

A Practical Subsidy Driven Pricing Model for Heterogeneous Communities

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Abstract—Pricing of telecommunication services in heterogeneous communities of developing countries is a daunting task and a very difficult one. The differences in social and economic factors among heterogeneous communities exacerbates the problem of developing a workable subsidy-driven pricing model. In developed countries different subsidy driven pricing mechanisms or economic models exists. In developing countries, however, this may require a different way of identifying potential subsidy beneficiaries, due to steep variations in incomes of users. Actually, the most likely question that governments of developing countries and individuals are likely to ask is; would increased internet penetration levels be realized by incorporating subsidies into communication economic models? The answer to this question is quite difficult and requires an understanding of the intricacies that come with social and economic dynamics of a heterogeneous community. Essentially, the administration of subsidies requires knowledge of the willingness-to-pay and users’ response towards price. In this paper we develop a pricing model using a case study approach that was conducted in South Africa and Zambia.

Index Terms—Pricing policy, Quality of Service, Subsidy, ICTs

I. INTRODUCTION

Developing countries have embarked on the promotion of Universal Service Objectives (USOs)¹ i.e. extending Information and Communication Technology (ICT) to underserved and unserved areas, with the underlying aim of promoting social and economic development [3] [4] [7] [14]. However, in trying to promote such USOs, communication institutions (usually such institutions are given a mandate by government to fulfill USOs) have often found themselves trapped in boulders of failure that may in one way or another hinder the successful implementation of USOs [14].

The causes of failing to attain some of the USOs in heterogeneous communities is not easily identified in multifaceted USOs. Usually, policy implementation regarding USOs in heterogeneous communities can be delayed due to resource constraints, geographical landscape, or budget underestimates characterized by cost over-runs. In some cases, delayed policy implementation in developing countries is sometimes associated with, especially in the promotion of USOs, low operational efficiency, political interest and inadequate understanding of how to incorporate subsidies into the economical models

¹USOs is an economic, legal and business term used mostly in regulated industries, referring to the practice of providing a baseline level of services to every resident of a country.

developed for societies with users who have large variations in income distributions.

Naturally, subsidies have been used by developed and developing countries to extend USOs in underserved or rural areas of such countries. Subsidies, as a matter of fact, have become an important part of service policy through which institutional frameworks are considering to extend USOs and enhance internet penetration in heterogeneous communities [4] [9] [10] [14]. However, such institutions find it difficult to incorporate subsidies into existing economic models which are tailored for developed countries. In developed countries, ways and means of extending USOs are defined and are implemented differently from country to country. For example, in a country like the USA, the usage of “Federal Poverty guideline” (FPG) is crucial in determining the beneficiaries of a government subsidy [4].

In developing countries, however, this may require different ways of identifying potential subsidy beneficiaries, due to large variations in the incomes of users [7] [10] [11]. Actually, the most likely question that governments of developing countries and individuals are likely to ask is; would internet penetration levels be increased by incorporating subsidies into price or economic models? The answer to this question is quite difficult and requires understanding the intricacies that come with social and economic dynamics of a heterogeneous community in developing country. Essentially, in our own opinion, administering of subsidies requires knowledge of the willingness-to-pay and users’ response towards price or perceived utility.

It is for the preceding reason that this paper proposes a pricing model (for observable heterogeneous communities) that draws its formulation from a case study conducted in South Africa and Zambia. Since the main purpose of USOs is the promotion of social and economic growth, this paper therefore has to span the intersection of developing a workable pricing model that will promote social and economic development in underserved and unserved areas of developing countries. This paper is organized as follows: In section II we present our research design and methodology used to conduct the study, while section III presents our results from the study conducted. In section IV we develop our pricing model describing all the necessary mathematical concepts and formulas, and we present a performance analysis of our pricing model in section V. Section VI concludes our study.

