Chapter 11
The Economic Impact of Telecommunications in Senegal

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Introduction

Ever since the launch of the Internet, but especially in the last 10 years, researchers have been attempting to measure the economic contribution of communications. Originally, the approach focused 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 has continued to be pursued,[1] researchers have focused recently on quantitative assessment of specific country studies. For example, aiming to understand the economic impact of broadband, the authors have conducted studies in Europe (Katz et al. 2010a), the United States (Katz and Suter 2009; Katz et al. 2010a, b), and Latin America (Katz 2011c; Katz 2010; Katz et al. 2011; Katz and Callorda 2011).

Increased data availability and lengthier time series would now allow researchers to extend single-country analyses by developing tracking models. Adding to cross-country comparisons and single-country studies, research can now shed light on how is technology contributing to the economy within a single

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[1] See Koutroumpis (2009), Waverman (2009), and Katz (2012).

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country over time. Policy makers could greatly benefit from this expanded view since it would allow them to change course or fine-tune policies without relying only on a "rearview" mirror or an analysis of "expected" impact.

The following study represents a contribution to this new capability. In 2010, the authors conducted an assessment of the economic impact of telecommunications in Senegal, focusing on the relative impact of wireless and broadband communications. This new study, which enhances time series with data up to 2013, attempts to answer three questions raised as hypotheses 2 years ago.

First, the 2010 study concluded that telecommunications had a sizable *direct* economic impact, accounting for over 10 % of Senegal's gross domestic product (GDP). In fact, Senegal's National Accounts indicated that between 2002 and 2010, the rate of growth of telecommunications' contribution to Senegal's GDP was three times that of construction and financial services, generating as much (Francs CFA 419 billion) as the two other sectors combined. Since 2010, Senegal's economy growth has slowed down to 2.6 % in 2011 (from 4.2 % the year before) but increased in 2012, reaching 3.7 %. While inflation reached 3.38 % driven by high energy prices, it dropped to 1.42 % in 2012. Finally, the rate of Gross Capital Formation increased from 28.93 % in 2010 to 30.33 % in 2011. In this context of changing economic conditions, it is relevant to research how sustainable has telecommunications' direct economic contribution been to the Senegalese economy. Is volatility in the economy as a whole mirrored by changes in telecommunications' contribution to the GDP, or is the sector continuing to grow anticipating a structural shift in composition of output?

Second, the econometric modeling of the 2010 study generated evidence of a substantial *indirect* contribution of wireless telephony. According to that study, the annual contribution on GDP growth from mobile phones was approximately 0.044 % for every 1 % of increase in wireless penetration. Given that the economy had grown—on average—at 4.1 % between 2003 and 2010, this figure suggested that wireless alone was responsible for 13.6 % of all economic growth in Senegal for that period. The study also concluded that, given the future growth in the penetration of wireless, the impact of the technology on GDP would continue to increase, albeit at a slower rate due to a saturation effect. As expected, wireless telephony has continued to grow in Senegal at a fast pace, averaging 18 % annually. Wireless penetration (in connections) has increased from 66.22 % by the end of 2010 to 92.68 % two and a half years later. Could we, in light of market developments, test the hypothesis of "declining returns" to wireless penetration? Or, alternatively, are we witnessing a "return to scale" whereby impact increases with penetration? This last counter-hypothesis is not to be discarded since universal adoption of the technology could lead to the creation of new markets and the acceleration of innovation.

Third, the study also did not find any econometric evidence of an economic contribution from broadband in Senegal for the period 2004–2011. This result was not inconsistent with the findings of other studies, where in many emerging countries broadband penetration yields almost nil economic impact due to very low network coverage, a concentrated market structure, consequent higher prices,

and limited consumer interest due to minimal local content and applications. However, the study also anticipated that the future of broadband in Senegal, particularly with regard to mobile broadband, could change this situation. Wireless broadband has, indeed, undergone a substantial growth in the past 2 years. While by the end of 2010 mobile broadband represented 24,000 subscriptions and fixed broadband amounted to 78,000, 2 years later mobile broadband subscriptions reached 491,000, compared to 95,000. Mobile broadband has continued to grow exponentially, reaching 631,000 by mid-2013. Could we actually start to witness the emergence of broadband's economic impact as a result of the dramatic growth in mobile broadband?

In this context, a study that revisits the impact equation 2 years later is quite pertinent for several reasons. First, how sustainable has the direct economic contribution of telecommunications been? Furthermore, even if the direct contribution did not change substantially, would it be possible that the indirect impact increases? Second, is there a condition of "declining returns" to wireless telephony, whereby it would be imprudent to extrapolate economic effects from mid-penetration levels to saturation points? Or, alternatively, is there a growing "return to scale" where economic effects tend to increase exponentially with penetration? Third, can we find evidence of economic effects of mobile broadband that would lead governments in emerging countries to formulate policies that stimulate its growth to the detriment, perhaps, of fixed broadband?

Along these lines, a caveat should be made. 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 and Onyeji 2007), significant economic effects of ICT do not materialize immediately after the introduction of a new technology. This study is predicated on the assumption that 2 years (or maybe less) could be sufficient enough to start detecting economic effects. An underlying premise of the research is that given the speed with which technology is developing around the world, multi-year lags in assessing social and economic impact might not be necessary, and that, measurement techniques notwithstanding, policy makers are better served by conducting multiple and frequent tracking studies that allow them to monitor the emergence of new effects and accelerate, slow down, or correct policies.

