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An Economic Assessment of Nigeria's Smart Phone Data Bundle Consumption, Subscriber Resource Constraints and Dynamics: The Case of Abuja and Lagos States

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Abstract

This paper examines ways in which smart phone data consumption trends influence demand for airtime data bundles. A model of subscriber response to economic and technical stimuli, conditional on cybernomic and subscriber characteristics, is developed. Three years of survey data, gathered from subscribers of data and voice bundles to evaluate the model empirically. Single SIM smartphones, subscribers are responsive to relative Data Bundle prices and Airtime volume discounts. However, different Data Bundle packages elicit different responses. In particular, some data sharing takes place primarily through subscriber-substitution and intensified smartphone use, while changes in tariff or volume discounts for subscribers having dual SIM smartphones induces frequent and spontaneous network migration. Subscriber and public power constraints bind at different points for different data bundles demand. These results suggest that because multiple data/voice bundle platform interact, subscriber smartphone response coefficient must have multiple strands in order to replace incentives to further bundle demands.

Keywords: Affordable; Consumption; Dynamics; Expansion; Evaluation

Introduction

In developing economies like Nigeria, the growth of data subscriber populations poses a challenge to the carrying capacities of telecommunication equips systems deployed. Single SIM Subscriber impacts of different data/voice bundle platforms, often characterized by relatively fragile subscriber loyalty, include subscriber and airtime volume loss to the company, drop calls, and impaired network speed. Dual/Triple SIM subscribers anguish include impaired network speed and frequent migration to alternate networks, reductions in smart phone performance and life expectancy of smart phone batteries, and loss in revenue [1,2]. While general SIM population growth relative to data subscriber is the direct source of many network problems, it is widely recognized that the persistent drive for SIM use growth is itself an outcome of wider trends, including economic and socio-cultural factors that promote and drive internet traffic and smartphone use intensification [3] without penalizing the actions of network providers that erode network quality and otherwise degrade their network resource base.

The Nigerian experience exemplifies both the network problems compounded by unchecked data service expansion, and the policy settings that encourage it. Even after years of reasonably robust growth in Nigeria's aggregate economy, Network expansion continues to be a fundamental characteristic of economic activity, with severe consequences. For instance, Nigeria's GDP is currently estimated at 8%, and with an unserved population of about 50m, the potential for a surge in GDP is not far off.

A 2011 study by Ericsson and Chalmers University of Technology found that doubling broadband speeds correlated with an average GDP growth of 0.3% in 33 developed nations, including the USA, Italy, New Zealand, and Norway. In monetary terms, the 0.3% growth represented an increase of $126 billion. Therefore network crisis is reaping off the economy based on this analysis.

Throughout the developing world, government policies influence incentives for both market expansion and intensification in resource input [4-8]. In Nigeria these policies find expression both in the tariffs faced by subscribers and in the set of technologies deployed and made available. Moreover, airtime tariff and technology policies clearly interact. Tariff dynamisms support, for example, increase the profitability of affected data bundles; this promotes the demand for equipment investments aimed at increasing the supply of technical innovations for that market niche. When telecom firms' budget constraints are inflexible, data bundle related network suffers as a consequence. In this way, tariff policies can significantly alter both the constituencies for and the perceived returns to telecom investments [6,9]. Tariff and technology biases can thus promote frontier subscriber base expansion, usually at the expense of network quality, as well as subscriber profiles consuming data bundles having differing propensities. In this chain of reasoning, the extent to which subscribers actually alter data bundle use in response to relative tariff and innovation shifts is an important empirical question. Data bundle subscribers in developing countries exist "at the margin" in more than a merely geographic sense; they are typically students and middle class workers, with few extra income sources, and may have only tenuous long-term control over the data they consume. These factors influence their resource allocation choices in ways that reinforce or counteract the effects of policy- or market-induced tariff shifts. At the extreme, market opportunities may be circumscribed entirely by internet access needs, in which case the search for airtime tariff policy answers to frontier telecom problems will be futile.

In this paper we use Abuja and Lagos data to conduct an econometric evaluation of the factors affecting subscribers' data bundle use decisions. Specific features of Abuja and Lagos economic policy and of the subscribers from which data are drawn influence

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our choices in modeling subscriber behavior, so we begin with a brief review of these features. Subsequently we present a model of subscriber growth and allocation by risk-averse subscribers and derive a reduced form suitable for econometric estimation. This allows us to test a number of hypotheses relating to the influence of tariff on data bundle subscribers. We conclude the paper by returning to the larger debate on ways in which development policies in general, and investments in telecommunication in particular, influence incentives for subscriber base expansion and SIM use intensification.

The Study Area

Lagos state

Data for our study come from a sample of 85 subscribers in Lagos State, South West Nigeria. It is acclaimed the most populous city in Nigeria, the second fastest-growing city in Africa and according to citymayors.com, the seventh fastest growing city in the world. The population of the state according to the State Government was 17.5 million as at 2013. Lagos Sate is Nigeria's commercial nerve center, generating a significant portion of the country's GDP. Most of the country's commercial banks, financial institutions, and major corporations are headquartered in the state. The ports in Lagos state has seen growing amounts of crude oil exported. According to the CIA fact book (2013) on Nigeria, Oil and petroleum products provide 14% of GDP and 90% of foreign exchange earnings in Nigeria as a whole. These volumes of transactions on daily basis would require on enormous amount of telecommunications.

Abuja, federal capital territory

Abuja is the political capital of Nigeria. Abuja has witnessed a huge influx of people; The Federal Capital Territory Administration puts the population of well over four million for 2013. Most government bureaucratic business is business is carried out in the city and as a result telecommunication is at the center of all activities.

Telecommunication liberalization policies and links to data bundle usage

Over time, the profitability derivable by telecom companies from data and voice bundle plans in Nigerian has been directly and indirectly affected by a number of government policies. These consist mainly of market interventions directed at supporting and stabilizing the telecom sector, tariff regimes; trade interventions aimed at reducing dependence on imports and boosting technology transfer, subscriber and telecom SMEs livelihoods alike; and technology interventions in the form of public support for assembly plants for telecom equipment aimed at raising network access and reducing vulnerability arising from the international market realities.

