The Economic Impact of Telecommunications in Senegal (*)

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Abstract: While the economic impact of telecommunications has attracted the focus of attention of research in the past, the area of sub-Saharan Africa has only recently become the subject of inquiry. Furthermore, the study of the region represents a case study by itself. Socio-economic parameters like economic stability and growth, compulsory education, access to basic services, rule of law and control of corruption shape an unpredictable environment and certainly affect the impact that wireless and broadband may have. Additionally, embryonic fixed line networks, limited banking facilities and patchy transport links may have an accentuated impact on the development and use of digital networks. In this paper a unique country-level sample was assembled for Senegal for the period 2004-2011 in order to measure the effect of wireless and broadband on the economic growth of the country. Our preliminary results suggest that mobile phones have a measurable impact on economic growth and lie within the estimates of previous work on a much larger scale. On the other hand, the economic effect of broadband cannot be measured yet because the technology is at its very early stages of adoption. However, the rapid growth of third generation services during 2011 suggests a transformation in this type of network access, which might result in important economic effects in the future.

Key words: broadband, economy, Senegal, ICT.

The transformation of ICT's during the last thirty years has led social scientists and policy makers to analyse the direct and indirect impact on economic development (see, for example, MADDEN & SAVAGE, 1998; MARSCH, 1976; NORTON, 1992; SCHAPIRO, 1976). The changing nature of the underlying infrastructure capabilities, services and usage has introduced unprecedented degrees of complexity in finding the right measurement approach for these techno-economic

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phenomena. ICT's have been found to affect economic prosperity, employment creation and substitution, as well as social welfare.

Until recently, the primary statistical approach to test the economic contribution of ICT has been based on the study of cross-sectional samples of countries. Due to limitations on data availability, the primary emphasis had been on OECD countries (facilitated by the extensive Eurostat data sets) or worldwide analysis (based on ITU statistical indicators). While this approach is continuing to be pursued (KOUTROUMPIS, 2009; WAVERMAN, 2009; KATZ, 2012), researchers are starting to focus their assessments on country-level studies acknowledging the location related specificities.

The following study focuses on assessing the economic impact of telecommunications in Senegal. It attempts to analyse the relative impact of wireless and broadband communications in a country setting that differs substantially from the primary focus of existing ICT impact research. The measureable economic impact of ICT infrastructure depends heavily on the introduction timing, existing adoption conditions and market maturity. As studies of the lagged impact of ICT have demonstrated (HARDY, 1980; JORGENSON *et al*., 2007; KARNER & ONYEJI, 2007), significant economic effects of ICT do not materialize immediately after the introduction of a new technology.

Mobile voice services represent a mature market that has affected the evolution of the Senegalese economy during 2004-2011 and is now used by the majority of the population. A structural model, relying on four equations that model the market operation was applied in this case. This approach takes into account the endogenous growth from existing capital and labour, together with the ICT infrastructural metrics; the demand for telecommunications services depending on the price and adoption patterns; the supply and competition of telecommunications taking into account the regulatory and infrastructural investments in ICT and last, the revenues and outputs of the telecoms market as a proxy for the 'health' and sustainability of the market.

The Internet/Broadband market has, so far, relied on fixed infrastructure and was relatively dormant during the same period. ADSL still has a limited audience while 3G, as a wireless broadband platform, has just recently (2011) been launched. The broadband economic impact is assessed through a structural model similar to the wireless one.

This study begins by providing a brief review of the research literature regarding the impact of telecommunications on the economy. In the section after, a view of the primary features of the Senegalese telecommunications market is presented. The review of the literature provides a context for the development of the approach utilized in this study. Having laid out the methodology that was followed, the results of the study are presented and discussed in the following section. The implications from a public policy standpoint are drawn in the Conclusion.

■ Background

The economic impact of mobile telephony

Assessing the macroeconomic effects from the deployment and adoption of new technologies is particularly important but their direct effects on everyday life are usually the tangible metrics for their value and use. Mobile phones affect all economies as they provide a platform with communication mobility attributes that either enhance and support innovation driven economies or substitute the lack of traditional fixed-line channels in the developing world.

There is ample support for the effects of mobile communication in regional emerging countries. More informed markets and agents perform more efficiently, are better coordinated and improve consumer welfare. These effects are permanent and not one-time gains as mobile infrastructure becomes a permanent fixture of market economies. An example is the fishery market of Kerala that experienced incredible changes after the introduction of mobile telephony. Prices decreased substantially, waste was eliminated and the fishing sector became a lot more informed and demand-driven (JENSEN, 2007). Similarly, the grain market in Niger experienced significant behavioral and consumer/trader welfare improvements. AKER (2010) estimates that, in this case, mean prices fell over 4.5% and well organised markets led to profit increases as well. Another micro-level analysis points to the effects of mobile coverage on market participation of banana farmers in Uganda (MUTO, 2008). The existence of mobile coverage and not the possesion of mobiles per se, had significant effects on the remote farmers that produce perishable crops as it significantly reduced the cost of crop marketing.