This study begins by providing a brief review of the results of last year's study ("Summary of 2010 Study Results" section). It then presents the changes that have taken place both in the Senegalese economy and in the telecommunications industry since last year ("Changes in the Senegalese Economy and the Telecommunications Sector Since 2010" section). This provides a context for conducting a new iteration of econometric modeling with the additional observations ("New Study Results" section). The implications from a public policy standpoint are drawn in "Discussion of Study Results" section.

Summary of 2010 Study Results

The impact of telecommunications in the period ending in 2010 on the Senegalese economy was assessed first in terms of the sector's direct impact, resulting from its importance in the GDP, the employment being generated by its operators and their local suppliers, and taxes being paid. Secondly, the economic impact of telecommunications was also assessed in terms of its indirect "spill-over" impact on the economy as a whole, by contributing to the growth of the GDP across sectors.

Direct Economic Contribution of Telecommunications Until 2010

The total revenues of the Senegalese telecommunications industry represented 1.4 billion USD (10.8 % of the national GDP) in 2010. This ratio had been consistently growing since 2002 indicating the increasing importance of the sector (see Fig. 11.1).

Furthermore, the value-added of the telecommunications and postal services sectors had reached 850 million USD, while their contribution to GDP growth was 104 million USD (8.5 %), the highest across industrial sectors.[2,3] When comparing it against other sectors, the direct contribution to GDP growth of the telecommunications and postal services sectors was higher than energy, construction, and finance (approximately 26 million USD each sector) and had been consistently growing faster since 2002 (see Fig. 11.2).

In parallel to its direct economic contribution, the telecommunications industry had an important impact in the creation of direct jobs (i.e., telecommunications employment). The total number of direct jobs in telecommunications reached 3,000, while the indirect employment reached 55,000. The total direct and indirect employment figure represented in 2010 1.11 % of the total employment in Senegal and 10.6 % of the service sector.[4] Finally, the Senegalese telecommunications sector contributed in 2010 12.6 % of the public treasury in terms of taxes being paid. For example, Orange Sonatel, the incumbent operator, contributes 10.4 % of the total fiscal revenues of the country.[5]

[2] When considering it with transportation (*source*: National Accounts).

[3] GDP of Senegal in 2010 was $12,954 m (current).

[4] Total population employment reached 5,194,107 in 2010; according to the Youth Employment Network study on Ghana and Senegal, 10.5 % of the labor force is employed in the service sector.

[5] *Source*: Sonatel.

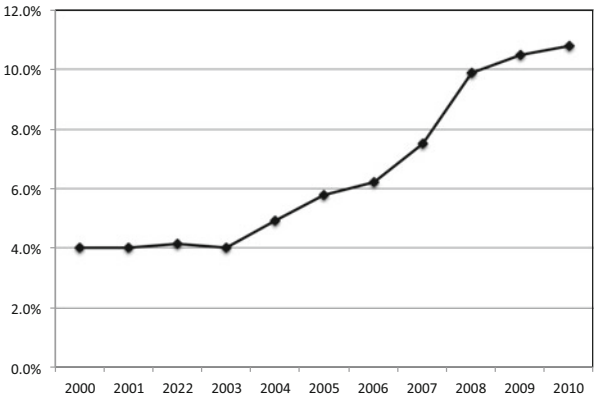

Fig. 11.1 Percentage of GDP. *Sources*: IMF; World Bank

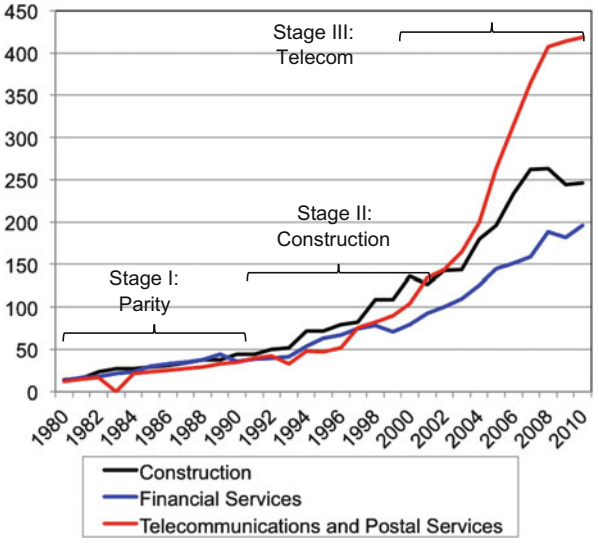

Fig. 11.2 Senegal: GDP by industry (1980–2010) (in CFA billion). *Source*: Senegal National Accounts

Indirect Economic Contribution of Telecommunications Until 2010

As indicated above, beyond the direct economic contribution, telecommunications can have a positive indirect contribution to economic growth. Given the different penetration rates exhibited by mobile telephony and broadband, the analysis of economic impact of both technologies was conducted separately.

Based on structural econometric models, mobile telephony was found to significantly affect the Senegalese economy between 2003 and 2010. The annualized average contribution to the GDP was estimated to be equal to 0.044 % growth of GDP for every 1 % increase of mobile penetration (see Table 11.1).