The population of Data and Voice subscribers is huge in Lagos, and their network providers have received considerable encouragement in the form of import concessions, etc. Relaxed regulatory environment in the country's telecom sector as regards on corn, cabbage and potato imports (recently converted to tariffs at the maximum allowable rate under the WTO) have raised their domestic prices relative to border (world) prices.

Recent reforms in Nigerian telecommunications have led to significant capacity investment, which has promoted service expansion and the introduction of new technologies. The Nigerian telecommunications sector was grossly underdeveloped before the sector was deregulated under the military regime of General Ibrahim Babangida in 1992 with the establishment of a regulatory body, the Nigerian Communication Commission (NCC). So far the NCC has issued various licenses to private telecommunications operator. These include 7 fixed telephony providers that have activated 90,000 lines, 35 Internet service providers with a customer base of about 17,000. Several VSAT service providers are in operation, and have improved financial intermediation by providing on-line banking services to most banks in Nigeria. These licenses allowed private telephone operators (PTOs), to roll out both fixed wireless telephone lines and analogue mobile phones. The return of democracy in 1999 paved the way for the granting of GSM license to 3 service providers: MTN, Nigeria, ECONET Wireless, Nigeria and NITEL Plc in 2001 and today NCC has issued more than 200 licenses to intending telecommunication operators. Telecommunication facilities in Nigeria were first established in 1886 by the colonial administration. These were geared towards discharging administrative functions rather than the provision of socio-economic development of the country. Accordingly, the introduction of public telegraph services linking Lagos by submarine cable along the west coast of Africa to Ghana, Sierra-Leone, Gambia and on to England was a greater priority than a robust telecommunications network. At independence in 1960, with a population of roughly 40 million people, the country only had about 18,724 phone lines for use. This translated to a tele density of about 0.5 telephone lines per 1,000 people. The telephone network consisted of 121 exchanges of which 116 were of the manual (magneto) type and only 5 were automatic. Between 1960 and 1985, the telecommunication sector consisted of the Department of Posts and Telecommunications (P&T) in charge of the internal network and a limited liability company, the Nigerian External Telecommunication (NET) Limited, responsible for the external telecommunications services. NET provided the gateway to the outside world. The installed switching capacity at the end of 1985 was about 200,000 lines as against the planned target of about 460,000. All the exchanges were analogue. Telephone penetration remained poor equaling 1 telephone line to 440 inhabitants, well below the target of 1 telephone line to 100 inhabitants recommended by ITU [10] for developing countries. The quality of service was largely unsatisfactory. The telephone system was unreliable, congested, expensive and customer unfriendly. Arising from the foregoing, in January 1985, the erstwhile Posts and Telecommunications Department was split into Postal and Telecommunications Divisions. The latter was merged with NET to form Nigerian Telecommunications Limited (NITEL), a limited liability company. The main objective of establishing NITEL was to harmonize the planning and co-ordination of the internal and external telecommunications services, rationalize investments in telecommunications development and provide accessible, efficient and affordable services. Almost 43 years down the line, the Nigerian Telecommunication Plc, NITEL had roughly half a million lines available to over 100 million Nigerians. NITEL the only national carrier had a monopoly on the sector and was synonymous with epileptic services and bad management. On assumption of office on May 29, 1999 the President Olusegun Obasanjo administration swung to gear to make a reality the complete deregulation of the telecom sector, most especially the much touted granting of licenses to GSM service providers and setting in motion the privatization of NITEL. This proactive approach by the government to the telecom sector has made it possible for over 8.5 million Nigerians to clutch GSM phones today.

Telecommunications is both dynamic and capital intensive and in view of its catalytic effect on the development of other sectors of the economy such as agriculture, health, tourism and education and its necessity for the commercial, industrial, socioeconomic and political development of the country, the need for an orderly and efficient development of telecommunications infrastructure in Nigeria has now been found more urgent in order to keep pace with the development of the other sectors of the economy.

The Nigerian Telecommunication Commission (NCC) introduced Global System for Mobile Communications (GSM) in Nigeria. The licence auction had took place from January 17-19, 2011 while Econet Wireless Nigeria (now Airtel) was the first to roll out on August 7, 2001. Before the licensing of GSM, in November 1997 Code Division Multiple Access (CDMA) telephone device had become operational in Nigeria. According to industry source, while CDMA operators focus on fixed wired access (landlines) and the fixed wireless access (mobile) that gives them limited mobility access, the GSM operators focus purely on mobile communication, which gives them unlimited mobile access. Unlike Nigerian Telecommunications, NITEL which had been the monopoly providing telephone service in Nigeria. The GSM value chain expanded. There are hundreds of thousands of Nigerians nationwide selling mobile handsets and accessories such as batteries, chargers, earpieces, memory cards, etc. Some are into sales and repair of handsets, music downloads to mobile phones, unlocking of handsets et cetera. Many others simply set up call centers where they also vend recharge cards. There are likewise companies manufacturing handsets and other accessories as well as those who are into production of recharge cards and telecom masts all being part of the chain.

As at 2013, the telecom sector's contribution this year, computed with Nigeria's gross domestic product figures put at $ 206.66bn by the International Monetary Fund, IMF, is estimated at $ 15.7bn, amounting to 7.6 percent of the GDP. Finance and Insurance, manufacturing and solid minerals are put at 2.5, 4.5 and 0.4 percent in that order, totalling 7.4 per cent, which is 0.2 per cent less than the 7.6 percent estimates for the telecoms sector. Since 2005 (four years after it was liberalized), the telecoms sector remains the third largest contributor to the country's GDP in the non-oil sector, after agriculture and trade. According to the Nigerian Communications Commission, NCC, estimates, active telephone subscribers in the country are now nearing the 184 million mark, while a teledensity of 93 percent currently obtains.

Some challenges of the sector in Nigeria are the poor services of the operators and the weakness of the regulators to enforce quality compliance. When GSM services started in 2001, the cost of handset and call rate was very prohibitive. Competition has however forced down the price. Despite the claims of cutting edge technology, there is still high level of drop calls and network failures. Along the GSM revolution, came the internet café diffusion, which is the wide acceptability of the services as it became more and more affordable to potential operators and consumers alike.