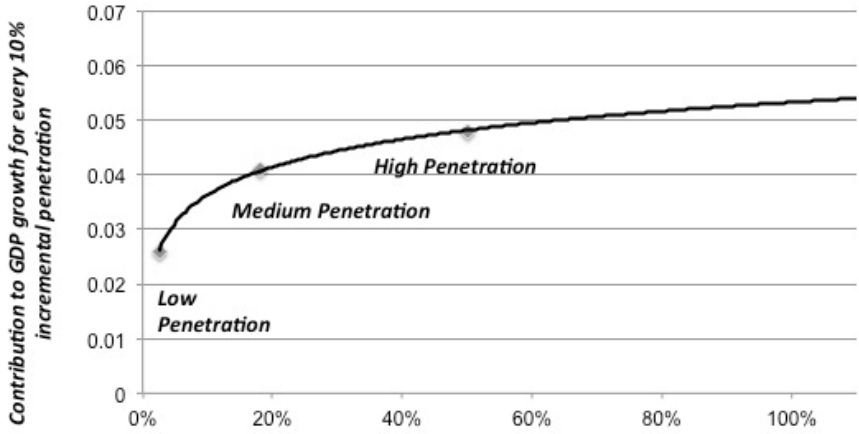
Apart from the basic communication services, mobile networks offer the necessary platform to launch innovative services. In certain cases, these services increase the capacity of existing business chanels (retail stores, geolocation, transport services) while in others, they tackle the lack of access to traditional services. A classic example is the lauch of financial services and micropayments through mobile networks in Kenya and Tanzania. In these countries, the rudimentary physical banking network was quickly substituted by cashless transactions with 'airtime' trading dramatically reducing the cost of service delivery and transaction burdens. This led to the rapid adoption of basic financial transactions services by millions of 'unbanked' population.

Mobile infrastructures have significant effects on the creation of new markets and services, hence reducing unemployment and openness of the economy. The vast substitution taking place through the transition to digital economies suggests a potential transfer of labour force rather than creation. However the net gains from the launch of new services, improvements in everyday life, increase of target audience and drop in transaction costs are expected to reduce unemployment rates. For example, KLONNER & NOLEN (2010) determined in their South African study that employment tends to increase substantially when a locality receives wireless network coverage. In another study, BATZILLIS *et al*. (2010) found that wireless coverage is linked to increased female labor participation in Malawi.

These multiple effects of mobile telephony on the economy appear to be characterised by a return to scale, whereby increased penetration tends to enhance the economic impact. According to the "return to scale" effect, the impact of wireless telecommunications on economic output is maximized once the infrastructure reaches a critical mass point, generally associated with levels of penetration of developed countries. As a result, we initially observe increasing returns to growth (see ROLLER & WAVERMAN, 2001; WAVERMAN, MESCHI & FUSS, 2005; SHIU & LAM, 2008; KATHURIA, UPPAL & MAMTA, 2009; ANDRIANAIVO & KPODRA, 2011). This effect was also validated by GRUBER & KOUTROUMPIS (2011) for a global sample for the period 1990-2007 (see figure 1).

As figure 1 indicates, the magnitude of the contribution of mobile telephony to GDP growth increases with wireless penetration, although effects tend to subside beyond penetration levels of 60%.

Figure 1 - Wireless Telephony contribution to growth versus wireless penetration



Source: GRUBER & KOUTROUMPIS (2011)

The impact of broadband

Broadband contributes to economic growth initially by producing a series of effects similar to those generated by infrastructure deployment. Beyond the benefits for GDP growth, it also has significant economic impact on consumer surplus. Some of these effects - such as the impact of investment on infrastructure - have been estimated quantitatively through input-output analyses (KATZ *et al*., 2009a; KATZ *et al*., 2010). Others, such as the impact on productivity growth and the elasticity of supply, as well as the multipliers of household income, require econometric models and have only recently attracted the attention of policy makers and researchers in the field.

Research in developed countries has begun to generate evidence of causality between broadband and growth coupled with the network effects the infrastructure can have on business productivity. Using data from OECD countries, two studies have evaluated the impact of broadband on GDP growth. They first analysed this impact in 25 OECD countries between 1996 and 2007 (CZERNICH *et al*., 2011). The authors estimated that a 10 percentage point increase of broadband adoption - using fitted adoption curves, rather than the actual adoption - was responsible for a rise in per capita GDP, between 0.9% - 1.5%. KOUTROUMPIS (2009) built a structural model that controls for reverse causality and used the broadband adoption metrics for 22 OECD countries over the period 2002-2007. Again, the results

indicated that there is a statistically significant relationship between broadband infrastructure and growth. The author also determined that broadband's contribution to GDP growth increases with its diffusion due to network effects: in countries with low penetration rates (less than 20%), a 10 percentage point increase leads to a 0.7% GDP growth; in countries with an average degree of penetration (between 20% and 30%), the effect is 0.8%; while in countries with high penetration rates (over 30%), the impact on GDP growth rate is almost 1%. A list of similar studies is presented in table 1.