Table 11.1 Results of 2010 mobile telephony model

Variables	Mobile model
Growth (GDP_{it})	
Labor 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
R^2	*(1)*
Growth	0.99
Demand	0.98
Supply	0.98
Output	0.30

* Significant at 80 %
** Significant at 90 %
*** Significant at 99 %

These results were found to fit rather well in the logarithmic growth impact curve of Gruber and Koutroumpis (2011). With a median mobile penetration of approximately 35 % between 2004 and 2010, every 1 % increase in mobile penetration would yield a 0.044 % increase in GDP. This estimate was only 3 % lower than the estimate of Gruber and Koutroumpis' exponential model[6] (see Fig. 11.3).

Based on the prior model, the expected impact of the sector according to industry forecasts was also estimated. Since it was estimated that mobile penetration would reach 115 % by the end of 2016 suggesting a saturation stage, the median mobile penetration for the period of study (2004–2016) would increase to 61.4 % and the annual impact from each 1 % increment of mobile penetration would contribute slightly more than 0.05 % to GDP. In fact, we hypothesized at the time that the wireless market saturation would lead to a stagnation of the economic effect of mobile adoption over time and that while the growth effects would be preserved, they would be transferred to broadband.

[6] Estimated value: $(0.0074 \times \ln(0.35)) + 0.0533 = 0.0455$, actual estimate: 0.44.

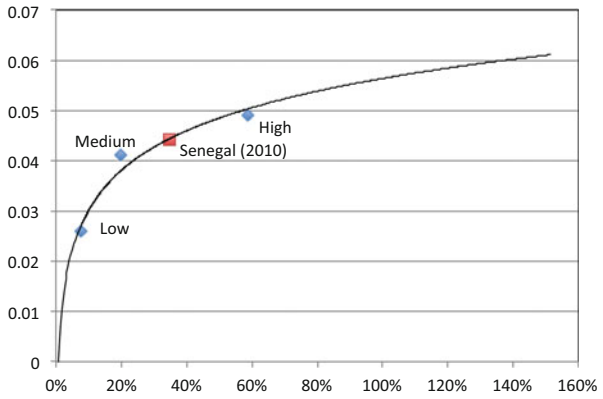

Fig. 11.3 Estimate based on fitted line of previous studies (median mobile penetration ~35 %)

For the analysis of the impact of fixed[7] broadband on the economy a model similar to the mobile telephony structural model was utilized. According to the model, no significant effects were found from the adoption of broadband for the period 2004–2010 (see Table 11.2).

This result was not inconsistent with the findings yielded by other studies such as the one completed by one of the authors for Colombia (Katz et al. 2011), where broadband penetration of 4.83 % yielded an economic contribution of 0.003 % to GDP growth for every 1 % increase in penetration. We hypothesized, however, that the real growth potential of broadband would come from the adoption of mobile broadband in the country.

Changes in the Senegalese Economy and the Telecommunications Sector Since 2010

Changes in the Senegalese Economy Since 2010

The 2010 study was conducted at the time where the global recession in 2009 and the Senegalese food and energy crisis of 2008 had significantly affected the country's economy. In fact, recovery began in 2010 after a combination of domestic structural reforms and the improved results of the global economy. GDP growth increased from 2.2 % in 2009 to 4.2 % in 2010, although it fell back to 2.6 %[8] in 2011. This number recovered in 2012, reaching 3.7 %, with projected growth of 4.3 and 5.1 % for 2013 and 2014, respectively. These projections are based on future

[7] Mobile broadband adoption was embryonic at the time.

[8] IMF: http://www.imf.org/external/pubs/ft/weo/2012/01/index.htm.

Table 11.2 Results of 2010 broadband impact model

Variables	Broadband model
Growth (GDP_{it})	
Labor 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
R^2	*(1)*
Growth	0.99
Demand	0.99
Supply	0.35
Output	0.16

implementation of the government's socioeconomic program and compliance with the IMF's Policy Support Instrument.[9]

The start of the recovery is also depicted by the changes in inflation. After a sharp rise during 2005–2008, inflation turned negative reaching −0.98 % in 2009 and 1.37 % in 2010. In 2011 inflation reached 3.38 % mainly as a result of higher energy prices but dropped down to 1.42 % in 2012[10] and hovered at 1.1 % until July 2013[11] (see Fig. 11.4).

Total imports of goods and services had steadily grown after 2001 reaching a peak of 53.8 % of GDP in 2008 but experienced a sudden drop thereafter declining to 44 % of GDP in 2010. Exports further fell to 24 % in 2011 further expanding the external balance of goods and services (see Fig. 11.5).

Foreign Direct Investment dropped from 3.01 to 1.62 % of GDP between 2008 and 2009, reaching 1.98 % in 2011. The rate of investment measured by the gross fixed capital formation (GFCF) was positive: 27.97 % of GDP in 2009, 28.93 % in

[9] African economic outlook: http://www.africaneconomicoutlook.org/en/countries/west-africa/senegal/.

[10] World Bank.

[11] http://www.tradingeconomics.com/calendar.