II. RESEARCH DESIGN AND METHODOLOGY

A. Preliminaries

A primary point to realize in carrying out well defined research is that, there are two broad approaches towards research: quantitative research and qualitative research. Quantitative research is the product of scientific research methods used in the physical sciences [13]. This research approach is an objective, formal and an organized type of research. While quantitative research methodologies test theory deductively from existing knowledge, through developing hypothesized relationships and proposed outcomes for study, qualitative researchers, on the other hand, are guided by certain ideas and perspectives regarding the subject to be investigated.

A case study design, with a combination of qualitative and quantitative methods of data collection, was used to carry out the investigation for this study. Dawson [16] explained that exponents of the case study design often favor qualitative research because it explores attitudes, behavior and experiences through such methods as interviews or focus groups. It attempts to get an in-depth opinion from participants, such as participant observation and unstructured interviewing, because these methods are viewed as particularly helpful in the generation of an intensive, detailed examination of a case study. The quantitative versus qualitative contest has often been so divisive and it has been a major debate among different scholars and academics [13]. Nonetheless, case studies are frequently cited for the employment of both quantitative and qualitative research (triangulation) because it counteracts the weaknesses in both qualitative and quantitative research [17]. The proponents of case studies usage in research argue that both qualitative and quantitative analysis can be used in order to gain an in-depth understanding of the study as seen from the following extract by Corbetta [17]:

“The quantitative and qualitative techniques yield different kinds of knowledge. Far from being a handicap, this is actually an advantage. Only a multi-faceted, differentiated approach can provide a complete vision of social reality, just as a statue in a square reveals the completeness of its form only when viewed from different angles”.

Other commentators such as Gorard and Taylor [15] point out that “if social phenomenon tends to have multiple appearances, then using only one method in each study can lead to the unnecessary fragmentation of explanatory models. Using combined approaches is, in these circumstances, most appropriate”.

In this research we used a case study approach, with a combination of both qualitative and quantitative methods of data collection and analysis. Even though, there are several differences between qualitative and quantitative research. The two research methods are not necessarily opposed to each other. As such, they can jointly be used or triangulated to fit the question under study. Actually, the combination of qualitative and quantitative enables the researcher to contrast

and compare specific information with information gained in other interviews [16].

B. Ethical considerations

Throughout this study the researcher strived to adhere to ethical research considerations. Most of the time, during this research, ethical considerations were strongly adhered to and at no certain point did the research harm or injure someone: legally, socially psychologically or in any other way. The researcher made sure that certain acts of misconduct in research were avoided; such as data fabrication, inaccurate reporting and plagiarism.

C. Sampling procedures

In this case study, two main methods of sampling were used in order to create a sampling frame. These were probability sampling, also known as random sampling, and non-probability sampling, which is sometimes called purposive sampling. In order to attain the preferred representation from various sub-groups in the population, purposive sampling was used first. This sampling technique enabled us to initially identify appropriate regions in Zambia and in South Africa which had telecentres and high population densities. Using random sampling technique, suitable areas or divisions had an equal chance of being selected. This sampling technique also helped to prevent bias in the selection process.

D. Data collection

Our empirical work relies on several major sources of data. Mobile telephone and internet penetration statistics were extracted from the ZICTA telecommunications database of 2010 and some literature from ICASA and USAASA. They capture specific trends in ICT and telecommunications penetration in urban and rural areas of these two countries. Other sources (such as statistics from other websites) have been used for gathering information concerning internet usage patterns in both urban and rural areas of Zambia and South Africa.

Additionally, questionnaires were distributed to a number of respondents in rural, semi urban and urban areas of Zambia and South Africa and respondents were asked to fill them in. The questionnaires and data collected from communication institutions and the local populace in Zambia and South Africa have formed the main research instrument for this study. We collected a total of 598 questionnaires from our respondents in all the areas where we conducted our surveys. In circumstances where the respondents were unable to understand English, the region’s national languages, namely Lozi and Chinyanja (in Zambia) and isiZulu (in South Africa), interpreters were used to communicate with the respondents. Note that in this survey respondents had used or heard about the internet.