Table 1 - Recent research regarding the impact of broadband on growth

Country/Region	*Study*	*Data*	*Impact*
United States	CRANDALL *et al*. (2007)	48 states in the United States, 2003-2005	No statistically significant impact on GDP growth
OECD	CZERNICH *et al*. (2009)	25 OECD countries, 1996-2007	10 percentage points increase in Broadband adoption leads to GDP growth between 0.9 % and 1.5%
	KOUTROUMPIS (2009)	22 OECD countries, 2002-2007	A 10 percentage point increase in broadband penetration produced between 0.7% and 1% increase in GDP growth
Germany	KATZ *et al.* (2010)	424 counties in Germany, 2000-2006	A 10% increase in broadband penetration produced a 0.255% increase in GDP growth
Arab States	KATZ (2012)	17 countries in the Arab world, 2004-2010	A 10% increase in broadband penetration produced a 0.208% increase in GDP growth
Developed countries	QIANG *et al*. (2009)	Developed counties from a sampling of 120 countries, 1980-2002	A 10% increase in broadband penetration produced a 1.21% increase in GDP growth
Low- and middle-income countries	QIANG *et al*. (2009)	Remaining countries (low- and middle-income developing economies) from a sampling of 120 countries, 1980-2002	A 10% increase in broadband penetration contributed 1.38% to economic growth

Beyond the impact on economic growth, researchers have also studied the subsequent effects of network externalities on employment variously categorized as "innovation", or "network effects" (ATKINSON *et al.*, 2009). The study of network externalities resulting from broadband penetration has

led to the identification of numerous effects including new and innovative applications and services, such as telemedicine, Internet search, e commerce, online education and social networking (ATKINSON *et al.*, 2009). Additionally new forms of commerce and financial intermediation have been introduced coupled with a mass customization of products (ATKINSON *et al.*, 2009). Subsequent effects include the reduction of excess inventories and the optimization of supply chains (ATKINSON *et al.*, 2009), business revenue growth (VARIAN *et al*., 2002; GILLETT *et al*., 2006) and the impressive growth in service industries (CRANDALL *et al*., 2007). In sum, a review of the research on the economic impact of broadband indicates multiple effects. The evidence is fairly conclusive about the contribution of broadband to GDP growth. While the amount of this contribution varies, the discrepancies can be related to different datasets as well as model specifications. In addition, the research has been successful in identifying the existence of a critical mass, indicating the existence of increasing economic returns of broadband penetration. We will now turn to reviewing the main features of the Senegalese economy in order to measure the impact of telecommunications.

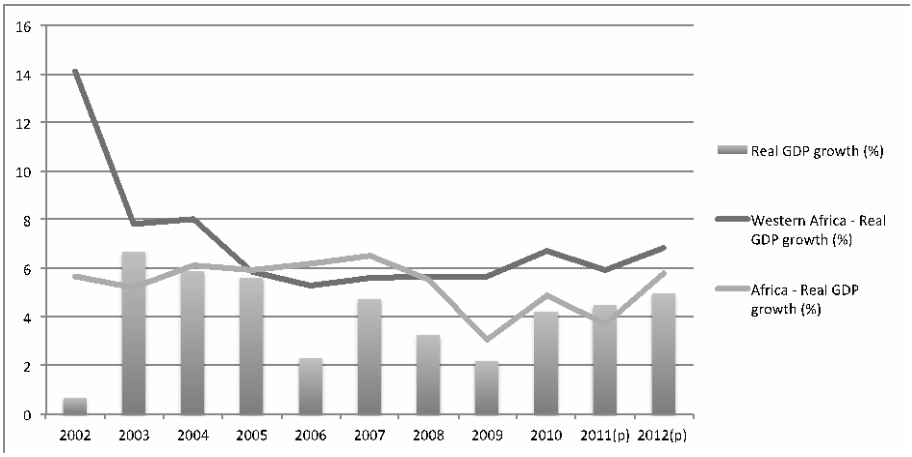
■ The Senegalese economy

Senegal is primarily a rural nation with limited natural resources located on the westernmost point of Africa. Its key export industries are commercial fishing, phosphate mining, and fertilizer production. Iron ore and oil exploration projects also contribute to the gross domestic product as well as tourism, services and peanut production. Its economy depends on rainfall variations, which combined with a lack of strong monetary policy make Senegal vulnerable to changes in world commodity prices. Senegal also relies heavily on donor assistance, representing almost a quarter of its government spending in 2007 [1].

The Senegalese economy suffered the repercussions of the global recession more than its West African neighbours in the region of Western Africa during 2008 and 2009 but overall it remained aligned with the average growth figures and forecasts across the continent. In particular, the real GDP growth of the Western Africa region has remained fairly stable (around 6% year-on-year) since 2005 after a sharp drop in 2003 (see figure 2).

[1] Source: *CIA Fact book*, US State Department.