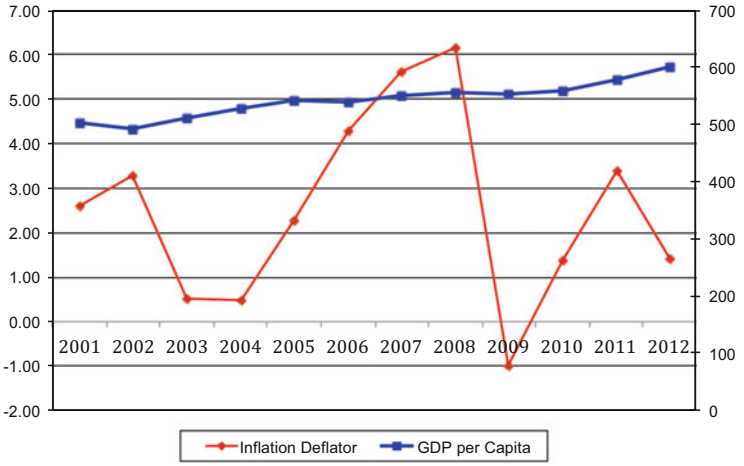

Fig. 11.4 GDP per capita and inflation. *Source*: World Bank (2011)

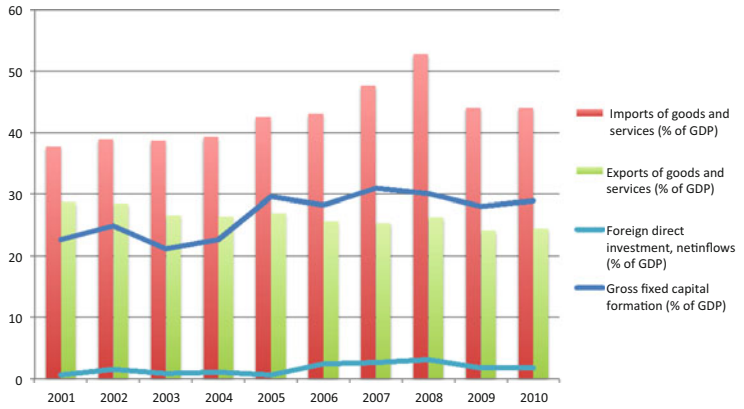

Fig. 11.5 Imports, exports, gross fixed capital formation, and foreign direct investment as % of GDP. *Source*: World Bank (2011)

2010, and 30.3 % in 2011. It is forecast that Senegal's external position will gradually improve during 2013 (7.1 %) and 2014 (6.7 %) after the steep increase to 7.6 % in 2011.[12] The overall budget deficit, including grants, increased from 5.2 % of GDP in 2010 to 6.7 % in 2011 but decreased to 5.9 % in 2012. It is estimated to drop to 4.9 % in 2013 and 4.3 % in 2014.

In light of these macroeconomic trends, it would be relevant to explore whether the relationship between the sector and the overall economy has changed at all.

[12] The 2011 IMF debt sustainability analysis (DSA).

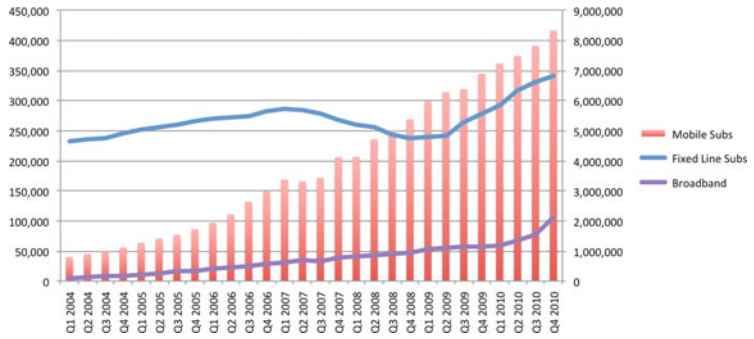

Fig. 11.6 Mobile, fixed line, broadband, and 3G subscribers in Senegal. *Source*: ARTP Senegal (2011)

Has the elasticity between GDP growth and telecommunications output changed? Has the sector benefitted from the increase in Gross Capital Formation?

Changes in the Telecommunications Industry Since 2010

As reported in the 2010 study, the telecommunications sector had grown rapidly during the last 15 years in Senegal primarily driven by the adoption of mobile telephony (see Fig. 11.6).

Since 2010, wireless has continued its growth, albeit with a momentary slowdown in 2011 (see Table 11.3).

In addition to the dramatic increase in wireless subscribership, fixed lines have also increased since 2008. Fixed lines had 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 3-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, with fixed lines reaching an all-time high in 2011 (346,400 lines), before declining slightly in 2012 to 338,167. 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 wireline, the Senegalese market continues to exhibit less of a technology substitution dynamic as the one that can be seen in other emerging countries.

The most important change since 2010 in the telecommunications market has been the development of mobile broadband. While ADSL lines continue to grow, the most significant boost in the Senegalese broadband market has been the deployment and launch of 3G networks that now account for 80 % of broadband connections (see Table 11.4).

Table 11.3 Wireless connections and subscribers in Senegal. *Source*: ARTP Senegal; GSMA Intelligence; IMF; analysis by the authors

	2008		2009		2010		2011		2012	
	Value	Annual delta	Value	Annual delta	Value	Annual delta	Value	Annual delta	Value	Annual delta
Wireless connections	5,389,133	48.43 %	6,901,492	28.06 %	8,343,717	20.90 %	9,325,828	11.77 %	11,470,996	23.00 %
Market penetration	45.72 %		57.00 %		67.10 %		72.93 %		87.51 %	
Wireless subscribers	3,467,227	34.57 %	4,165,843	20.15 %	4,778,799	14.71 %	5,208,366	8.99 %	5,955,032	14.34 %
Market penetration	29.02 %		33.95 %		37.93 %		40.26 %		44.84 %	

Note: The difference between connections and subscribers is driven by double SIMs