An internet café or cybercafé is a place which provides internet access to the public, usually for a fee. These businesses usually provide snacks and drinks, hence the café in the name. The fee for using a computer is usually charged as a time-based rate. Internet cafés are located worldwide, and many people use them when traveling to access webmail and instant messaging services to keep in touch with family and friends. Apart from travellers, in many developing countries Internet cafés are the primary form of Internet access for citizens as a shared-access model is more affordable than personal ownership of equipment and/or software. In most countries the primary goal of establishing these internet café is profit making. However, there are other objectives, including provision of employment, financial stability, and provision of democratized access to the information web.

The priority of profit making and maximization over other policy goals tends to be widely accepted in most countries. Changes in production input mix are triggered by the firm's business environment shocks that can impact the attainment of set goals. Cyber café operators change their production strategies by resetting their resource inputs, usually price adjustment or airtime volume. These instruments affect the output through various mechanism of transmission to the ultimate goals. Cyber café service production strategies therefore, refers to the specific action(s) taken by a firm operator to regulate supply, values, and the cost of internet airtime with the view of achieving predetermined objectives. While the internet, on the other hand is a global system of interconnected computer networks that use the standard internet protocol suite to link several billion devices worldwide.

The internet a.k.a World Wide Web (www) functions basically to provide information sharing platform for all end users. The term "information sharing" in the information technology lexicon refers to exchange of data between a sender and receiver. These information exchanges are implemented via a dozen of open and proprietary protocols, messages and file formats. Electronic Data Interchange is a successful implementation of commercial data exchange.

From the view point of computer science, the primary information sharing design patterns are sharing one-to-one, one-to-many, many-to-many and many-to-one. It is argued that cyber café enable efficient and effective diffusion of information and its transmission in the information space. This process contributes to expand as the need arises.

It is of great concern to a typical firm operator that a particular resource-outlay strategy leads to strategic contribution which enables maximization of profit over time so to engender business growth. This can only be achieved if they properly embedded into the café service provision through various channels notably adequacy of capital, adequacy of office space, skilled labor, availability of power and airtime price. An effective transmission mechanism will be one that will increase the return on investment. A Cyber café investor can only benefit from return on investment if earnings per resource input are increasing over time.

Hence the understanding of how these variables or factors affects the output of cybercafés as well as how these changes affect the behavior of consumers. Several factors have been identified in existing studies as affecting the demand and supply of internet airtime. Chief among them are network diffusion, stability in power supply and network itself [5].

Cyber café operation in Nigeria at the inception enjoyed unrivalled control of access to the web. It however lasted until 2003 when the Global System for Mobile Communication enabled smart phones further democratized access to the web. Café operators' major challenge was and still is power supply. The extent of their profit maximization was influenced and predicated on the development and diffusion internet network. Inadequate power supply and hence overreliance on diesel generators meant higher energy cost.

The process of telecommunications sector reform and deregulation started under the military regime of General Ibrahim Babangida in 1992 with the establishment of a regulatory body, the Nigerian Communication Commission (NCC). The development and expansion of the Nigerian telecommunication networks is significantly influenced by the regulatory framework put in place by the regulatory authority, Nigerian Communication Commission (NCC) to oversee the evolution of the networks towards a competitive system through policies aimed to protect new comers from aggression by the incumbents and to protect the public against the capacity of large firms to exercise their market power through their inflated price or reduced quality, diversity and quantity of telecommunications services or both.

A dynamic model of subscriber data bundle decisions under risk

With the preceding observations in mind, we now develop an *ex ante* model to study the effects of tariff changes and technological improvements on data bundle usage patterns, while taking account of potentially binding household resource constraints that would dampen responsiveness to shifts in airtime and tariff distributions. Our objective is to identify subscriber's data bundle use responses to economic and technological stimuli, conditional on relevant cybernomic and household characteristics. We assume that subscribers choose data bundle use strategies consistent with utility maximization over time, based on per-period net subscriber income. We characterize a representative subscriber's economic choices in stylized form and derive an estimable econometric model.

To begin, we suppose that subscriber are endowed with family members as subscribers, a data bundle subscribers, and network quality. These opportunities on the internet drive the market for smartphone. For convenience, we work with a Two-Smartphone portfolio. The subscriber purchases inputs (including smartphone), and consumes airtime at a market-determined tariff. Given family subscription availability and initial network quality, the major decisions each subscriber faces at the beginning of a bundle usage are (1) data bundle platform to subscribe, and (2) the fraction of airtime to allocate to each smartphone.

Since tariff and airtime consumption are stochastic, we assume that subscribers seek to maximize the net present value of a stream of expected utility. That is, they have the objective function

$$\text{Max } {}^{0}\!\int_{T} e - {}_{rt} \text{EU}(t)dt \tag{1}$$

Which they maximize subject to conditions outlined below. In equation (1), r is a discount rate and the planning horizon is defined by the interval [0, T]. We suppress time subscripts, except where required for sake of clarity. Following the studies of Eke, Magaji [6,9], we construct a per-period expected utility function EU in terms of expected browsing time and its variance:

$$EU = U(\text{E}(\pi), \text{Var}(\pi)) \tag{2}$$

We adopt the conventional assumptions that

$\partial U/\partial E(\pi) > 0$ and

$\partial U/\partial(\text{Var}(\pi)) < 0$.

Uncertainty has two sources, tariff and consumption. New Smartphones prices per time are assumed unknown when data bundle use decisions are made (input prices are observed at purchase time). Consumption risk arises both from the characteristics of the Network and family endowments, and from external events such as income, budget constraints, and network crisis. Assuming no bundle sharing, the consumption function for each smartphone is

$$Y_i = f_i(N_i, F_i, \mathbf{X}_i, \varepsilon_i, q) \tag{3}$$

where N_i is airtime consumed by the i' th smartphone, F_i is family subscription dynamics, $\mathbf{X}_i$ is a vector of variable inputs (Public power supply, access to generator, and network quality), ε_i is a random variable representing consumption risk, and q is an index of network quality. Using a standard multiplicative representation of consumption uncertainty, the random consumption function can be written:

$$Y_i = \varepsilon_i f_i(N_i, F_i, \mathbf{X}_i, q) \qquad \text{i = c, v} \tag{4}$$

$$\text{E}(\varepsilon_i) = \mu_i;\ \text{Var}(\varepsilon_i) = \sigma_2, \qquad \text{i = c, v;}$$

$\partial f_i/\partial N_i > 0$,

$\partial f_i/\partial L_i > 0$,

$\partial f_i/\partial X_{ik} > 0$, $\forall$ variable inputs k.