III. ICT USER BEHAVIOR AND PATTERNS

This section presents the empirical information or data that was collected from the questionnaires, institutional frameworks, semi-structured interviews and discussions. The semi-structured interviews conducted in Zambia and South Africa

was done with users and non-users of internet service, as well as people responsible for ICT (more specifically internet service provision). In our previous section we presented information on how the study was conducted and the methods which were used to conduct the study. In this section, we will categorize data according to specific mathematical variables that will define our pricing model. Note that only a select few and necessary results will be presented in this section.

A. Potential for subsidies in heterogeneous communities

In Figure 1 we present results of respondents concerning their views on subsidies for cheaper internet access and utilization. From both countries it was extremely difficult to determine the threshold or reservation price to which customers were much willing to pay for the internet. Statistical data show that an overwhelming number i.e. (98%) of respondents were in support of subsidized ICT services as shown in Figure 1.

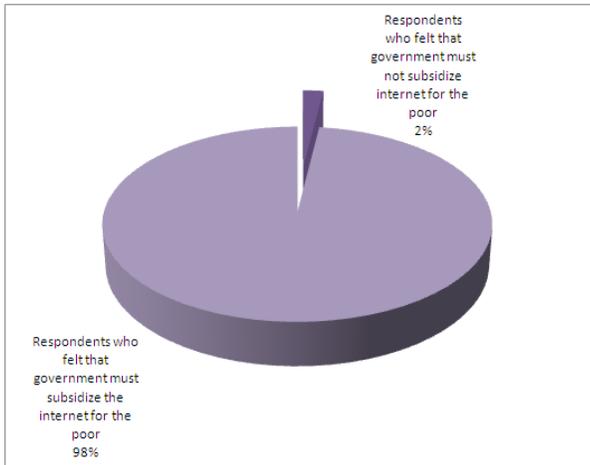


Fig. 1. Users’ response towards subsidizing the internet for the poor

B. Number of hours spent on the internet

Information concerning the number of hours spent on the internet by respondents is shown in Figure 2, from which it was clear that given the prevailing prices in developing countries (Zambia and South Africa), there was less usage of internet in unserved areas. Interviewed users alluded this to high prices of internet, given the fact that every user has a threshold value of the maximum amount of money he is willing to pay for a particular service. Beyond this reservation price the user abandons the service [4]. It is, actually, from this information that the reservation price variable, (p_{th1}) and (p_{th2}) , is deduced. It will be elaborated in details in section IV of this paper.

C. Willingness-to-pay in heterogeneous communities

In order to determine the number of users who were willing to pay for the internet, we conducted a survey that would give us an estimate on how much users in developing countries were willing to pay for the internet. From the survey, consumers of internet services in urban areas were