Table 11.4 Subscriber market shares across telecommunication platforms in Senegal (2010). *Source*: IMF; Orange; ITU; analysis by the authors

		2009		2010		2011		2012	
		Number	Annual growth rate	Number	Annual growth rate	Number	Annual growth rate	Number	Annual growth rate
Fixed broadband	Number	58,720	23.99 %	78,647	33.94 %	92,713	11.88 %	95,561	3.07 %
	Penetration	0.49 %		0.63 %		0.73 %		0.73 %	
Wireless broadband	Number	5,067		35,591	602.41 %	188,362	429.24 %	447,786	137.73 %
	Penetration	0.04 %		0.29 %		1.48 %		3.42 %	

Table 11.5 Subscriber market shares across telecommunication platforms in Senegal (2010). *Source*: Orange Sonatel; Business Monitor International; analysis by the authors

	Fixed line		Fixed broadband		Wireless	
Player	2010	2012	2010	2012	2010	2012
Orange Senegal	92.4 %	86.4 %	97.41 %	95.00 %	60.41 %	62.85 %
Tigo Senegal					27.96 %	24.30 %
Expresso	7.53 %[a]	13.6 %	2.59 %	5.00 %	11.63 %	12.85 %
Total	100 %	100 %	100 %	100 %	100 %	100 %

[a]Fixed wireless offering

From an industry structure standpoint, 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. While the market is still primarily controlled by Sonatel (62.85 % in 2012), Tigo has 24.30 % of the customer base and Expresso the remaining 12.85 % (see Table 11.5).

Despite the apparent stability of market shares, competitive intensity in the wireless market has increased since 2010. The Hirschman–Herfindahl Index (HHI), that measures market concentration, declined from 4,634 in 2010 to 4,603 at the end of 2012, reaching 4,506 by mid-2013. An assessment of market share in wireless by specific products highlights the centers of gravity of the competitive battles (see Table 11.6).

As Table 11.6 indicates, competition as noted by market share volatility has been intense across all segments of the wireless industry. Since 2010, Tigo has lost five points of prepaid share at the expense of Orange and Expresso, Orange has lost five points of postpaid share to the other two players, and the wireless broadband market is now being fought between Orange and Expresso.

Finally, total service revenues have increased US$ 100 million since 2010, reaching a total of US$ 1.5 billion. The trend clearly relates to the rise in mobile adoption and usage as well. The slight increase since 2010 does not match the previous momentum between 2002 and 2008 (see Fig. 11.7).

As a result, the elasticity of telecommunications demand with respect to the growth of the economy is still behind that experienced between 2001 and 2008 (see Fig. 11.8).

This has to be considered in the context of the dramatic growth of mobile telephony. In fact, the stabilization of revenue growth is primarily due to the decline in mobile average revenue per user (ARPU) resulting from increased competition. Nevertheless, the data shows that the telecommunications sector growth is now aligned with the GDP growth trend. We will come back in "Discussion of Study Results" section to provide an interpretation of this trend.

Table 11.6 Subscriber market shares across telecommunication platforms in Senegal (2010). *Source*: GSMA Intelligence

	Prepaid		Postpaid		Wireless broadband	
Player	2010	2012	2010	2012	2010	2012
Orange Senegal	60.89 %	61.99 %	77.44 %	72.45 %	100 %	68 %
Tigo Senegal	28.35 %	23.08 %	11.55 %	13.64 %		
Expresso	10.75 %	14.93 %	11.02 %	13.91 %		32 %
Total	100 %	100 %	100 %	100 %	100 %	100 %

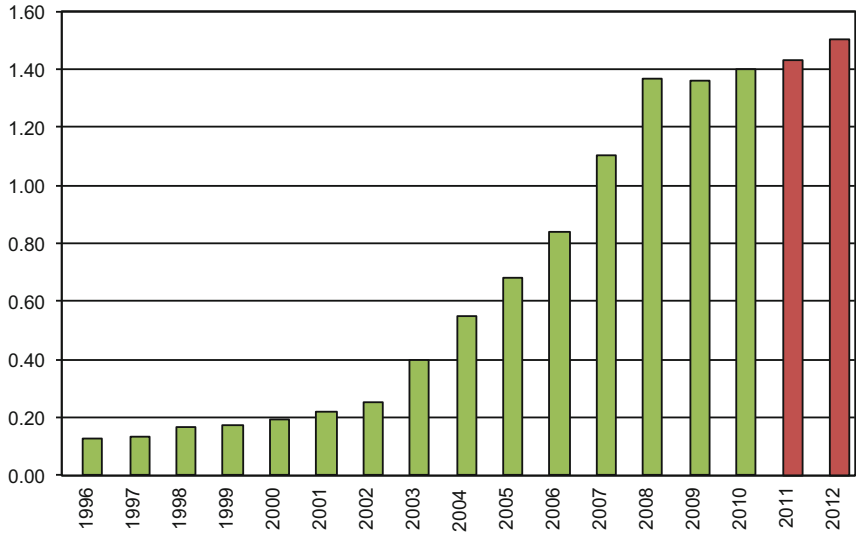

Fig. 11.7 Telecommunications service revenues 1996–2010. *Sources*: ITU; Euromonitor; The Economist; analysis by the authors

New Study Results

To what extent do the changes both in the economy and the telecommunications sector changed the economic impact equation? This will be explored in terms of descriptive economic statistics similar to the ones reported in the first study for the direct effects as well as equivalent econometric modeling techniques for the indirect contribution.

