.907	0.2585	961.45	4.257	0.9661	0.2349
Mar'06 - Sep'14	Dec-14	0.3179	1433.1	-2007.4	751.74	0.8942	0.2592	982.61	4.29	0.9612	0.2331
Mar'06 - Dec'14	Mar-15	0.3169	1420.1	-2004.2	755.16	0.8794	0.2605	1004.5	4.323	0.9556	0.2313
Mar'06 - Mar'15	Jun-15	0.3276	1409.3	-2003.5	759.45	0.8623	0.2619	1027.8	4.358	0.9494	0.2295
Mar'06 - Jun'15	Sep-15	0.3292	1362	-1967.8	756.8	0.8377	0.2655	1053.2	4.393	0.9404	0.2276
Mar'06 - Sep'15	Dec-15	0.3297	1315.9	-1932	753.5	0.8194	0.2689	1076.3	4.423	0.933	0.2261
Mar'06 - Dec'15	Mar-16	0.3302	1267.8	-1894.2	749.81	0.801	0.2724	1099.8	4.453	0.9256	0.2246
Mar'06 - Mar'16	Jun-16	0.3365	1215.6	-1852.9	745.57	0.7808	0.2763	1124.4	4.484	0.9175	0.2230
Mar'06 - Jun'16	Sep-16	0.3335	1143.9	-1791.7	736.92	0.7606	0.2816	1148.3	4.512	0.9089	0.2216
Mar'06 - Sep'16	Dec-16	0.2914	1089.1	-1746.3	731.2	0.7459	0.2857	1170.7	4.538	0.9022	0.2204
Mar'06 - Dec'16	Mar-17	0.2071	1144.9	-1808.8	747.66	0.7461	0.2824	1188.4	4.564	0.9017	0.2191
Mar'06 - Mar'17	Jun-17	0.1876	1280.5	-1946.7	778.89	0.764	0.2743	1188.8	4.564	0.905	0.2191
Mar'06 - Jun'17	Sep-17	0.1938	1418.8	-2086.4	810.19	0.7845	0.2667	1188.2	4.563	0.9086	0.2192
Mar'06 - Sep'17	Dec-17	0.1604	1557.3	-2226.7	841.74	0.8008	0.2598	1193.8	4.573	0.9118	0.2187
Mar'06 - Dec'17	Mar-18	0.1306	1705	-2374.3	874.29	0.8222	0.2531	1195.2	4.576	0.9157	0.2185
Mar-06 - Mar'18	Jun-18	0.1136	1939	-2605.7	924.55	0.8467	0.2437	1200.2	4.585	0.9202	0.2181
Mar'06 - Jun'18	Sep-18	0.1075	2056.5	-2721.3	949.41	0.8687	0.2394	1199.1	4.583	0.9244	0.2182
Mar'06 - Sep'18	Dec-18	0.1051	2139.7	-2802.8	966.89	0.8859	0.2366	1198	4.581	0.9282	0.2183
Mar'06 –Dec'18	Mar-19	0.1032	2272.1	-2932.5	994.64	0.8989	0.2323	1204.1	4.593	0.9319	0.2177
Mar'06 –Mar'19	Jun-19	0.1060	2394	-3051.8	1020.1	0.9087	0.2286	1212	4.607	0.9351	0.2171
Mar'06 –Jun'19	Sep-19	0.1076	2496.8	-3152.6	1041.7	0.916	0.2258	1221	4.624	0.9379	0.2163
Mar'06 –Sep'19	Dec-19	NA	2571.7	-3226	1057.5	0.9222	0.2238	1228.8	4.639	0.9403	0.2156

Note: The data in columns 2, 3, 4 & 7 of Table 4A viz: Subscriber numbers, Wireless Tele-density, ARPU(Average Revenue Per User) per month per subscriber; and MOU (Minutes of Usage) per subscriber per month have been taken from Quarterly Performance Indicator Reports of Indian Telecom Services issued by Telecom Regulatory Authority of India (TRAI) periodically. Each of the reports for the Quarters ending June- 2006 to September-2019 have been downloaded from the regulator's website www.trai.gov.in and has been compiled by the authors for use in the table above. Column 5 of Table 6 is based on annual GDP at current prices taken from http://statisticstimes.com/economy/gdp-capita-of-india.php which has been linearly interpolated to arrive at quarter end GDP. The data for other columns have been derived using the relationships mentioned in Table 8 below.

