REGULATION OF LATIN AMERICAN'S INFORMATION & COMMUNICATIONS TECHNOLOGY (ICT) SECTOR: AN EMPIRICAL ANALYSIS

James
Alleman

Paul
Rappoport

2015/46

CÁTEDRA TELEFÓNICA
POLÍTICA Y REGULACIÓN TELECOMUNICACIONES E INTERNET

James Alleman

University of Colorado–Boulder
Institut Barcelona d'Estudis Internacionals (IBEI)

james.alleman@colorado.edu

Paul Rappoport

Temple University

prapp4@gmail.com

ISSN: 1886-2802

INSTITUT
BARCELONA
ESTUDIS
INTERNACIONALS

IBEI WORKING PAPERS

2015/46
Regulation of Latin American's Information & Communications Technology (ICT) Sector: An Empirical Analysis

Edita: IBEI
Ramon Trias Fargas, 25–27
08005 Barcelona
Tel. 93 542 30 30
E–mail: ibei@ibei.org
URL: www.ibei.org

Depósito legal: B–21.147–2006
ISSN: 1886–2802
Barcelona, July 2015

REGULATION OF LATIN AMERICAN'S INFORMATION & COMMUNICATIONS TECHNOLOGY (ICT) SECTOR: AN EMPIRICAL ANALYSIS

James Alleman
Paul Rappoport

Abstract: In the mid-1980s a movement towards privatization and de-regulation of the telecommunications sector was begun. The sector has been privatized in most countries and subjected to regulatory reform. The major reform occurred in the late 1990s. Since then the internet and cellular-mobile industries have advanced significantly. Mobile service has exploded, particularly in the developing world. This has changed the dynamics of the industry dramatically. This paper empirically evaluates the reforms twenty-plus years after they have been implemented in selected Latin American countries using cross-country analysis. Earlier studies did not account for the regulatory environment nor cover the entire ICT sector. This paper empirically evaluates the impact of regulation in selected Latin American countries. The results are only suggestive, but not conclusive – that weaker regulation supports investment in the ICT sector due to higher prices for the service.

Keywords: Information & Communications Technology (ICT); Economic Growth; Investment; Mobile Phones; Privatization; Regulation; Regulatory Reform.

Comments: In 2014 Prof. Alleman was awarded a Senior Fellowship at Institut Barcelona d'Estudis Internacionals (IBEI) to research regulation of Information and Communications Technology (ICT) in Latin America, granted by Catedra Telefonica Catedra Telefonica de Política y Regulación de las Telecomunicaciones e Internet América Latina – Europa.

Acknowledgements: Partial Funding was provided by a Visiting Research Fellowship granted by Cátedra Telefónica de Política y Regulación de las Telecomunicaciones e Internet América Latina – Europa. Administration of the Fellowship and support was kindly provided by Institut Barcelona d'Estudis Internacionals (IBEI). Useful Comments were provided by Juan Jung, a colleague and Research Fellow at IBEI and Áine Ní-Shúilleabháin, Research Fellow at Columbia Institute of Tele-Information, Columbia University.

1. INTRODUCTION

Thirty years ago, virtually the entire telecommunications sector was state owned, managed and controlled. Government intervention was usually justified on the basis of monopoly/oligopoly power – a market failure. Without state intervention prices would be too high, demand would be restricted and excess profits (beyond the normal return on investment) would be obtained, which creates inefficiencies and leads to high social costs and loss of welfare. Because of the large fixed cost of provision of the services, it was felt a monopoly could provide the services at the lowest possible cost. The sector was perceived as a public utility. More recently, network externalities have been suggested as a rationale for intervention in this sector – that is the more people connected to the network, the more valuable it will be. Its public value is greater than its private value. Thus virtually all of the telecommunications systems have been owned, managed and controlled by the state since their inception[1].

However, in the mid-1980s a movement towards privatization, liberalization and de-regulation took hold, pushed by President *Reagan's administration* in the United States and Prime Minister *Thatcher's administration* in the United Kingdom. Now the sector has been privatized in most countries and subjected to regulatory reform of one sort or another: liberalization, competition or "light-handed" regulation. The major reform occurred in the late 1990s (Estache *et al.* 2006). Since then the Internet and cellular-mobile industries have advanced significantly. Mobile service[2] has exploded, particularly, in the developing world. This has changed the dynamics of the industry dramatically[3].

The paper updates and expands the work on the efficacy of regulation using cross-country analysis of selected Latin American countries. It follows the frameworks of Röller and Waverman (2001); and Waverman *et al.* (2005); and Czernich *et al.* (2009). It is in the spirit of Estache *et al.* (2006) in that it examines outcomes after privatization and regulatory reform. It examines the metrics of success (or failure): increased penetration of the mobile telephone service. Related to these metrics is the requirement that investment incentives are maintained or enhanced.

The paper is organized as follows: A Literature Review following this Introduction/Overview. It reviews the economic literature on ICT's impact on economic growth and development and the research on the effectiveness of regulation. The third section describes the countries under review: their descriptive statistics. The fourth section describes the methodology and the sources of the data; the results are in the fifth section. The final section presents conclusions and recommendations.