Figure 2 - Real GDP growth in Senegal, West Africa and Africa, adapted from *Africa Economic Outlook 2011*, IMF



In light of this macro-economic analysis, telecommunications could play a significant role in contributing to the development of the Senegalese economy. Based on the economic impact analysis highlighted in chapter 2, efficient and affordable telecommunications could improve the performance of fishing, as the leading export industry. Similarly, broadband could enhance the efficiency of the tourism sector, while mobile telecommunications and broadband could foster social and financial inclusion of wide portions of marginalized population

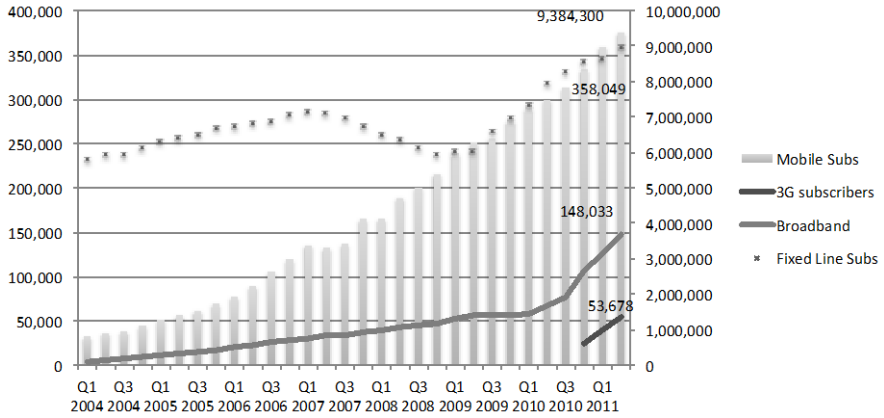
■ The telecommunications industry in Senegal

Telecommunications demand

The Telecommunications sector has grown rapidly during the last fifteen years in Senegal primarily owing to the adoption of mobile telephony (see figure 3). However, in addition to the dramatic increase in wireless subscribership, fixed lines have also increased since 2008. Fixed lines experienced a very slow rate of adoption before 2007 reaching 286,000 lines. Significant substitution effects took place after the quick adoption of mobile services resulting in 21% drop in fixed line services during 2007-2009. This three-year drop in fixed line subscribers lasted until the second

quarter of 2009. A steep rise in the demand of ADSL lines after 2009 has turned this trend, reaching an all time high in 2011 (358,000 lines).

Figure 3 - Mobile, Fixed-line, Broadband and 3G subscribers in Senegal



Source: ARTP Senegal

Fixed line networks have been thin on the ground for a long time in Senegal. The rapid take off of mobile services was achieved due to the technology's capacity to tackle the chronic problems that kept fixed networks on the ground: high connection fees and recurrent monthly payments that are largely unsuitable for the vast majority of sub-Saharan African subscribers. In particular, the launch of prepaid mobile schemes, with relatively low connection fees [2] and 'a la carte' micro payments [3] led this communications revolution.

This phenomenon of simultaneous growth of both technologies indicates an industry context of a market searching for any possibility to meet its needs through either technology. While the growth rate in mobile telephony is dramatically higher than wireless, the Senegalese market exhibits less of a technology substitution dynamic as that which can be seen in other emerging countries [4].

Mobile subscribers exceeded 9.3 million in 2011, reaching 74.94%, thereby representing the most popular telecommunications platform in

[2] Less than the local currency equivalent of $2.

[3] A simple 'top up' starts at the local currency equivalent of $0.25.

[4] See the example of Latin American countries.

Senegal. The growth rate and the net additions per quarter continued to rise throughout 2010 and 2011. Senegal has remained above the West Africa average mobile penetration (54.3% in 2010) and ranks 7th behind Gambia, Cape Verde, Mauritania, Benin, Cote d'Ivoire and Ghana.

The vast majority (99.4%) of Senegalese mobile subscribers use prepaid services and only 60,000 have contracts. In terms of technology, 99.4% of the subscribers use second-generation services (GSM) with 54,000 lines connected to 3G networks.

Since the beginning of 2010, broadband, both through wireline and wireless technologies, has also been increasing at a growth rate similar to that of mobile telephony. However, the broadband market is still in its infancy with a combined (fixed and mobile) subscriber penetration now at 1.50%. Occasional internet users in Senegal exceed 923,000 but this is not reflected in the subsctription metrics [5]. The main reason is that Senegal is home to more than 4,000 telecenters that allow communal access to basic services like telephony, internet browsing, fax, printing, etc.

The main forms of fixed line broadband have been the simple PSTN (dial-up) services and now ADSL. Broadband penetration now accounts for 0.75% having experienced almost twice the demand and net additions per quarter after 2010. Wireline penetration is 0.3% penetration (Q2 2011) and continues to decrease. The most significant boost in the Senegalese broadband market has been the deployment and launch of 3G networks that now account for almost one third of broadband connections. Their adoption is so dynamic, that it is forecast in Q4 2012 they will represent 81% of the broadband market.

Telecommunications supply

From an industry structure, the mobile market was still a monopoly of the local incumbent - Sonatel, now Orange Senegal - until 1999 when a second operator - Tigo - entered. In 2009, Expresso, the third operator started to provide services in the Senegalese market. The local regulator, Agence de Regulation des Telecoms et Postes (ARTP), has yet to apply number portability mandates. The market is still primarily controlled by Sonatel

[5] Local operators have indicated that frequent users of the Internet through telecenters exceed the actual subscribers of ADSL networks by a factor of 10.