Table 8: Various Derived parameters used in Table 6 & 7.

Parameter	Unit	Derivation
RPM	Rupees/Minute	=ARPU/MOU
Gross Minutes of Usage (GMOU)	Billion Minute	= MOU * (Arithmetic Mean of Subscribers (in million) in present quarter and previous Quarter) /1000
Per Capita Minutes of Usage (PCMOU)	Minute /Month	= MOU * Tele-density
Rate per Minute (RPM)-as a multiple of 10 millionth part of PCGDP (RPM/x.PCGDP)	Unit per minute (Unit = PCGDP/10^7)	= RPM* 10^7 / Per capita GDP

Table 9: Predicted rates for Revenue Maximization using Per Capita MOUs.

Period used for regressing	Rate for QE	Actual RPM (INR/Min)	Quadratic Demand Function					Exponential Demand Function			
			$D=Ax^2+Bx+C$			R^2	Predicted RPM	$D= \alpha e^{-\beta P}$		R^2	Predicted RPM
			A	B	C			α	β		
Mar'06 - Dec'08	Mar-09	0.3958	464.54	-815.32	388.15	0.9846	0.3326	613.39	3.715	0.9824	0.2692
Mar'06 –Mar'09	Jun-09	0.3820	522.58	-887.85	410.25	0.9872	0.3233	622.19	3.737	0.9853	0.2676
Mar'06 – Jun'09	Sep-09	0.3713	548.22	-919.49	419.76	0.9896	0.3196	625.15	3.745	0.9874	0.2670
Mar'06 - Sep'09	Dec-09	0.3356	543.95	-914.28	418.21	0.9914	0.3202	620.94	3.734	0.9889	0.2678
Mar'06 - Dec'09	Mar-10	0.3093	502.67	-865.25	404.2	0.9922	0.3264	605.2	3.692	0.9894	0.0003
Mar'06 - Mar'10	Jun-10	0.2967	502.11	-864.59	404.1	0.9938	0.3266	594.68	3.663	0.9903	0.2730
Mar'06 - Jun'10	Sep-10	0.2937	535.85	-903.65	414.8	0.9943	0.3214	592.44	3.657	0.9914	0.2734
Mar'06 - Sep'10	Dec-10	0.2860	545.67	-914.99	417.92	0.9951	0.3199	588.77	3.647	0.9922	0.2742
Mar'06 - Dec'10	Mar-11	0.2827	580.52	-954.87	428.77	0.9945	0.3150	591.33	3.654	0.9928	0.2737
Mar'06 - Mar'11	Jun-11	0.2833	626.94	-1007.8	443.09	0.9925	0.3088	598.08	3.673	0.9931	0.2723
Mar'06 - Jun'11	Sep-11	0.2835	679.16	-1067.4	459.23	0.9888	0.3024	608.31	3.702	0.9928	0.2701
Mar'06 - Sep'11	Dec-11	0.2920	715.66	-1109.1	470.53	0.9871	0.2982	616.43	3.724	0.9927	0.2685
Mar'06 - Dec'11	Mar-12	0.2841	756.57	-1156.8	483.81	0.9821	0.2938	628.76	3.757	0.9915	0.2662
Mar'06 - Mar'12	Jun-12	0.2785	812.3	-1220.3	501.01	0.9754	0.2882	643.08	3.796	0.9898	0.2634
Mar'06 - Jun'12	Sep-12	0.2829	864.4	-1279	516.61	0.9712	0.2834	655.76	3.829	0.9886	0.2612
Mar'06 - Sep'12	Dec-12	0.2774	899.62	-1319.1	527.44	0.9691	0.2803	666.16	3.856	0.9879	0.2593
Mar'06 - Dec'12	Mar-13	0.2786	931.09	-1354.4	536.77	0.9684	0.2777	674.75	3.877	0.9875	0.2579
Mar'06 - Mar'13	Jun-13	0.2901	973.82	-1402.5	549.55	0.9645	0.2743	686.62	3.907	0.9862	0.2560
Mar'06 - Jun'13	Sep-13	0.2950	1010.2	-1445.5	561.75	0.9563	0.2717	701.2	3.942	0.9834	0.2537
Mar'06 - Sep'13	Dec-13	0.2999	1032.9	-1473.3	570	0.9516	0.2702	713.12	3.97	0.9816	0.2519
Mar'06 - Dec'13	Mar-14	0.2946	1051.7	-1497.8	577.79	0.9448	0.2692	726.16	3.999	0.979	0.2501
Mar'06 - Mar'14	Jun-14	0.3092	1079.6	-1531.8	587.8	0.9371	0.2675	740.11	4.031	0.9762	0.2481
Mar'06 - Jun'14	Sep-14	0.3129	1086.5	-1546.2	594.19	0.9226	0.2677	756.44	4.065	0.9711	0.2460
Mar'06 - Sep'14	Dec-14	0.3179	1086.3	-1552.6	598.36	0.9122	0.2682	770.81	4.094	0.967	0.2443
Mar'06 - Dec'14	Mar-15	0.3169	1077.2	-1550.2	600.8	0.8998	0.2695	785.66	4.123	0.9623	0.2425
Mar'06 - Mar'15	Jun-15	0.3276	1069.4	-1549.8	603.86	0.8854	0.2706	801.6	4.153	0.9569	0.2408
Mar'06 - Jun'15	Sep-15	0.3292	1035.2	-1524	601.95	0.864	0.2740	819.07	4.184	0.949	0.2390
Mar'06 - Sep'15	Dec-15	0.3297	1002.5	-1498.6	599.61	0.8485	0.2771	834.72	4.21	0.9426	0.2375
Mar'06 - Dec'15	Mar-16	0.3302	968.4	-1471.8	596.99	0.8327	0.2804	850.57	4.236	0.9362	0.2361