For convenience we assume that σ_{2i} captures consumption risk from all sources. It is worth noting that, from our survey, we observe three basic subscriber responses to external shocks and perceived changes in network quality. At the extensive margin, subscribers' increase and decrease airtime by buying airtime. At the intensive margin, they adjust generator and input use by smartphone, using more or less of each to attain a desired consumption target. And between the intensive and extensive margins, subscribers adjust airtime allocation among different smartphone. Accordingly, the airtime constraint is:

$$\sum_{i=c,v} N_i \le A - 1 + \Delta A \tag{5}$$

Where A_{-1} is total airtime consumed in the previous month, and ΔA is the change in consumption between months. i.e. the addition of new data bundle or just voice calls. A cost is associated with bringing new data plan. We write this as

$M(\Delta A)$, with $M' > 0$.

As highlighted below, availability of a bundle of complementary factors, such as family subscription, may influence ΔA. Family gross subscription and network quality are not perfect substitutes, because family subscription embodies collaborator capacity as well as subscriber- specific airtime and smartphone management skills. It is reasonable to assume that, in the short run, family subscription is fixed in demand. We assume that each unit of data bundle requires s units of family subscription for management and supervision, in addition to airtime used in usual voice calls. It follows that we can write the constraint for family subscription as:

$$F_i + s\left(\sum_{i=c,v}^{A-1} + \Delta A\right) \le F \tag{6}$$

Where F is the number of adult family members who subscribe to any GSM network in the sampled states.

Dynamics of the model are defined by a constraint equation that specifies the evolution in network quality, which we define as:

$$q^{\cdot} = h(\mathbf{N}, \mathbf{X}, \Delta A), \tag{7}$$

Where q represents the per-period change in an index of network quality on the spot. Equation (7) expresses the fact that changes in network quality reflect choices regarding smartphone mix, levels of input use, and changes in airtime usage. Signs of these relationships are indeterminate.

Defining a vector $\mathbf{W}_i$ of the prices of variable inputs used in smartphone i, the current period

Browsing time function is:

$$\underset{i=c,v}{\pi} = \sum[P_i \varepsilon_i f_i(\bullet) - X_i \bullet W_i] - \delta M(\Delta A) \tag{8}$$

Where $\delta = 1$ when, $\Delta A > 0$; 0 otherwise

For simplicity, we assume tariff risk and airtime risk are independent. If we define expected tariff as $\text{E}(P_i) = \theta_i$ and the variances of tariff as $\text{var}(T_i) = \varphi_{I2}$ then we can write expected profit as:

$$\underset{i=c,v}{E}(\pi) = \Sigma[\theta_i \mu_i f_i(\cdot) - \mathbf{X}_i \cdot \mathbf{W}_i] - \delta M(\Delta A) \tag{9}$$

And the expected variance rate for browsing time as:

$$\underset{i=c,v}{var}(\pi) = \sum f_{i2}(\bullet)(\phi_i^2 \sigma_{2i} + \sigma_I^2 \mu_i^2 + \phi_i \theta_i) \quad (10)$$

To minimize notation, it is convenient to define $V_i = \varphi_I{}^2\sigma_I^2 + \varphi_i^2\sigma_I{}^2 + \theta_I^2\sigma_i^2$.

The present value Hamiltonian for this problem can be written:

$$H = e - {}_{rt}EUdt + \lambda_q h\,(\mathbf{N}, \mathbf{X}, \Delta A) \quad (11)$$

Subject to the definitions provided above, constraints (5)-(7), and an initial condition for the network quality, $q\,(0) = q^0$. In this expression the multiplier λ_q is the shadow tariff of network quality. Maximizing the Hamiltonian with respect to **N**, **F, X**, and ΔA, and subject to the per-period and dynamic airtime constraints the following system of first-order conditions:

$$\partial H/\partial N_i = \partial EU/\partial N_i + \lambda_{q\ \theta\theta}$$

$$\partial h/\partial N_i = 0\ \forall i \quad (12)$$

$$\partial H/\partial F_i = \partial EU/\partial F_i + \lambda_q$$

$$\partial h/\partial F_i = 0\ \forall i \quad (13)$$

$$\partial H/\ \partial X_{ki} = \partial EU/\partial X_{ki} + \lambda_q$$

$$\partial h/\partial X_{ki} = 0\ \forall i,\ k \quad (14)$$

$$\partial H/\partial A = EU/\partial \Delta A + \lambda_q$$

$$\partial h/\partial A = 0 \quad (15)$$

$$q^{\cdot} = \partial H/\partial \lambda_q = h(\mathbf{N},\mathbf{X}, \Delta A) \quad (16)$$

$$\lambda_q = -\,\partial H/\partial_q = -\,e_{-rt}\,\partial EU/\partial q - \lambda_q\ \partial h/\partial q = 0, \quad (17)$$

along with the initial condition $q(0) = q^0$ and transversality condition $lim_{T\to\infty}\lambda_q\,(T)q(T) = 0$.

Equations defining the paths of the choice variables can be written in expanded form as:

$$N_i : \partial U(\cdot)/\partial E(\pi)\ [\theta_i \mu_{ic}]\ \partial f_i\,\partial N_i + \partial U(\cdot)\ \partial Var(\pi)\ V_i 2 f_i\,(\cdot)\partial f_i\,\partial N_i + \lambda_q\,\partial h\ \partial N_i = \lambda_N\,\forall_i \quad (12')$$

$$F_i\,\partial U(\cdot)/\partial E(\pi)\ [\theta_i \mu_i c]\ \partial f_i \partial F_i\ + \partial U(\cdot)\ \partial Var\,(\pi) V_i\,2\,f_i\,(\cdot)\partial f_i\,\partial F_i + \lambda_q\,\partial h\ \partial F_i\ = \lambda_F\,\forall_i \quad (13')$$

$$X_{ki}\!: \partial U(\cdot)\partial E()\ [_{ii}\ \partial f_i \partial X_{ki} + \partial U(\cdot)\ \partial Var(\pi)\ V_i 2 f_i\,(\cdot)\ \partial f_i \partial X_{ki} + \lambda_q\ \partial h\ \partial X_{ki} = W_k\,\forall_i,\,k \quad (14')$$

$$\Delta A\!: \partial U(\cdot\ \partial E(\cdot\ M'(\Delta A) + \lambda_q\,\partial h\ \partial \Delta A + s\lambda_F = \lambda_N \quad (15')$$

Where we now explicitly incorporate the inequality constraints in (5) and (6). The multipliers associated with the inequality constraints, λ_N and λ_F, can be interpreted as the shadow tariff of airtime and family subscription.