(60.41% in 2010) while Tigo has 27.96% of the customer base, and Expresso the remaining 11.63% (table 2).

Table 2 - Subscriber market shares across telecommunications platforms in Senegal (2010)

	Local	*Broadband*	*Wireless*
Sonatel	100%	97.41%	60.41%
Tigo Senegal			27.96%
Others		2.59%	11.63%
Total	100%	100 %	100%

Source: France Telecom

Total Service revenues have seen a seven-fold increase since 2001, now well above 1.4 billion USD. The trend clearly relates to the rise in mobile adoption and usage as well as the subsequent increase in competition and drop in tariffs. Revenues have also been hit by the macroeconomic conditions and food and energy crises in 2008 and 2009 breaking an increasing trend of more than 10 years and leading to a net drop in 2009. Results increased slightly in 2010 but have not yet regained the previous momentum.

■ The economic impact of telecommunications in Senegal

As shown in the literature reviewed above, beyond the direct economic contribution, telecommunications can have a positive contribution to economic growth. This section assesses the positive externalities of telecommunications for the case of Senegal. As anticipated in the introduction, given the different penetration rates exhibited by mobile telephony and broadband, the analysis of economic impact of both technologies will be conducted through a structural econometric model.

Mobile telephony economic impact

In this study a structural econometric model, initially developed by ROLLER & WAVERMAN (2001) for fixed line telephony and later adapted by KOUTROUMPIS (2009) for broadband and GRUBER & KOUTROUMPIS

(2011) for wireless, has been used. In particular, the model consists of four equations: an aggregate production function modelling the operation of the economy and subsequently three demand, supply and output functions. The last three functions model the mobile market operation and, controlling for the reverse effects, the actual impact of the infrastructures is estimated. In the production function, GDP is linked to the fixed stock of capital, excluding ICT infrastructure and labour and the mobile infrastructure proxied by mobile penetration.

The demand function links mobile penetration to the average consumption propensity of individuals proxied by GDP per capita, the cost of a basic mobile service (price of a 3 minute call and a text message) and the competition in the mobile market.

The supply function links the aggregate mobile revenue to mobile price levels, the industry concentration index of the mobile market (HHI) and GDP per capita. These parameters affect potential and existing operators as well as the dynamics of the supply side of the market.

The infrastructure equation links annual change in mobile penetration to mobile revenues, used as a proxy of the capital invested in a country during one year.

The econometric specification of the model is as follows:

Aggregate Production function:

$$GDP_{it} = a_1 K_{it} + a_2 L_{it} + a_3 Mob\_Pen_{it} + \varepsilon_{1it} \quad [1]$$

Demand function:

$$Mob\_Pen_{it} = b_1 MobPr_{it} + b_2 GDPC_{it} + b_3 HHI_{it} + \varepsilon_{2it} \quad [2]$$

Supply function:

$$Mob\_Rev_{it} = c_1 MobPr_{it} + c_2 GDPC_{it} + c_3 HHI_{it} + \varepsilon_{3it} \quad [3]$$

Output function:

$$\Delta Mob\_Pen_{it} = d_1 Mob\_Rev_{it} + \varepsilon_{4it} \quad [4]$$

Based on these models, mobile telephony has been found to significantly affect the Senegalese economy during the last 7 years (2004-2011). The annualized average contribution to the Gross Domestic Product has been estimated to be equal to 0.044% of GDP for every 1% increase of mobile penetration (see table 3).

Table 3 - Results of mobile telephony model

Variables	*Mobile model*
Growth (GDP_{it})	
Labour force (L_{it})	0.416***
Fixed Capital Stock (K_{it})	0.615***
Mob Penetration (Mob_Pen_{it})	0.044*
Constant	-
Demand (Mob_Pen_{it})	
GDPC ($GDPC_{it}$)	0.165
Mob. Price ($MobPr_{it}$)	-5.238***
Market Conc (HHI_{it})	-3.590***
Constant	10.588***
Supply (Mob_Rev_{it})	
Mob Price ($MobPr_{it}$)	-3.122***
GDPC ($GDPC_{it}$)	0.929***
Market Conc (HHI_{it})	0.123
Constant	-3.360***
Output (ΔMob_Pen_{it})	
Mob Revenue (Mob_Rev_{it})	0.867***
Constant	7.150***
Year Effects	YES
Quarter Effects	YES