Mar'06 - Mar'16	Jun-16	0.3365	931.33	-1442.4	593.98	0.8152	0.2840	867.19	4.263	0.9291	0.2346
Mar'06 - Jun'16	Sep-16	0.3335	880.64	-1399.2	587.87	0.7976	0.2888	883.26	4.287	0.9216	0.2333
Mar'06 - Sep'16	Dec-16	0.2914	842.64	-1367.7	583.9	0.7852	0.2926	898.06	4.31	0.9159	0.2320
Mar'06 - Dec'16	Mar-17	0.2071	878.26	-1407.6	594.4	0.7857	0.2897	908.74	4.33	0.9157	0.2309
Mar'06 - Mar'17	Jun-17	0.1876	946.02	-1476.5	610	0.8002	0.2842	906.33	4.325	0.9184	0.2312
Mar'06 - Jun'17	Sep-17	0.1938	1022.7	-1553.9	627.36	0.8167	0.2784	903.45	4.318	0.9212	0.2316
Mar'06 - Sep'17	Dec-17	0.1604	1108.5	-1640.9	646.92	0.8299	0.2722	905.28	4.322	0.924	0.2314
Mar'06 - Dec'17	Mar-18	0.1306	1204.6	-1736.9	668.1	0.8473	0.2659	904.37	4.32	0.9272	0.2315
Mar-06 - Mar'18	Jun-18	0.1136	1373.4	-1903.9	704.35	0.867	0.2557	906.74	4.326	0.9311	0.2312
Mar'06 - Jun'18	Sep-18	0.1075	1456.1	-1985.2	721.85	0.8853	0.2513	904.76	4.321	0.9347	0.2314
Mar'06 - Sep'18	Dec-18	0.1051	1513.4	-2041.4	733.89	0.8998	0.2483	902.86	4.316	0.9379	0.2317
Mar'06 –Dec'18	Mar-19	0.1032	1608.4	-2134.5	753.81	0.9106	0.2437	906.31	4.325	0.941	0.2312
Mar'06 –Mar'19	Jun-19	0.1060	1695.4	-2219.5	771.96	0.9188	0.2398	911.09	4.337	0.9439	0.2306
Mar'06 –Jun'19	Sep-19	0.1076	1767.3	-2290	787.07	0.925	0.2367	916.58	4.351	0.9463	0.2298
Mar'06- Sep'19	Dec-19	NA	1816.9	-2338.6	797.51	0.9304	0.2347	921.02	4.362	0.9484	0.2293