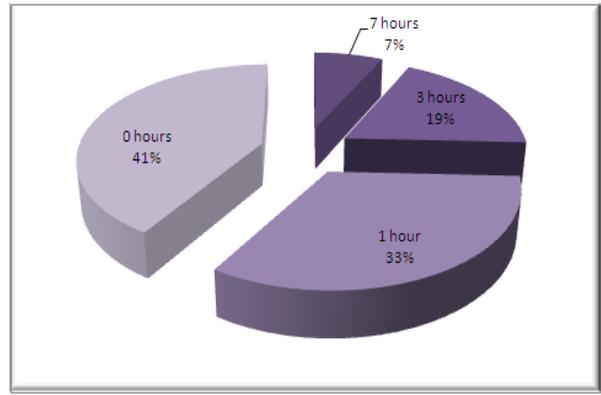


Fig. 2. Internet usage patterns in Zambia and South Africa

more willing to pay for the internet while the rural people or those in underserved areas were hesitant to paying for the internet. In extreme cases, even the teachers, who are better off than average, interviewed in rural areas of Mongu and kwa-Zulu Natal expressed concern over the exorbitant fees charged by service providers and telecentres. The information gathered from the survey is displayed graphically in Figure 3. The number of respondents who were not willing to pay for the internet at the current prevailing prices in kwa-Zulu Natal (South Africa) and Mongu (Zambia) declined as the price increased. From the survey that was conducted we were able to conclude that internet usage in rural areas is price driven. Actually, the willingness-to-pay for most users in South Africa and Zambia was a factor of their income and showed a decrease from urban to rural areas. For example, in Mongu teachers expressed their willingness-to-pay only if internet prices were pegged between 50 cents and USD 1 for a 30 minute internet session. More people in both the rural and underserved areas of the two countries were inclined to using mobile (cellular) internet services which were much cheaper than the ADSL. It is from the information above and research data that, we were able to determine the slope of the curve of the price versus number of users. (Note that prices were normalized and the equation will be modified in the following section).

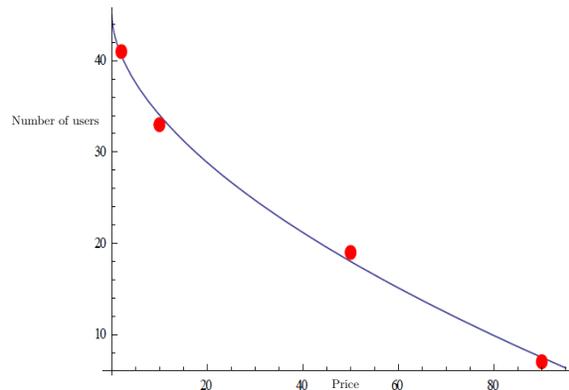


Fig. 3. Number of users in percentage versus the price

IV. PRICING MODEL FORMULATION

Generally, characterizing the heterogeneous users' behavior is important for devising a pricing mechanism which could induce a desirable user behavior [1] [11]. In general, user behavior is related to the price charged and some network externality and sometimes may depend on the type of application and service [1]. Heterogeneous users have differing demands and attributes, as such; the usage of internet services is defined by a number of factors such as the consumer's income level, needs, perceived utility, and the person's learning curve, personality, lifestyle, and so forth. Furthermore, attributes such as culture, family and geographical location plays an important role in shaping the internet usage behavior and pricing models of a heterogeneous community.

To develop a model that will capture specific trends in user behavior from developing countries, we used the data as shown in Figure 1, Figure 2 and Figure 3. For example, one may note that as the price or the amount of hours spent on the internet increased, the number of users decreased significantly (creating an inverse relationship between price and the number of users) as shown in Figure 3. To validate such a supposition, one might argue that consumers gain knowledge of the prices over time and adapt to optimal behavior through repeated exposure. Having observed such a experience, we were able to make some generalized observations about the entire consumer population. We list these observations as follows:

- There exists a finite price $p_1 > p_{th1}$ and $p_2 > p_{th2}$ where a customer will not subscribe to any ISP.
- Customers are rational, they will prefer a subsidized price or a lower price to a higher price.
- The number of user who supported the usage of a subsidy discount rate was approximately 98%, implying that users were more willing to subscribe to an ISP as long as the government subsidized the internet. From our statistics only 2% of users were not in favor of government subsidy.
- The number of users who will accept a given price in any heterogeneous communities of developing countries does not increase with price. For example very few customers were willing to pay for the price of USD 3 per hour of connectivity [3] in underserved areas of Zambia and South Africa.

Given the above motivation, we can therefore define the number of users in a network as a function of price p_1 and p_2 and the reservation price p_{th1} and p_{th2} . Li et al [6] and Jagannathan and Almeroth [12] investigate user behavior upon price change using a hyperbolic model. We adopt this model with extensive modification to reflect our price setting and the number of users. Thus, when the price is zero the number of users increases significantly and when the price is very high the number of users decreases to approximately zero (see Figure 4). The following equations are equivalent for the information "have-nots" (N_1) and the information "haves" N_2 users respectively:

$$N_1 = \left(\frac{\beta p_2}{p_{th1}} \right)^{-\alpha_1} - 1 \quad (1)$$

$$N_2 = \left(\frac{p_2}{p_{th2}} \right)^{-\alpha_2} - 1 \quad (2)$$

Therefore, the total number of users who are willing to subscribe to any ISP is the sum of the two equations above and can be approximated as follows: $N_{total} = N_1 + N_2$:

$$N_{total} = \left(\frac{\beta p_2}{p_{th1}} \right)^{-\alpha_1} - 1 + \left(\frac{p_2}{p_{th2}} \right)^{-\alpha_2} - 1 \quad (3)$$