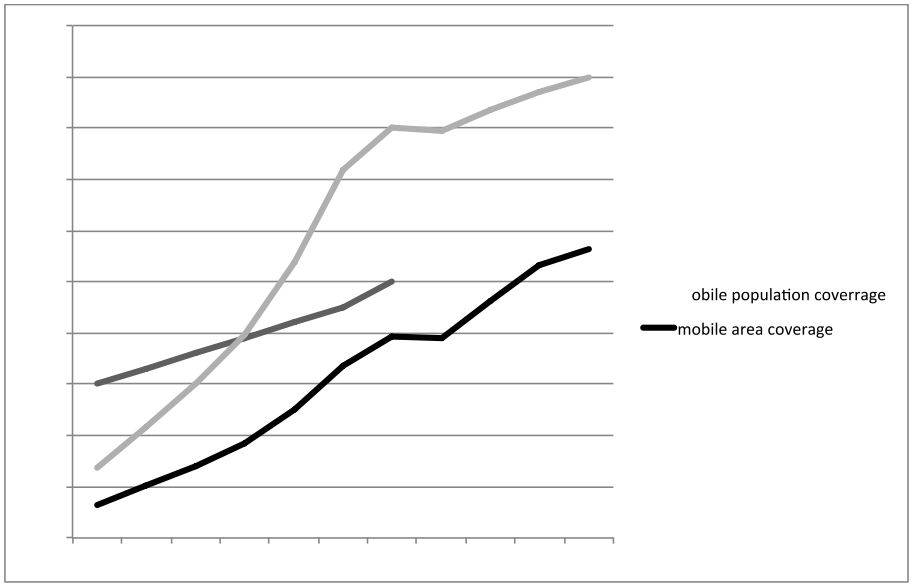
***,**,* denote statistical significance at the 1%, 5% and 10% respectively

The CAGR for Senegal for the period 2004-2011, i.e. the annual contribution on GDP from mobile phones is approximately 0.55% of GDP. Given that the economy grew - on average - at 4.1% during this period, this figure suggests that mobiles alone were responsible for 13.6% of all economic growth in Senegal. Subscribers in Senegal use mobile phones predominantly for voice services. The percent of voice revenue in 2006 was 95% of the industry, although it dropped to 85% in 2010 - primarily due to the large margins over data services. The contribution of voice services to the local economy has acted on two levels: wireless subscribers have quickly surpassed fixed lines and provided the country with a rapid rollout of simpler communications services. This fixed substitution effect is one reason why the returns in Senegal might reflect a catch-up effect too; until 2006, only half of Senegal was covered by a basic fixed access network.

The second level of contribution is mobility. Coordination of everyday activities - business or personal - is much more productive with the added value of mobility. Urban and rural population can use the same platform for an immense diversity of needs only restricted by adequate network coverage. In terms of data services, they are now starting to become an important part of the subscribers' basket. Their impact could be found after a period of incumbation of eGovernement, eHealth, eBanking and other more advanced services (see figure 4).

Looking again at the results, Senegal firmly fits the exponential growth impact curve of GRUBER & KOUTROUMPIS (2011). With a median mobile penetration of approximately 35% in the sample period, the country has a coefficient of 0.044 implying a 0.044% increase in GDP for every 1% increase in mobile penetration. This estimate is only 3% lower than the estimate of the exponential model [6] (see figure 5).

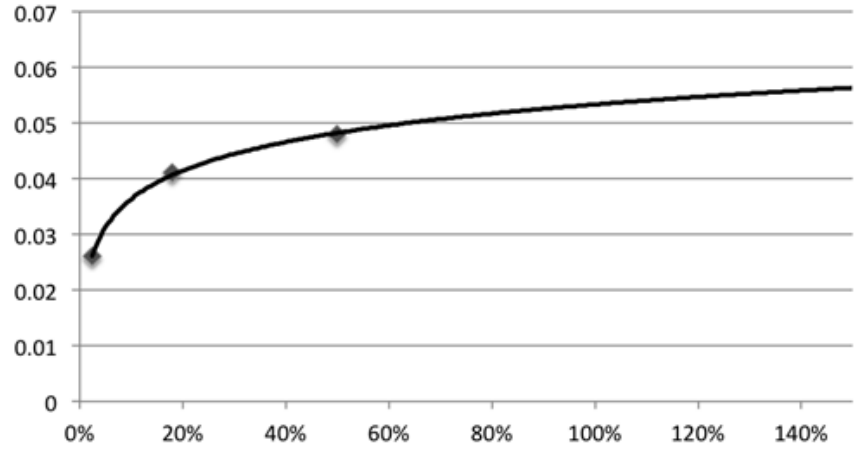
Figure 4 - Fixed and mobile coverage



Source: Sonatel

[6] Estimated value: (0.0074 * ln(0.35)) + 0.0533 = 0.0455, Actual estimate: 0.44.

Figure 5 - Estimate based on fitted line of previous studies (median mobile penetration ~35%) & expected annual effect of mobile penetration on GDP for the period 2004-2016 (median mobile penetration ~61%)



Based on the prior model, we have explored the expected impact of the sector according to industry forecasts. It is estimated that mobile penetration will reach 115% by the end of 2016 suggesting the formation of a saturated market - given the usage of multiple cards per subscriber. This estimate will effectively shift the median mobile penetration for the period of study (2004-2016) to 61.4% and suggests an annual impact from each 1% increment of mobile penetration to contribute slightly more than 0.05% on GDP. This in turn implies that the contribution of mobile telephony on GDP, until 2016 is expected to be 0.62% annually, driven by the higher impact of mobile contribution and the gradually saturating market. [7] Given the IMF projection for the period (2009-2016), GDP is expected to grow at a rate of 4.6% thus implying that mobile networks account for 13.7% of all growth in the country. Market saturation suggests that the effect of mobile adoption growth stagnates during 2015 and the growth effects will be preserved and mitigated to data and broadband platforms.