Table 10: Predicted Service Rates (modified) based on per capita MOU and actual service rates expressed as a multiple of ten millionth part of per capita GDP.

Rate for QE	Actual RPM (INR/Min)	Quadratic Demand Function						Exponential Demand Function				
		$D=Ax^2+Bx+C$			R^2	Predicted RPM	Modified RPM	$D=\alpha e^{-\beta P}$		R^2	Predicted RPM	Modified Prediction -RPM
		A	B	C				α	B			
Mar-09	83.93	0.0047	-2.0131	273.52	0.9939	111.38	162.04	310.8	0.01044	0.9921	95.7854	72.3745
Jun-09	77.62	0.0051	-2.2382	283.8	0.9941	92.89	64.41	321.5	0.01068	0.9927	93.6330	63.3990
Sep-09	72.52	0.0052	-2.2822	287.07	0.9952	91.52	60.15	325.9	0.01079	0.994	92.6784	59.5834
Dec-09	68.24	0.0051	-2.2433	284.24	0.9958	92.58	63.43	321.9	0.01069	0.9947	93.5454	58.2749
Mar-10	59.14	0.005	-2.2047	281.54	0.9964	93.75	67.22	317.1	0.01057	0.9953	94.6074	57.2604
Jun-10	52.26	0.0052	-2.2669	285.76	0.9968	92.42	62.90	319.6	0.01063	0.9961	94.0734	54.5989
Sep-10	48.07	0.0056	-2.3729	292.8	0.9959	91.03	58.70	324.9	0.01078	0.9962	92.7644	51.8576
Dec-10	45.63	0.0056	-2.3913	294	0.9965	89.80	55.20	324.5	0.01077	0.9968	92.8505	50.9332
Mar-11	43.27	0.0059	-2.4695	299.05	0.9958	88.82	52.57	328.9	0.0109	0.9966	91.7431	48.4750
Jun-11	41.63	0.0062	-2.5692	305.4	0.9939	86.55	46.94	335.2	0.01109	0.9954	90.1713	45.7528
Sep-11	40.64	0.0066	-2.676	312.15	0.9914	85.14	43.76	342.3	0.0113	0.9936	88.4956	43.2755
Dec-11	39.60	0.0068	-2.7398	316.15	0.991	83.91	41.14	346.5	0.01142	0.9934	87.5657	41.9853
Mar-12	39.61	0.0071	-2.8132	320.74	0.9897	83.23	39.78	351.4	0.01157	0.9925	86.4304	40.3409
Jun-12	37.41	0.0075	-2.9214	327.34	0.9863	81.78	36.99	359.2	0.01181	0.9896	84.6740	38.0660
Sep-12	35.62	0.0078	-3.0157	332.98	0.9843	80.10	34.02	365.7	0.01201	0.9881	83.2639	36.2145
Dec-12	35.13	0.008	-3.0652	335.93	0.9845	79.61	33.20	368.6	0.0121	0.9885	82.6446	35.5949
Mar-13	33.53	0.0081	-3.1037	338.17	0.9849	78.76	31.83	370.5	0.01216	0.9891	82.2368	35.2749
Jun-13	32.77	0.0084	-3.1724	342.13	0.9839	78.23	30.99	375	0.01231	0.9884	81.2348	33.9647
Sep-13	33.20	0.0087	-3.2438	346.28	0.9823	77.60	30.04	380	0.01248	0.9872	80.1282	32.5411
Dec-13	32.85	0.0088	-3.2755	348.1	0.9826	77.08	29.26	381.8	0.01254	0.9876	79.7448	31.8709
Mar-14	32.64	0.0089	-3.313	350.26	0.9826	76.35	28.22	384.1	0.01261	0.9877	79.3021	30.9694