Where β is the subsidy discount rate and $p_1 = \beta p_2$. If $\beta = 1$, the information "have-nots" (N_1) and the information "haves" N_2 pay the same price, while for $\beta = 0$, the information "have-nots" (N_1) are completely subsidized by the government. $0 < \alpha_{1,2} \leq 1$ is the consumer sensitivity or response towards price². This sensitivity increases with an increasing value of α_1 and α_2 , with 0 implying low elasticity of demand and 1 greater elasticity.

The motivation behind this is in line with the fact that consumers especially in heterogeneous communities exhibit variations in response towards prices. Since the number of users determines the number of packets sent ($N_{total}\lambda$), we can define the number of users as the amount of packets sent in the network by users. The larger the number of users subscribing to an ISP, the larger the numbers of packets sent at a particular time. Thus, by controlling the subsidy discount rate β , we can approximate the number of packets versus price curve to be similar to the users versus price curve. Using ($N_{total}\lambda$), we can approximate the number of packets sent over the network given the price p_2 as shown in Figure 4:

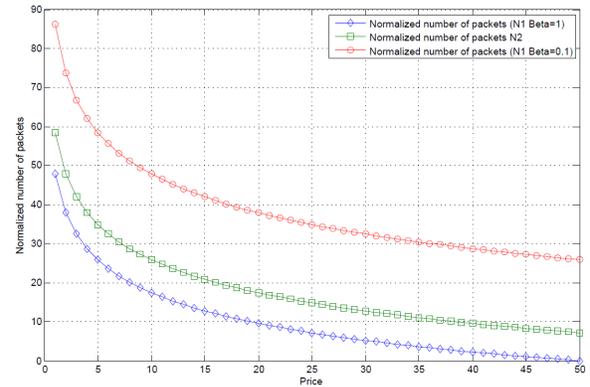


Fig. 4. Expected number of packets per price and per second at different subsidy factors

Since the aim of this study is to develop a price model for heterogeneous community, i.e. the information "haves" (N_2) and "have nots" (N_1), we incorporate a cost function c to account for the costs incurred by the service provider. Given a price p_2 for a packet rate λ and a cost c we can define the service provider's profit function as:

$$\Pi = \lambda \left(\left(\frac{\beta p_2}{p_{th1}} \right)^{-\alpha_1} - 1 \right) (p_2 - c)$$

²Note that the price sensitivity, $\alpha_{1,2}$, decreases or increases the number of users and does not affect the subsidy discount rate value given to the information "have nots"

$$+\lambda \left(\left(\frac{p_2}{p_{th2}} \right)^{-\alpha_2} - 1 \right) (p_2 - c) \quad (4)$$

If we consider the first and second order conditions of equation 4, we see that $\frac{\partial \Pi}{\partial p_2} = 0$ has a maximum point since $\frac{\partial^2 \Pi}{\partial p_2^2} < 0$, meaning that within the interval of $0 < p_2 < p_{th2}$, the profit function is positive for all the values of p_2 in $c_i < p_i < p_{thi}$. Therefore, it is clear that the profit function, Π , is strictly concave in the region of $c_i < p_i < p_{thi}$ for $i \in 1, 2$. Moreover, it can be inferred from Equation 4 that if $\frac{\partial^2 \Pi}{\partial p_2^2} < 0$, Π contains at least one maximization point or fixed point (see Kakutani fixed point theorem) [1], at which $\frac{\partial \Pi}{\partial p_2} = 0$ within the range of $c < p_2 < p_{th2}$. Thus the optimal price can be found by equating the first derivative to zero i.e. $\frac{\partial \Pi}{\partial p_2} = 0$ and solving for p_2^* .