Direct Economic Contribution Since 2010

Two years after the 2010 study, the total revenues of the Senegalese telecommunications industry increased by US$ 100 million (slightly dropping as a percent of

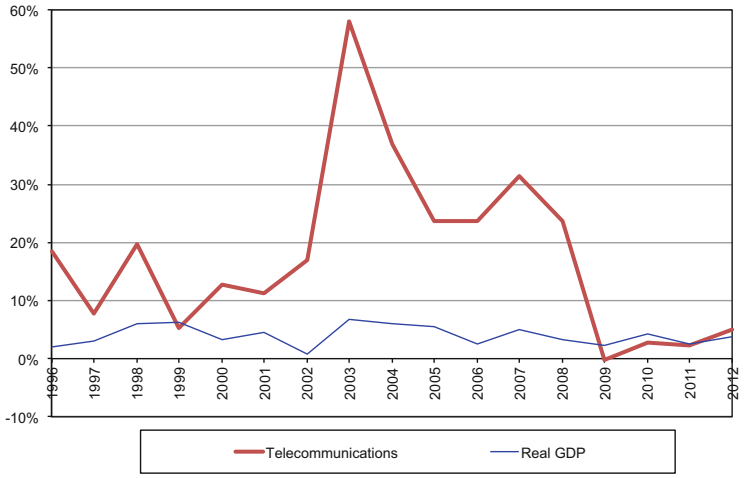

Fig. 11.8 Annual change in real GDP and the telecom market (1996–2012). *Sources*: ITU; World Bank; IMF; ISI; analysis by the authors

the GDP from 10.8 % in 2010 to 10.3 % in 2011 and increasing to 10.6 % in 2012).[13] This ratio, which had been consistently growing since 2003 indicating the increasing importance of the sector , has been relatively stable since 2009 (see Fig. 11.9).

Furthermore, the output of the telecommunications and postal services sectors reached Franc CFA 438 billion, still higher than construction and finance, but losing ground to the two other sectors given their rebound in 2011 (see Fig. 11.10).

Indirect Economic Impact Since 2010

To measure the indirect economic impact since 2010 we constructed a model similar to the one specified for the 2010 study for mobile telephony. To reiterate, the model consists of four equations: an aggregate production function modeling the economy and, subsequently, three demand, supply, and output functions. The last three functions model the wireless market operation, and, controlling for the reverse effects, the actual impact of the infrastructure is estimated. In the production function, GDP is linked to the fixed stock of capital, labor, 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, and the competition in the mobile market, measured by the HHI index. The supply function links the aggregate mobile

[13] National Accounts are still not published for 2012. Data for 2012 sector revenues is estimated by Hot Telecom Services.

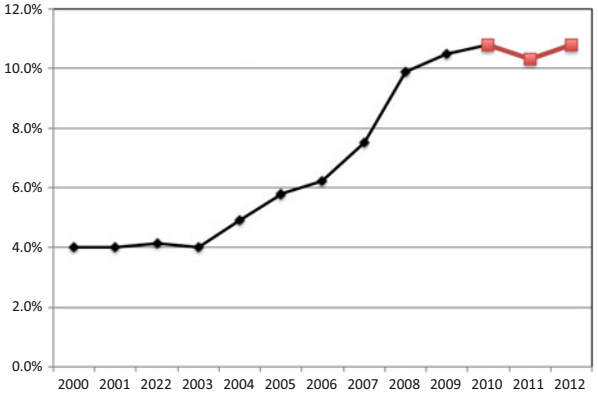

Fig. 11.9 Telecommunications as percentage of GDP (2000–2012). *Sources*: IMF; World Bank (2011)

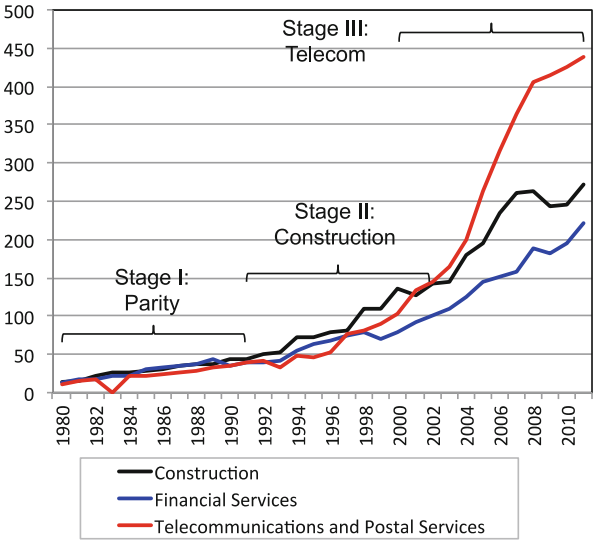

Fig. 11.10 Senegal: GDP by industry (1980–2011). *Sources*: National Accounts (2012)

revenue to mobile price levels proxied by ARPU, industry concentration index of the mobile market (HHI), and GDP per capita. The infrastructure equation links annual change in mobile penetration to mobile revenues, used as a proxy of the capital invested in a country during 1 year.