Broadband economic impact

For the analysis of the impact of broadband on the Senegalese economy a model similar to the mobile telephony structural model was utilized. The model also consists of four equations: an aggregate production function

[7] We estimate the CAGR based on the period 2009-2016 using formula [5].

modelling the operation of the economy and subsequently three demand, supply and output functions. The latter functions model the broadband market operation and estimates the economic impact of broadband, while controlling for the reverse effects.

It is worth emphasizing that the Senegalese broadband market poses some important differences compared to other country-level studies. Part of the population frequently accesses the Internet through telecentres but this is not taken into account in the broadband market model. The reason for this is two-fold. First the contribution of shared ownership to the broadband telecoms market is marginal if it actually exists. Second, shared ownership of any telecommunications connection is possible in many cases but rarely has the impact of the individualized use from the local business or home. Going back to the model, GDP is linked in the production function to the fixed stock of capital excluding ICT infrastructure, labour and the broadband infrastructure proxied by broadband penetration.

The demand function links broadband penetration to the average consumption propensity of individuals proxied by GDP per capita, the cost of a basic ADSL service (price of a monthly subscription), the percent of individuals that fulfil secondary education and the percent of population residing in densely populated urban areas. Education and urbanization are both critical for ADSL networks as these demand significant ICT literacy skills and coverage is usually higher in urban demographic segments. The supply function links the aggregate ADSL revenue to the relevant price levels and the GDP per capita. Due to the quasi-monopolistic nature of the market, there is limited competition. The infrastructure equation links annual change in ADSL penetration to the market revenues, used as a proxy of the capital invested in a country during one year.

The econometric specification of the model is as follows:

Aggregate Production function:

$$GDP_{it} = a_1 K_{it} + a_2 L_{it} + a_3 BB\_Pen_{it} + \varepsilon_{1it} \quad [6]$$

Demand function:

$$BB\_Pen_{it} = b_1 BBPr_{it} + b_2 GDPC_{it} + b_3 Edu_{it} + b_4 Urb_{it} + \varepsilon_{2it} \quad [7]$$

Supply function:

$$BB\_Rev_{it} = c_1 BBPr_{it} + c_2 GDPC_{it} + \varepsilon_{3it} \quad [8]$$

Output function:

$$\Delta BB\_Pen_{it} = d_1 BB\_Rev_{it} + \varepsilon_{4it} \quad [9]$$

According to the model, there is still no significant effect from the adoption of broadband in Senegal for the period 2004-2011 (see table 4). This result is not inconsistent with the findings yielded by other studies such as the one recently completed for the country of Colombia (KATZ & CALLORDA, 2011), where broadband penetration of 4.83% yields an economic contribution of 0.03% to GDP growth for every 10% increase in penetration. This is primarily related to the very low network coverage, the monopolization of the market and the subsequent higher prices and the limited consumer interest due to minimal e-government and other applications. On this last point, the recently completed study for Colombia indicates that the introduction of e-government applications has a positive impact on broadband penetration: an increase of 1 percentage point in e-Government users results in 0.55 percentage points increase in broadband penetration (although causality works in reverse as well). The future of broadband in Senegal appears quite dynamic in tackling this situation. DSL lines are expected to exceed 200,000 subscribers by 2016. However the real growth potential comes from the adoption of 3G and EDGE netwokrs in the country. These conections will represent more than a third of all the population and could help drive the adoption considerably higher than the current situation suggests [8].

The structural model provides again some interesting estimates for other important parameters of the Senegalese economy. The capital labour contribution is at the expected 60/40 percent contribution level suggesting a first level of validity for the results. In terms of demand of ADSL service, income and urbanization positively affect the adoption of the technology. Education enters the regression without statistical significance, suggesting that ICT literacy is not highly correlated with secondary education completion. Nonetheless, urbanization is usually a significant parameter for ADSL coverage and demand as there are significant scale economies from dense demographic segments. Prices negatively affect adoption, as expected, at the 1% level.

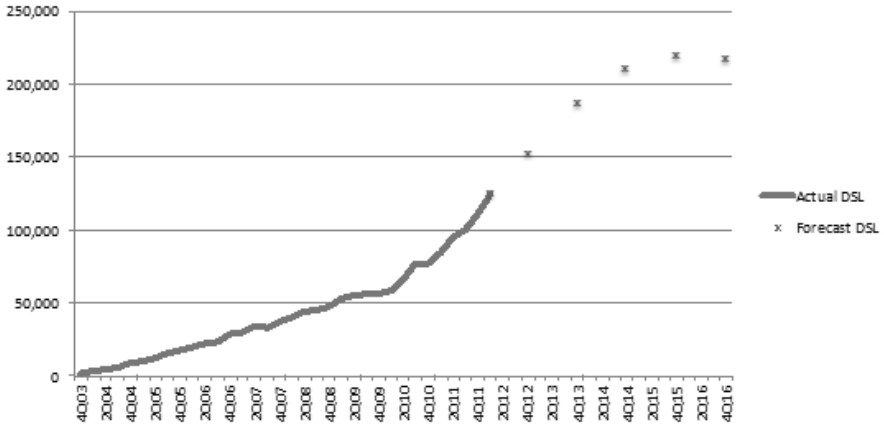
[8] Sonatel reports that its mobile broadband network covers 30% of the population and expects to reach 95% by 2016.