Jun-14	31.34	0.0098	-3.4866	357.16	0.9814	74.82	26.14	387.8	0.01274	0.987	78.4929	29.8048
Sep-14	32.15	0.0101	-3.5543	360.86	0.9793	74.29	25.45	392.4	0.01289	0.9854	77.5795	28.5821
Dec-14	31.79	0.0102	-3.5938	363.01	0.9791	73.51	24.49	395	0.01298	0.9853	77.0416	27.7729
Mar-15	31.61	0.0104	-3.6356	365.28	0.9786	73.28	24.20	397.6	0.01307	0.985	76.5111	26.9590
Jun-15	30.83	0.0106	-3.6936	368.37	0.9771	72.48	23.26	401.5	0.0132	0.9839	75.7576	25.9082
Sep-15	31.19	0.0109	-3.7645	372.18	0.9741	71.86	22.55	406.5	0.01337	0.9814	74.7943	24.7852
Dec-15	30.66	0.0111	-3.8111	374.65	0.9733	71.47	22.11	409.6	0.01348	0.9808	74.1840	23.9964
Mar-16	29.98	0.0113	-3.8611	377.26	0.9723	70.96	21.56	412.9	0.0136	0.9802	73.5294	23.2065
Jun-16	29.31	0.0115	-3.9227	380.43	0.9705	70.10	20.66	417.1	0.01375	0.9789	72.7273	22.2835
Sep-16	29.15	0.0118	-3.9759	383.15	0.9693	69.99	20.55	420.7	0.01388	0.9781	72.0461	21.5533
Dec-16	28.20	0.0119	-4.0119	384.95	0.9693	69.41	19.96	422.8	0.01396	0.9783	71.6332	21.0034
Mar-17	24.10	0.012	-4.0373	386.13	0.9701	69.12	19.67	423.4	0.01398	0.979	71.5308	20.4102
Jun-17	16.75	0.0126	-4.1718	391.83	0.968	67.77	18.39	430.2	0.0143	0.9789	69.9301	19.2938
Sep-17	14.84	0.0135	-4.3679	399.99	0.9624	65.95	16.80	441.5	0.01485	0.9766	67.3401	17.9601
Dec-17	15.00	0.0143	-4.5592	407.96	0.9567	64.03	15.26	453.1	0.01541	0.9741	64.8929	16.6926
Mar-18	12.11	0.0157	-4.8558	419.97	0.944	61.72	13.60	472.6	0.01638	0.9679	61.0501	15.0968
Jun-18	9.62	0.0179	-5.3434	439.28	0.9143	58.02	11.30	509.9	0.01828	0.9516	54.7046	12.8736
Sep-18	8.16	0.0199	-5.7916	456.8	0.897	55.06	9.75	542.6	0.01995	0.9461	50.1253	11.0475
Dec-18	7.53	0.0218	-6.1985	472.62	0.8863	52.87	8.74	569.1	0.02129	0.9452	46.9704	9.3323
Mar-19	7.19	0.0238	-6.647	489.99	0.8726	50.62	7.81	598.9	0.02278	0.9421	43.8982	7.6951
Jun-19	6.88	0.0258	-7.0717	506.39	0.8626	48.88	7.16	624.7	0.02405	0.9409	41.5800	6.3084
Sep-19	6.89	0.0275	-7.4422	520.7	0.8572	47.48	6.68	644.6	0.02501	0.9417	39.9840	5.1389
Dec-19	NA	0.0288	-7.7442	532.35	0.8563	46.36	6.32	658.1	0.02566	0.9441	38.9712	4.2129

Note: Modified rates as above are calculated using $P_{modified} = 0.6254\ e^{0.0499*P}$ and $P_{modified} = 0.0092*P^2 - 0.4265*P + 6.929$ respectively for the quadratic demand function and exponential demand function respectively.

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