The econometric specification of the model is as follows:

Aggregate production function:

$$\mathrm{GDP}_{\mathrm{it}} = a_1 K_{\mathrm{it}} + a_2 L_{\mathrm{it}} + a_3 \mathrm{Mob\_Pen}_{\mathrm{it}} + \varepsilon_{1\mathrm{it}} \tag{11.1}$$

Table 11.7 Results of mobile telephony model

Variables	Mobile model
Growth (GDP_{it})	
Labor force (L_{it})	0.366***
Fixed capital stock (K_{it})	0.785***
Mob penetration (Mob_Pen_{it})	0.061*
Constant	–
Demand (Mob_Pen_{it})	
GDPC ($GDPC_{it}$)	5.365***
Mob. price ($MobPr_{it}$)	0.6223
Market concentration (HHI_{it})	−0.0002
Constant	−39.324***
Supply (Mob_Rev_{it})	
Mob price ($MobPr_{it}$)	1.594***
GDPC ($GDPC_{it}$)	5.750***
Market concentration (HHI_{it})	−0.0005***
Constant	−36.806***
Output (ΔMob_Pen_{it})	
Mob revenue (Mob_Rev_{it})	0.539***
Constant	9.545***
Year effects	YES
Quarter effects	YES
Operator effects	YES
R^2	*(1)*
Growth	0.99
Demand	0.62
Supply	0.90
Output	0.23

Demand function:

$$\text{Mob\_Pen}_{it} = b_1\text{MobPr}_{it} + b_2\text{GDPC}_{it} + b_3\text{HHI}_{it} + \varepsilon_{2it} \tag{11.2}$$

Supply function:

$$\text{Mob\_Rev}_{it} = c_1\text{MobARPU}_{it} + c_2\text{GDPC}_{it} + c_3\text{HHI}_{it} + \varepsilon_{3it} \tag{11.3}$$

Output function:

$$\Delta\text{Mob\_Pen}_{it} = d_1\text{Mob\_Rev}_{it} + \varepsilon_{4it} \tag{11.4}$$

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 GDP has been estimated to be equal to 0.061 % of GDP for every 1 % increase of mobile penetration (see Table 11.7).

The model results confirm the economic spillover of wireless telephony in Senegal. In addition, the structural model yields other interesting findings:

- Capital deepening has an unusually high impact on economic growth (coefficient of 0.785 versus 0.1349 for Cote d'Ivoire).
- Incomes are crucial for adoption and investments (coefficient: 5.635), which indicates that affordability remains a critical barrier for demand.
- Competition has a positive impact on investments (coefficient: −0.0005 and significant), but not on adoption (not significant).

The actual contribution of mobile technology was calculated by multiplying the compound annual growth rate of wireless penetration between 2005 and 2013 (11.5) by the coefficient of economic impact derived from the econometric model presented in Table 11.7 (11.6):

$$\text{CAGR} = (\text{Wireless penetration 2Q 2013}\,(92.68\%) - \text{Wireless penetration 4Q 2005}\ (15.70\%))^{(1/7.5)-1} \tag{11.5}$$

The CAGR for Senegal wireless telephony for the period 2005−2013 is 26.71%.

$$\text{Impact of wireless on GDP}\ (2005{-}2013) = \text{CAGR}\ (26.71\%) \times \text{Coefficient of Impact}\ (0.061) \tag{11.6}$$

According to the formula, the annual contribution to GDP from mobile phones is 1.63 % of GDP. Based on the difference between the 2012 GDP of US$ 14,159 million and the 2005 GDP of US$ 8,699 million, the indirect annual contribution of wireless telephony amounts to US$ 176 million.

Furthermore, looking at the results in light of the exponential growth impact curve of Gruber and Koutroumpis (2011), the impact forecast in 2010 study is confirmed. To reiterate, in 2010, with a median mobile penetration of approximately 35 % in the sample period, the country had a coefficient of 0.044. Next, considering that mobile penetration was forecast to reach 115 % by the end of 2016, the median mobile penetration for the period of study (2004–2016) would have shifted to 61.4 %, resulting in a coefficient of 0.05 %. Now, with median mobile penetration in the 2004–2012 period shifting to 61.4 %, the coefficient has increased to 0.061 indicating an acceleration of impact (see Fig. 11.11).

The new coefficient being higher than that estimated by Gruber and Koutroumpis' exponential model could be partially explained by the standard deviation of the specification. However, another potential explanation for which we remain cautious about is that the economic contribution of mobile telephony is accelerating due to the new services that rely on telecommunications to reach consumers. We consider, in particular, financial services like mobile money that rely on text messaging.

For the analysis of the impact of mobile 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 modeling the operation of the economy and subsequently three demand, supply, and output functions. The latter functions model the mobile broadband market operation and

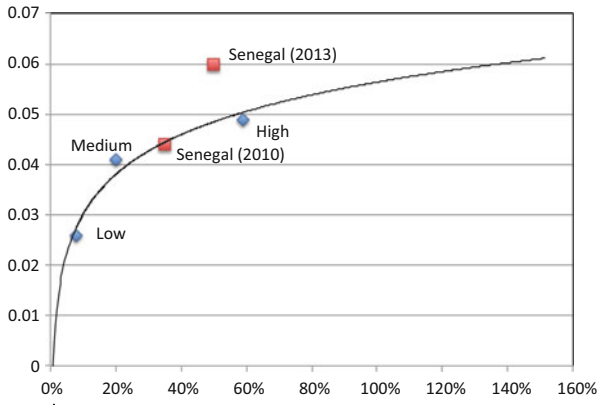

Fig. 11.11 Estimate based on fitted line of previous studies (median mobile penetration: 2004–2010: ~35 %; 2010–2016: 61.4 %)

estimate the economic impact of mobile broadband while controlling for the reverse effects. The demand function links mobile broadband penetration to the average consumption propensity of individuals proxied by GDP per capita, the cost of a basic mobile broadband service (price of a monthly subscription), the percent of individuals that fulfill secondary education, and the percent of population residing in densely populated urban areas. The supply function links the aggregate mobile broadband revenue to the relevant price levels and the GDP per capita. The infrastructure equation links annual change in mobile broadband penetration to the market revenues, used as a proxy of the capital invested in a country during 1 year.