Table 4 - Results of broadband impact model

Variables	*Broadband model*
Growth (GDP_{it})	
Labour force (L_{it})	0.402***
Fixed Capital Stock (K_{it})	0.552***
Broadband Penetration (BB_Pen_{it})	-0.003
Constant	-
Demand (BB_Pen_{it})	
GDPC ($GDPC_{it}$)	0.832**
BB. Price ($BBPr_{it}$)	-0.794***
Education (Edu_{it})	0.082
Urbanization (URB_{it})	25.402***
Constant	-87.929***
Supply (BB_Rev_{it})	
BB. Price ($BBPr_{it}$)	0.161
GDPC ($GDPC_{it}$)	3.273***
Constant	-7.223***
Output (ΔBB_Pen_{it})	
BB. Revenue (BB_Rev_{it})	0.572
Constant	7.554
Year Effects	YES
Quarter Effects	YES

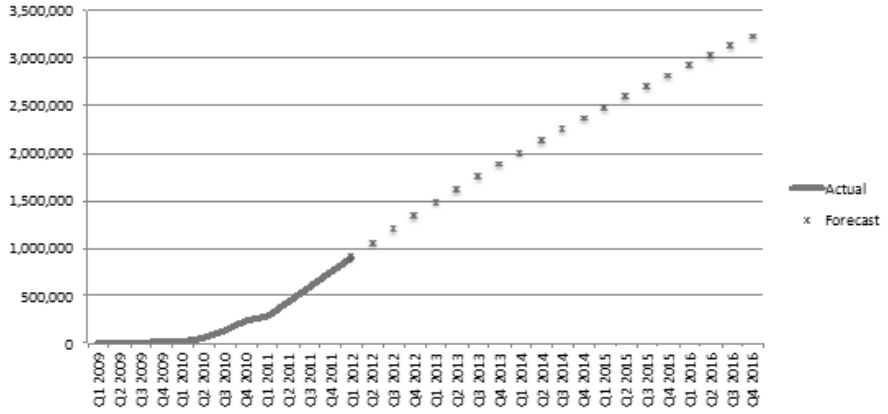
***,** denote statistical significance at the 1% and 5% respectively

Figure 6 - DSL forecast in Senegal



Source: Wireless Intelligence

Figure 7 - 3G and EDGE forecast in Senegal



Source: Wireless Intelligence

Supply dynamics suggest that disposable income affects the revenues and investments of operators. Lack of competition makes pricing a rather insignificant parameter of supply, as there is no new entry in the market during the period of study. Revenues are found to be insignificant in terms of the output of the industry, implying a lack of adequate investment in the market during that period. This result should be analyzed further as the broadband industry has a significant multyplying effect on economic growth that Senegal failed to realize in the recent past.

■ Conclusion

The Senegalese market appears to be in a transitional phase in terms of ICT adoption. With mobile telephony already having a significant impact on the economy, the West-African nation has managed to improve its basic communication needs and overcome the serious impediment of low fixed line adoption. As the next step is upon it, higher connection speeds through 3G or fixed broadband networks will be required. These connections are costly to build and use while the country seems to be in a fairly uncertain macroeconomic situation. As ADSL lines never took off, both due to affordability and coverage, 3G looks like a great candidate to put the country on the global broadband map.

The contribution of digital networks on the improvement of the socio-economic conditions in Senegal can be realized by the applications and

services rather than the infrastructure itself. The importance of digital connectivity in the country may affect sectors like education, health and others. In particular, the educational system in Senegal has 11 participating institutions on the Pedagogical Integration scheme of ICT's Observatory aided through the Pan-African Research Agenda. Nevertheless the deployment of any ICT application within this context has to account for the particularities of the learning process in the region's unique environment [9].

While the country is expected to meet its health related Millennium Development Goals by 2015 and a national ICT procurement policy for the health sector is already functioning, there are still several ways that telecoms can help the delivery of primary and secondary care. Several mHealth initiatives are taking place and together with Kenya the local government has funded and adopted mobile applications [10] as a first step towards electronic health records.

Coverage is a key issue, as the relatively rural country would greatly benefit from the widespread availability of data services. Among others, transport, e-Government and mobile payments depend on the quality of wireless access and the efficient use of simple applications. In practice, Senegal is a fertile technological greenfield already ripe for an abundance of applications and services that could drastically reduce poverty, increase life quality, sustain growth and promise a brighter future.

9 Comments from Michael Trucano, World Bank ICT in Education.

10 EpiSurveyor: Source http://www.cio.de/index.cfm?pid=156&pk=884595&p=1

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