Equations (12′)-(15′) require that along the optimal path the implicit value of network quality must be equal to the marginal cost of enhancing network quality, either through additions of data bundle or through application of inputs in smartphone upgrade. For well-behaved utility and consumption functions, the constraints specified by (5) and (6) are binding at all points along the path and the system of equations yields optimal path values for

$$T^*,\ F^*,\ X^*,\ q^*,\ \Delta A^* \text{ and } \lambda_{l^*},\ i = (N, F, q)$$

At each point along the planning horizon the problem comprises $(2k + 9)$ equations with the same number of endogenous variables. Given observed data, we can construct a set of reduced form equations that provides a solution for T^*, F^*, X^*, and ΔA^*. Since each endogenous variable depends only on the set of exogenous variables, we can estimate each equation independently.

The presence of a fixed cost associated with the purchase of another smartphone means that even if the solution of ΔA^* is positive, it does not necessarily follow that subscribers will buy more data bundle. In theory, a threshold for ΔA^* exists, below which subscribers make no change in the airtime. As long as the indirect browsing time function $\pi^*(\Delta A^*)$ and the network quality equation $h^*(\mathbf{N}^*, \mathbf{X}^*, \Delta A^*)$ are increasing in ΔA^*, we can define $U\,(\pi^*, q^*)$ as the instantaneous indirect expected utility function. In theory, a subscriber will buy more data bundle if the expected discounted return along the continuation path warrants doing so; that is, if the following condition holds:

$$\int e_{-rs} U[\pi^*\Delta A^*\!,q(*)dt - M\,\Delta A(*)] > {}_T\!\int e_{-rs} U\,\pi^*\,[(0,q\,)\,dt] \quad (18)$$

Where the interval $[s,\ T]$ represents the time remaining in the planning horizon. Equation (18) defines the minimum amount of airtime consumable. The new data bundle may be part of the airtime that was previously unused, or it may be newly acquired; we do not distinguish these cases. An increase (reduction) in the fixed cost of airtime acquisition will move the threshold up (down) monotonically. Because of the managerial input required to cultivate smartphone, the empirical analysis below explicitly accounts for the fact that household subscription endowments may constrain the amount of airtime in any period.

Equation (15′) is the condition that governs subscribers' decisions to change data bundle consumption. In this equation, λ_N is the marginal benefit of adding a unit of airtime, $M'(\Delta A)\ [\partial U/\partial E\,(\pi)]$ is the marginal loss in utility associated with the cost of acquiring data bundle, $s\lambda_F$ is the family subscription cost, and $\lambda_q\,[\partial h/\partial(\Delta A)]$ is the amount by which the new data bundle will contribute to greater overall network access along the continuation path.

Other things equal, an exogenous shock that raises the marginal productivity of airtime increases the value of λ_N. Condition (15′) then requires that subscribers respond by allocating family subscription to data bundle socialization. This adjustment increases total airtime consumed, reduces the quantity of family subscription budget available for acquiring smartphones. Condition (15′) holds so long as the consumption function is concave and the data bundle purchased is of greater average network access than previous ones. It thus provides insights into why policy makers emphasize policies to improve network quality or reduce the rate of its decline. Other things equal, policies that reduce the rate at which network quality degrades (such as promotion of network conservation practices such reduction of promos, upgrade of systems) also reduce incentives for network expansion. However, it is important to note that decisions regarding network expansion are conditioned by access to complementary inputs such as smartphones, data bundles, and network-specific promos.

How do subscriber respond to exogenous shocks such as changes in expected tariff and data bundle discounts, tariff or data bundle volatility, and subscriber-level endowments of airtime and family subscription? On the basis of the model just developed, we can make the following observations.

First, the airtime to each smartphone is an increasing function of expected tariff and airtime volume.

For cross tariff responses, since N_c and N_v are clearly substitutes by (5), we expect $\partial N^*\ \partial\theta_j < 0$ for $i \neq j$. Similarly, an increase in the

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expected network access of one smartphone should reduce airtime demand on the other. Under risk neutrality, and without constraints on subscribers and network resources or access to credit, tariff shocks and airtime shocks (representing factor-neutral technical progress) should dominate the explanations of airtime to smartphones.

Risk-aversion will bring new variables into play and will also alter the above predictions. Under risk-neutrality we expect airtime consumption by smartphone to be invariant to own tariff and airtime variability. Under risk aversion, the signs associated with own variance will be unambiguously negative.[3] For a positive data bundle tariff or airtime volume shock, risk-neutral subscribers will expand data bundle by more than risk-averse subscribers, since an increase in data bundle also implies an increase in the variance associated with internet access from data bundle. In general, risk-averse responses to tariff or airtime shocks should be less strong than risk-neutral responses. Since data bundle prices and airtime volumes are rather stable, however, $\partial N_c^{*}\partial\theta_c >$ 0 should continue to hold under risk aversion.

The same reasoning holds for voice calls, although empirically, voice call tariff and consumption are both more volatile than data bundle, so we expect that small increases in expected price/tariff or expected airtime volume may elicit very small (or even zero) responses among risk-averse subscribers.

Exogenous changes in variances may have more measurable effects. An interesting feature of our empirical sample is that some subscribers avoid voice calls on smartphones, only data transaction. Though the model presented above does not fully explain such specialization, it can provide insights into why some subscribers might be reluctant to change to voice only. A corner solution (using only one smartphone) implies discontinuity in the response function; only a sizable jump in the expected voice call tariff relative to data bundle (or equivalent shifts in relative access to the network) will provide sufficient incentives to diversify. Once again, if variances are the subject of exogenous shocks through tariff policy or technological innovation, then risk-averse subscribers might find it advantageous to make non-marginal changes in their data bundle portfolios.

Finally, we note the role of airtime and subscriber budget constraints. The model permits airtime build up by subscribers at the beginning of each period. This airtime can only be acquired at some cost, however. This might be the cost of preparing data bundle, or of establishing a potential bundle reservoir. The nature of these costs directly implies that family airtime availability is likely to be a binding constraint on the acquisition of new airtime, and a reduction in family airtime availability may cause the size of the data bundle to contract.