V. PERFORMANCE ANALYSIS OF THE PRICING MODEL

In Figure 5, we evaluate the effect of subsidy on revenue maximization, given any price p_2 and the reservation price of consumers i.e. p_{th1} and p_{th2} at a constant sensitivity $\alpha_{1,2}$. From figure 5, we can conclude that the value of $\alpha_{1,2}$ actually determines the number of users in each group while the value of the optimal subsidy rate that is to be given to the users is determined by the reservation price. Suppose we assume that $p_{th1} = p_{th2}$, general knowledge will tell us that such a society is a homogeneous society and the subsidy rate, if at all is needed, must be dispersed equally among all users. However, if there is a large variation in the income of users it will be to the benefit of the government and the users to subsidize the information “have nots”. With that statement we provide the following theorem:

Theorem 1 For the N_1 and N_2 to be in equilibrium, p_{th1} must be equal to p_{th2} otherwise the free rider problem or the tragedy of the commons will occur \square

Proof: Consider the two types of users i.e. the N_2 and N_1 users. Assume that the price charged by the service provider is p_2 for N_2 users and p_1 for N_1 users and the reservation price is the same i.e. $p_{th1} = p_{th2}$ for all the users. If we further assume that there is no subsidy for the information “have nots” i.e. $\beta = 1$, for maximum revenue, the Nash equilibrium of the game can be defined as in equation 4. It is easy to show, from equation 4, that this game has a unique Nash equilibrium. Since $p_{th1} = p_{th2}$, by symmetry the prices charged by the service provider at equilibrium must be the same i.e. $p_1 = p_2$.

Consider now that the government heavily subsidizes the N_1 users i.e. $\beta \approx 0$. Inserting $\beta \approx 0$ into equation 4 will increase the reservation price of N_1 users, significantly resulting in more users subscribing to the ISP. This intuition is in line with fact that as government increases the subsidy rate, the number of users willing to gain access to subsidized resources increases drastically for the simple reason that their reservation price is stretched. However, an increase in the subsidy discount rate, given a very big price differential between p_2 and p_1 , may result in the tragedy of commons and the free rider problem [5]. If the price differential exceeds the threshold value, N_2 users will defect to N_1 users and the free rider problem appears.

Consider again that this time the ISP increases the price beyond the reservation price of customers, with no subsidy given $\beta = 1$, from equation 4 and Figure 5, one can see that as p_2 increase the number of users decreases, which in turn reduces the revenue of the service provider drastically and actually reaches 0 when $p_2 > p_{thi} \forall i \in (1, 2)$. Although this solution is in itself an equilibrium it is, however, not desirable to the ISP and the government. In actual fact it does not promote social and economic objectives set out by the government. \blacksquare

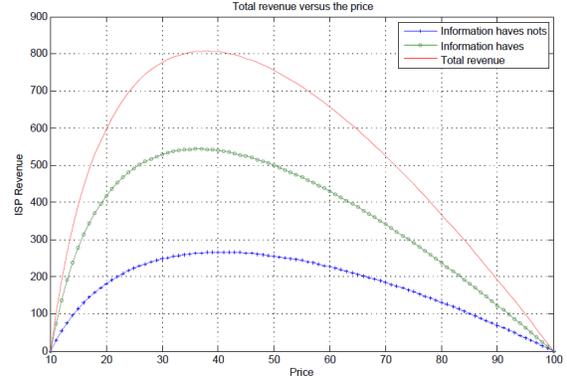


Fig. 5. Revenue versus price N_1 users $\alpha_1 = 0.3$, N_2 users $\alpha_2 = 0.7$, $p_{th1} = 40$, $p_{th2} = 100$, $\beta = 0.4$, $\lambda = 20$