The econometric specification of the model is as follows:

Aggregate production function:

$$\mathrm{GDP}_{it} = a_1 K_{it} + a_2 L_{it} + a_3 \mathrm{BB\_Pen}_{it} + \varepsilon_{1it} \tag{11.7}$$

Demand function:

$$\mathrm{BB\_Pen}_{it} = b_1 \mathrm{BBPr}_{it} + b_2 \mathrm{GDPC}_{it} + b_3 \mathrm{Edu}_{it} + b_4 \mathrm{Urb}_{it} + \varepsilon_{2it} \tag{11.8}$$

Supply function:

$$\mathrm{BB\_Rev}_{it} = c_1 \mathrm{BBPr}_{it} + c_2 \mathrm{GDPC}_{it} + c_3 \mathrm{HHI}_{it} + \varepsilon_{3it} \tag{11.9}$$

Output function:

$$\Delta \mathrm{BB\_Pen}_{it} = d_1 \mathrm{BB\_Rev}_{it} + \varepsilon_{4it} \tag{11.10}$$

According to the model, mobile broadband appears to have an initial effect on the economy. Contrary to the 2010 results, every 1 % increase in mobile broadband penetration yields 0.022 % growth in GDP (see Table 11.8).

Table 11.8 Results of mobile broadband model

Variables	Mobile broadband model
Growth (GDP_{it})	
Fixed capital stock ($l_{fcapital}$)	0.632***
Labor force (l_{labedu})	0.960***
Mobile broadband penetration ($l_{mbbusers}$)	0.022***
Constant	−21.742***
Demand ($l_{mbbusers}$)	
GDPC (l_{gdpc})	−1.565
Mobile broadband price (l_{mocost})	−6.332***
Competitive intensity (hhi_mb)	−2.719***
Constant	36.994**
Supply ($l_{revenue}$)	
GDPC (l_{gdpc})	−0.157
Mobile broadband price (l_{mocost})	0.246***
Competitive intensity (hhi_mb)	−0.252***
Constant	19.885***
Output (d_{mbob})	
Mobile broadband revenue ($l_{revenue}$)	11.687
Constant	−218.389
Year effects	YES
Quarter effects	YES
R^2	
Growth	0.99
Demand	0.96
Supply	0.39
Output	0.00

This effect is quite reasonable, since, while the coefficient is lower than what is found in comparable fixed broadband studies, one would expect a smaller effect since mobile broadband is not as intensively used for accessing the Internet as fixed broadband.

One should consider though that the impact of mobile telephony and mobile broadband are cumulative. Therefore, while the indirect contribution of telecommunications to the GDP in the 2010 study was 0.04 % for every 1 % increase in mobile penetration, in 2013 the impact would be 0.061 % for every increase of 1 % in wireless penetration, *plus* 0.022 % for every increase of 1 % in wireless broadband penetration.

Discussion of Study Results

The interpretations of the new study results in light of the 2010 evidence are quite enlightening. The data on direct economic contribution of the telecommunications sector indicate that its overall impact has not substantially changed. The sector

revenues as a percentage of the GDP have stabilized in the range of 10 % since 2009. However, this does signify that the relative importance of telecommunications has remained constant since. The primary reason of this stabilization is that unit prices have declined significantly as a result of competition. For example, the effective price per voice minute dropped to US$ 0.03 between 2005 and 2009 and US$ 0.05 between 2009 and 2012. Similarly, ARPU (considered as total spend per customer) decreased from US$ 10.36 to US$ 9.93 between 2005 and 2009, respectively, but dropped from US$ 9.93 to US$ 5.78 between 2010 and 2012. The decline in prices is fairly correlated with the increase in competitive intensity in the wireless sector across segments.

Despite the relative stability of direct contribution of telecommunications, the indirect effects have greatly expanded. First, the contribution of mobile telephony to GDP growth has increased significantly since 2010, well beyond the estimate of the exponential growth model. This could be the result of wireless moving to a next level of impact, beyond the voice and mobility contributions. Second, broadband, due to the acceleration of mobile broadband adoption, has started to have an economic impact, albeit not at the level achieved in more developed environments.

The policy implications of these findings are manifold. It is critical for emerging markets to first implement policies that help grow infrastructure investment in order to achieve critical mass in terms of network deployment and device adoption. Once this is achieved, policy focus needs to shift to the areas that maximize spillovers, which means focusing in promoting intense usage and stimulating technology innovation. Along those lines, while direct contribution of the telecommunications sector is a relevant metric to initially monitor infrastructure deployment and adoption, over time policies should focus on maximizing indirect effects.

Beyond these, the Senegal case demonstrates that mobile broadband is, as expected, the technology most suited to tackle the digital divide in the emerging world. While it is reasonable to assume that not all 3G users use the technology to access the Internet, all estimates point to the fact that once devices are in the hands of non-adopters, over time digital literacy, combined with increasing affordability of data plans, will stimulate Internet access.

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