Family airtime and bundle constraints should also operate differently between smartphone. Voice calls are considerably more management-intensive than data bundle, so whereas data bundle consumption can be expanded by acquiring more airtime (given subscribers), the same may not be true of voice calls. Conversely, relaxing the subscriber budget constraint (given family airtime) should expand data bundle, but may have to leave voice consumption unchanged if the household cannot provide matching managerial resources. The presence of airtime and subscriber budget constraints indicates a short-run model. Empirically, if these constraints are found to bind, then we can draw inferences about the incentives for subscribers to take steps to relax them, following a shock of a given kind.

Data and econometric method

Our model implies the following equations for econometric estimation:

$$N_c^{*} = (N_c\,\theta_i, \varphi_{i2}, {}_i, \sigma_{i2}, \mathbf{W}, A_{-1}, F, \mathbf{Z}_N)\text{i} = \text{c, v} \quad (19)$$

$$N_v^{*} = (N_v\,\theta_i, \varphi_{i2}, {}_i, \sigma_{i2}, \mathbf{W}, A_{-1}, F, \mathbf{Z}_N)\text{i} = \text{c, v} \quad (20)$$

$$\Delta A_v^{*} = (\Delta A_v\,\theta_i, \varphi_{i2}, \mu_i, \sigma_{i2}, \mathbf{W}, A_{-1}, F, \mathbf{Z}_A)\text{i} = \text{c, v} \quad (21)$$

Where N_c is airtime allocated to data bundle, N_v is airtime allocated to voice calls, and ΔA is the month-on-month change in total airtime. To the set of exogenous variables in each equation we add a vector $\mathbf{Z}_i$ of subscriber-specific variables that might serve as additional constraints on airtime use behavior. For all equations, we include a variable representing quality of network; this takes several values ranging from low quality to high quality. We also include a binary "borrow-me credit constraint" variable. This takes a value of 1 if the subscriber reported either not subscribing to data bundle, or altering total airtime, because he was unable to obtain borrow-me credit (or if he reported being constrained in other ways readily capable of the same interpretation). For the total airtime change equation, we also include dummy variables for other reported reasons for changes, notably contractual reasons (such as Terms and Conditions).

Data are drawn from three month surveys of consumption, household, cybernomic characteristics of a sample of 85 subscribers in Abuja and Lagos state. Tables 1 and 2 provide brief summaries. The data provide direct observations of airtime use, technology, input use, consumption, and subscriber and household characteristics. Variables representing expected tariff and their variances were constructed from a separate survey of subscribers. Variables representing expected access to network and their variances were constructed from the predicted values and residuals of consumption functions fitted to the data (Appendix).

The system (19) - (21) is a reduced form in which individual equations explain the allocation of airtime between voice and data bundle change in terms of the exogenous variables of the model presented earlier. Because the equations contain lagged values we use only data from the second and third months in estimation. We construct subscriber-level Smartphone use, airtime and subscriber characteristics variables by aggregation. In estimation, a practical problem arises due to lack of variation in incomes; this requires that we exclude income from the set of explanatory variables used in estimation. For Cell phone

Occupation type	10-20%		20-40%		40-90%	
	Abuja	Lagos	Abuja	Lagos	Abuja	Lagos
Worker's (Public)	69.5	38.9	88.3	59.9	91.7	57.3
Worker's (Private)	43.7	47	51.8	52.4	41.6	40.1
Traders/Artisans						
Services	30.0	31.1	56.2	22.7	30.9	32.5
Food	40.0	52.1	31.2	51.7	61.4	50.9
Small scale Manufacturing	37.6	41.8	43.4	33.1	41.9	37.0

Source: Field Survey, 2014

Table 1: Subscribers assessment by slope (10% and greater), Abuja and Lagos.

Variable	Units	Mean	Std Dev.
No of Adult Subscriber in Household		4.16	3.055
Total Number of Subscribers		7.69	3.772
Average Calls/Month	N/m	16.82	0.932
Average Data Usage/Month	N/m	640.332	0.426
DATA			
Airtime Price/Second	N/s	0.58	2.593
Variance of Price		0.336	0.140
Duration of Access	Seconds	637,836	0.156
Access variability		8.225	0.6983
CALLS			
Airtime Price/Second	N/s	0.936	1.686
Variance of Price		4.499	2.825
Duration of Access	Seconds	2787.6	3278.6
Access variability		7.267	4.171

Table 2: Subscriber level summary.

battery life, the difficulty of variation, and of aggregating these across different CPBL, precludes their inclusion in the estimation.

Results

Estimated OLS coefficients of (19) - (21) are reported in Tables 3 and 4 summarizes these in elasticity form. Most coefficients exhibit the expected signs but, overall, the efficiency of the estimates is low. This may be due to genuinely weak economic relationships or to the fact that data are measured with error, as is typical in studies of this kind. Moreover, we find a high degree of correlation between the expected yield variables (r=0.96).

In the regressions in which smartphone serves as dependent variable, estimated responses to own prices are positive and estimated responses to cross-prices are negative. Input prices also exhibit the expected signs: data bundle tariff declines when the generator price rises, and a higher cell phone battery life, which is used most intensively on voice calls, reduces voice call airtime.

However, none of the smartphones prices, and only the two input prices just mentioned, have statistically significant relationships with the dependent variables. More explanatory power resides with the variables indicating risk aversion. Airtime changes are negatively correlated with increases in own-price variances, and are positively correlated with increases in cross-price variances. Airtime changes are also negatively correlated with increases in the variability of access to network, and are positively correlated with increases in cross-network access variability. These results, which are statistically robust, are consistent with a hypothesis of risk-aversion on the part of sample subscribers. The elasticity measures in Table 4 show that changes in the riskiness of data bundle are more important than changes in the riskiness of voice calls both for data and voice calls decisions. Network and data bundle constraints are clearly important overall, and the pattern of statistical significance of coefficient estimates reveals the expected differences between smartphones. Consistent with our expectations, the subscriber budget constraint binds for data bundle, but not for voice calls. If more airtime to be added, it would go mainly into data bundle subscription. Conversely, the number of adults in the household limits the airtime allocated to voice calls, but not to data bundle. These findings accord with our hypothesis that voice call consumption is more intensive in use of the resource use economics at the house hold level best provided by family members. Finally, lack of access to borrow-me credit significantly constrains the airtime volume used for subscribing data bundle.