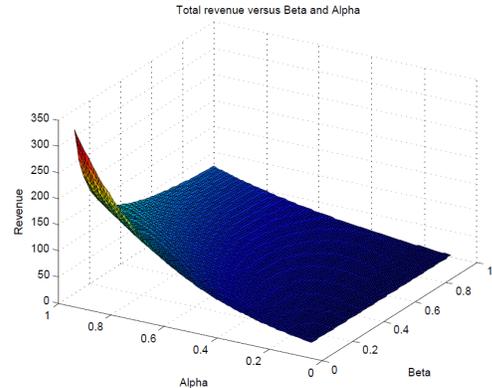


Fig. 6. Revenue versus beta and alpha when $p_2 = 60$

Since the solution to equation 4 is mathematically intractable and requires considerable computational ability to solve for the equilibrium, a numerical example and a graphical analysis of the equation will provide us with an approximate solution of the equilibrium prices at which the ISP’s profit will be maximized. Figure 5 depicts the results of how the value of p_2 , given the reservation prices, affects the revenue generated by the ISP while Figure 6 presents the results on how $\alpha_{1,2}$ and β affect the revenue generated by the ISP.

Clearly Table 1 provides us with an approximate value of β at which no user will unilaterally change his or her strategy. From Table 1 the value of β , at equilibrium, is dependent on the reservation price or the maximum price that consumers are willing to pay and not on the sensitivity to price value, $\alpha_{1,2}$.

TABLE I
APPROXIMATE OPTIMAL SUBSIDY DISCOUNT RATE β WITH VARYING p_{th1} AND p_{th2} : WHEN $\alpha_1 = 0.4$, $\alpha_2 = 0.7$

Type of Users	P_{th1}	P_{th2}	P_2	P_1	β	$\alpha_{1,2}$	ISP Revenue
N_1	10		20	2.2	0.11	0.4	166.4890
N_2		90	20	2.2	0.11	0.7	373.1638
N_1	10		35	3.85	0.11	0.4	232.4630
N_2		90	35	3.85	0.11	0.7	468.4833
N_1	10		50	5.5	0.11	0.4	216.1198
N_2		90	50	5.5	0.11	0.7	407.2042
N_1	40		20	6.62	0.331	0.4	210.6868
N_2		120	20	6.62	0.331	0.7	501.0288
N_1	40		35	11.59	0.331	0.4	320.7967
N_2		120	35	11.59	0.331	0.7	684.5387
N_1	40		50	27	0.331	0.4	338.6619
N_2		120	50	27	0.331	0.7	676.5150
N_1	70		20	10.80	0.54	0.4	222.3765
N_2		130	20	10.80	0.54	0.7	541.4286
N_1	70		35	18.90	0.54	0.4	344.1595
N_2		130	35	18.90	0.54	0.7	752.8082
N_1	70		50	27	0.54	0.4	371.0723
N_2		130	50	27	0.54	0.7	761.6055

Essentially, the sensitivity to price value, $\alpha_{1,2}$ determines the number of users subscribing to the ISP. From Table 1 we can conclude that the subsidy discount rate(β) is a function of the reservation price.

VI. CONCLUSION

In this paper, we have developed a subsidy driven pricing scheme given the statistical data that was obtained from the two developing countries. Given any pricing policy, government and service providers can adjust the value of the price p_2 and the subsidy discount rate β in order to reach an optimal solution where no user from either the information “haves” or “haves nots” will deviate to the other group. The value of subsidy (the additional money the government pays) is critical to achieving a social and economic growth in underserved areas of developing countries. This paper has shown that increasing the value of subsidy increases the selfish, utility-maximizing decision-making process of users or consumers leading to a significant reduction in payoff for all users of a network resource.

A numerical example and graphical analysis is provided to show how β and other parameters of equation 4 affect the number of users and subsequently the revenue of the service provider. Also, we have shown that the sensitivity of customers towards price (perceived utility or value) as exhibited by α , has severe effects on the revenue and the number of users subscribing to an ISP.

By knowing the reservation prices of the consumers and the value of subsidy discount rate β , the ISP can adjust its price accordingly so as to obtain an equilibrium price where no user will defect to the other group.

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