The third equation captures change in total Airtime Volume. As in the smartphone equations, prices have no measurable effect on the month-on-month airtime volume change. Nor is airtime volume significantly affected by tariff and voice calls/data bundle variability, although we note that increases in the variability of data bundle and tariff and positive associated with growth of the network access, while instability of voice calls has an opposed sign. Subscribers clearly reduce risk through their data bundle portfolios rather than by pulling out of a network completely. The fact that expected tariff, bundle prices, airtime volumes, and other input factors and prices have low explanatory power is perhaps not surprising, given that we are estimating a short-run model.

As expected, increases in pooled family airtime and greater access to borrow-me credit are both correlated with the addition of more lines. The empirical link between borrow-me credit availability and smartphone ownership expansion accords with predictions from a formal intertemporal model of a credit constrained household presented by studies of Eke [9]. These authors have argued that while the effects of borrow-me credit constraints on incentives for indebted subscribers in sampled households to invest in smartphone accessories are ambiguous, it may be rational for severely indebted households

Variable	Sampled Subscribers Data (S^D)	Sampled Subscribers Calls (S^C)	Net Subscriber Difference
Data Tariff	0.0613 (0.428)	-1.5352 (-2.736)[a]	-0.0110 (-0.314)
Call Tariff	-0.064 (-0.479)	1.3821 (2.664)[a]	-0.0353 (-1.101)
Data Volume	0.0006 (0.006)	0.4382 (1.183)	-0.0754 (-3.261)[a]
Call Volume	-0.0761 (-1.575)	0.5484 (3.475)[a]	-1.2401 (-2.997)[a]
Variance of Data Tariff	0.0581 (1.329)	-0.3060 (-2.09)[b]	-1.0684 (-2.736)[a]
Variance of Call Tariff	0.0049 (0.161)	-0.0259 (-0.248)	-2.9051 (-10.12)[a]
Data Access Variability	-0.1425 (-0.452)	-0.0752 (-3.407)[a]	-1.9076 (-6.516)[a]
Call Access Variability	0.1601 (0.5434)	-0.0060 (-0.350)	0.3740 (0.788)
Access to Generator	0.2688 (1.312)	0.0167 (1.371)	1.2537 (1.756)[c]
Lagged Subscriber	0.2391 (0.516)	0.0473 (1.127)	0.3112 (0.5699)
Price of Generator	0.1500 (0.3524)	-0.1856 (-4.923)	0.6514 (0.202)
Lagged Subscriber	-0.3347 (-1.171)	-0.4894 (-1.774)	-1.2614 (-0.421)
Adult Subscribers	-2.1229 (-1.406)	0.3233 (11.661)	1.3975 (0.659)
Number of SIM per smartphone	0.7136 (0.500)	-0.1572 (-0.560)	0.0581 (1.329)
Borrow-me Credit constraint	-0.8154 (-0.812)	-0.1392 (-5.166)	0.0049 (0.161)
Terms and Conditions constraints	0.1599 (1.936)[c]	-0.0003 (0.007)	0.3233 (11.661)
Other constraint	-0.0877 (-1.126)	0.1088 (2.649)[a]	-0.1572 (-0.560)
Constant	0.0439 (0.803)	0.1500 (5.090)[a]	0.1599 (1.936)[c]
R^2 Adj	0.612	0.304	0.645
OBS	158	162	170

T-statistics in parentheses. Superscripts a, b, and c indicate significance at 1%, 5% and 10% respectively

Table 3: Estimated smartphone and subscriber response functions.

Variables	Data Subscribers	Call Subscribers	Net Subscriber difference
Expected Data Tariff	0.3769	-0.7607	0.0089
Expected Call Tariff	-0.6600	0.9789	0.1124
Expected Network Access	-0.1382	0.3016	0.6817
Variance of Data Tariff	0.2320	0.2826	-0.8489
Variance of Call Tariff	-1.3120	0.8564	-1.3173
Call Network Access Variability	0.6983[c]	-0.7432	0.5005
Data Network Access Variability	-1.4896[a]	2.6042[a]	1.1114
Access to Phone Charging Points	0.5321[a]	-0.5766[b]	-0.0657
Price of Generator	-0.9027[a]	-0.1407	0.5240
Total Subscribers	0.4898	-3.7306[a]	-1.3240[c]
Adult subscribers	0.9921[a]	-0.0937	-1.1171[a]
Average number of SIM per phone	0.0010	0.7002[a]	1.2998[a]
Airtime Borrow-me credit	-0.0370	-0.2297	-0.6616[a]
Terms and Conditions	-0.5564[a]	-0.0931[a]	-0.3407[a]
Others	--	--	-0.1678[a]

T-statistics in parentheses. Superscripts a, b, and c indicate significance at 1%, 5% and 10% respectively

Table 4: Estimated elasticities of smartphone and subscriber response functions.

to downgrade to voice calls only at a greater rate when liquidity is increased.

Implications for policy and environmental outcomes

Our results provide some basis for speculation as to the effects of tariff/airtime/data bundle policy changes on incentives for smartphone acquisition. Our goal in this section is to assess the influence of GSM Network Company policy-driven exogenous changes in bundle prices/tariff, airtime volume discounts, and variances on smartphone acquisition bearing in mind that the degree of statistical confidence of some of our results is rather low. Given the rather limited number of empirical studies on this subject matter, we see value in linking our econometric evidence to the policy atmosphere in which the fate of GSM companies, GSM smartphone vendors and assemblers, is decided.

From a policy perspective, the pronounced pattern of risk averting behavior observed among the sample subscribers is of great importance. In the short run, it appears that subscribers alter their smartphone acquisition more or less predictably, in line with changes in expected prices and tariff. But more significantly, we find that subscribers will switch network access among smartphones so as to avoid the uncertainty associated with income volatility, especially as driven by network access variability. This focus on network access risk, more than price/tariff risk, appears to be the main expression of risk aversion in the sample. Furthermore, our estimates of changes in data subscription indicate a savings-first motive among subscribers: increases in the volatility of data bundle induce subscribers to expand network access time size, while higher voice volatility, if it has any effect at all, reduces incentives to expand smartphones. These results accord with findings from other publications where subscribers appear to take into account risk considerations both when choosing between smartphones [11] and when undertaking investments in data bundle accessories Taken together, the main policy message behind these findings is that policies that reduce economic risks are likely to be environmentally favorable: resource "overuse" is, in part, insurance against loss.

We now return to our earlier discussion of price/tariff and telecommunication technology, in light of these results. Recall that the most important policies, from the perspective of smartphone users, are those that protect or encourage consumption of stable network access and those that seek solutions to more offerings online.

For data bundle consumption, our results suggest that policies to support and stabilize prices/tariff (e.g. Through import substitution/ restrictions) have little short-run effect on smartphone? Technical progress aimed at reducing the variability in data bundle, in contrast, will raise the share of smartphone with data bundle flexibilities options. In other words, improving the stability of internet networks may be sufficient to discourage more smartphone acquisition per subscriber, even if expected incomes do not rise. For voice calls, tariff discounts and price stabilization will also increase in the number subscribers will spike the demand for smartphones. Technical progress that reduces the volatility of voice call network will result in a marked subscriber substitution towards voice calls services, but again we would expect little impact at the extensive margin. This is because in the short run expansion of airtime and network access remains constrained by access to borrow-I credit and by the availability of the special smartphone skills and attention brought to subscribers and smartphone by family members. These latter findings draw attention to some potentially relevant interactions among economic and smartphone telecommunication technology policies as they affect use. First, much investment by subscribers using smartphones in data bundle and voice calls is driven by the perception that constant access to the internet generates potentially high utility. We have seen, however, that much of this perception is due to the tariff dynamics, particularly those reflecting huge bundle discounts. For IPAD users, which are classified as a "high-value" and thus targeted for additional research, current consumption might be non-existent, if not for survey samples [12].

However, having been brought into existence by economic policies, the GSM voice call industry could be rendered viable even at free tariff by sufficiently large shifts in the consumption function (including reductions in network quality crisis). Similarly, the widespread replacement of non - smartphones by smartphones a pronounced shift to permanent online presence subjected to bundle constraints can be attributed both to subscriber policy preference and to the effects of R&D and development investments in smartphone.

Finally, Nigeria's NCC broader policy context of ICT development, coupled with continuing pressure of population can largely be explained by reference to past policies that failed to set the country on a path of stable network aggregate growth and local content-intensive industrialization. Policy reforms in the 1990s in the multifaceted ICT-specific areas such as ICT-centric trade, finance and banking, and macroeconomic management, have contributed over the years to raising the growth rate of GDP; over time, the reorientation of the Nigerian economy thru the recent rebasing can be expected to raise the opportunity cost of voice calls. This will diminish incentives to expand network access in spite of technical progress in ICT. Of course growth outside ICT, especially growth in the manufacturing sector, petro-chemical sector, services sector, etc. is likely to generate other sets of concerns. Nevertheless, it seems clear that a realignment of economic incentives could reduce demand for innovations in non-smartphones, and might in turn reduce the number of subscribers seeking such phones, with the long-run result that non-smartphones will simply loose its demand in the market (Tables 1-4) [13,14].

Appendix: Data and the Construction of Variables

Most data used in this study were reported directly by smartphone subscribers' interviews in Lagos and Abuja in 2013. Some variables, however, was either missing from the data sets or required external information? These include expected smartphone price and price variances and smartphone preference variances. Other variables, such as expected smartphone variances, were inferred from the data by methods described below.

Expected smartphone price

Expected smartphone prices are constructed from a 3-monthly weekly price series collected at several marketing points in Lagos and Abuja. We use these series to predict prices of each smartphone for the month.

We assume that smartphone, call and data prices follow an AR (1) process,

$$P_{t+1} = P_t + D + e, \text{ where D is a seasonal dummy.} \tag{A1}$$

We further assume that subscribers base their decision on expected prices/tariff. For example, the average innovation spans three weeks. If the subscriber makes the decision of how much airtime to subscribe, he or she forecasts the prices favorable and can be written:

$$E(P_{C\,t+4}) = \eta_C P_t + D_C \tag{A2}$$

$$E(P_{t+2\,V}) = \eta_V P_{tV} + D_V \tag{A3}$$

Combining (A1) with (A2) and (A3), the forecast function for Smartphone, Call and Data prices is:

$$E\,(P_{t+4}) = \lambda_C\,)_4 P_{t\,C} + [1 + \lambda_C + \lambda(_C)_2 + \lambda(_C\,)_3] D_C \tag{A4}$$

$$E(P_{t+2\,V}) = (\lambda^V)_4\, P_{t\,V} + [1 + \lambda_V] D_V \tag{A5}$$

Price variances

We hypothesize that subscribers are risk averse, and therefore expect that the perceived variance of prices may have an impact on allocation decisions. Variance forecasts for prices are constructed in the following way. Suppose that subscriber makes the decision of how much airtime for call or data in time *t*. We assume the subscriber's information set includes the price history to time *t*, and use this price history to calculate the subscribers' perceived price variance at time *t* using the regression residual from the expected price regression.

Expected smartphone, and network performance

We estimate expected performance from production functions (Table A-1) fitted to the subscriber-level data consumption and input data (Table A-2). We then aggregate these subscriber-level data to the network-level. Many Network-specific, idiosyncratic and covariate factors contribute to performance variability. Unfortunately, we have little information from which to construct *ex ante* predictions of performance variability. We use the absolute value of the residual of the consumption function as a measure of variability. We assert that subscriber-level performance variability is positively related to slope, and negatively related to the adoption of smartphone battery and network access charges conservation practices such as logging off and logging onto the web as the need arises. We thus constructed subscriber-level performance variances as the absolute value of the predictions from the regression:

$$\sigma = \beta_0 + \beta_{1*}\text{SLOPE} + \beta_{2*}(\text{SLOPE}^*\text{CONS}) + \beta_{3*}\text{SMARTP} + \beta_{4*}\text{DATA} + \beta_{5*}\text{CALL} + \beta_{6*}\text{LOCA} \tag{A6}$$

Where SLOPE takes values of 0 for first generation smartphones, 0.15 for second generation smartphone, and 0.35 for third generation smartphone, and CONS is a dummy with a value of 1 when subscribers report any bundle conservation practices (Tables A-1 and A-2).

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