1 The exceptions were the United States and Canada where the inventor of the telephone started companies and some Scandinavian systems.
2 Cellular-mobile, cellular and mobile are used interchangeable in this paper.
3 The sector is now referred to as information and communications technology (ICT) to address its expanded scope.

2. LITERATURE REVIEW

A variety of papers review the economic literature on ICT's contribution to growth and development – including Internet, broadband, mobile services as well as fixed line service – regulation, regulatory governance, and Latin America ICT environment. Thus, we indicate where these reviews may be found and update the material as appropriate.

2.1 Growth

The determinants of economic growth have been a concern of researchers since the beginning of the discipline. It is only relatively recently, beginning in the early 1980's, that the contribution of the ICT sector has been a concern.[4] Earlier research by Alleman *et al.* (1991) addresses the research on telephony's impact on economic growth and development and has a comprehensive literature review of the work up to 1991. Koutroumpis (2009, pp. 2-4) has a review of the literature on the determinants of economic growth in general, as well as telephony and broadband networks in particular. Vu (2011, pp. 354-355) has a brief review of the ICT cross-country studies as well as the national studies.

Early work on ICT's contribution to growth was relatively modest in its approach, using simple regression models of GDP growth against telephone penetration (in logarithmic transformations) or similar variables. The more recent work has attempted to account for endogeneity and to determine the magnitude and direction of causality. Two strategies have emerged to address this – the use of instrumental variables (Czernich *et al.* 2009) and the use of a structural model of the sector (Röller and Waverman 2001). Röller and Waverman's (2001) seminal work constructed a micro supply and demand model before addressing the macroeconomic impacts. They provide a strong critique of the earlier models. The variance in others' results could be clarified by their approach. Others followed in their footsteps: Koutroumpis (2009); and Waverman *et al.* (2005).

Koutroumpis (2009) estimates the impact of broadband on the infrastructure and growth for 15 European countries over the period 2003 to 2005. He finds a significant positive causal impact, particularly when the infrastructure has a critical mass. Similarly Waverman *et al.* (2005) estimated the impact of mobile telephone service on growth. They found it contributed significantly in low income countries; indeed, it may be twice as large in developing countries as in developed.

4 Solow (1987) famously stated that "You can see the computer age everywhere but in the productivity statistics"; this became known as Solow's Paradox (Brynjolfsson 1993). The ICT literature addressed this "Paradox."

Katz and his coauthors (2009a, b, c; Katz, *et al.* 2009, and Katz and Suter 2009) have done a number of studies on the economic impact of ICT in Latin America and elsewhere. The global, national and regional studies of the economic impact of ICT are reviewed in Katz (2009).

More recently, Vu (2011) showed that the marginal effect on growth of the penetration of Internet users was larger than that of cellular phones, which was larger than that of personal computers for the average country.

Jung (2014) does a review of the literature of ICT's infrastructures impact on economic growth. While his focus is on broadband, he does a comprehensive review of ways in which ICT can enhance economic activities as suggested by the literature. Thus, they will not be discussed here.

These studies, generally, do not account for the regulatory environment and, in most cases, do not cover the entire ICT sector. This is the contribution of this paper.

Public Policy & Regulation

Two strands of the literature on economics of regulation are theoretical or empirical, with a few exceptions (see Krämer *et al.* 2014). This review will focus on empirical approaches in terms of efficacy of regulatory reform and quality of the regulation.

Cambini and Jiang (2009) have a comprehensive review of the literature of regulation and broadband investment up to the late 2000s. They note that the conflict between competition, regulation and investment has been addressed in both the theoretical and empirical literature, which they review. They found that the impact of regulation on investments is not conclusive; more research is needed.

Efficacy of Reforms

As noted, the evolution of the ICT sector was perceived as a public utility and hence, it has been owned and controlled by the state or subject to regulation, licensing, and a variety of other public policy controls. But this changed in the mid-1980s with privatizations and regulatory reform. This process is virtually complete, and is even being reversed in some cases.

Since then the Internet has developed and the cellular-mobile industry has exploded, particularly in the developing world. This has changed the dynamics of the industry dramatically. The success of regulatory policy in Latin America is the focus of this paper.

The economics literature on the reform of the telecommunications sector is extensive. It is one of the most analyzed of all of the basic infrastructures. Some are an evaluation of general reform; most are country specific studies with significantly fewer cross-country studies. A detailed review of the cross-country studies is contained in Estache *et al.* (2006).

However, many of the studies of the efficacy of the telecommunications reform policies were completed before the growth of mobile and Internet services. They concentrated on fixed line growth and did not address wireless or broadband services. Other strands of the ICT regulatory literature examine quality (e.g. Ai *et al.* 2004) such as price, etc.

Quality of the Regulation

The degree to which regulation is independent of the government is another metric that has been analyzed in the economics literature. In general it is assumed and supported by empirical research that the more independent the regulator is from government, the "better" the regulation will be. The matrix of performance indicators are; quality of service, access charges, affordability, fiscal costs and productivity (Estache *et al.* 2006). The "independence" of the Independent Regulatory Agencies (IRA) is important in performance, but also private capital makes an important contribution.

> …the basic data analysis tells us that countries with private capital and an IRA have, on average, more subscribers, lower prices of local calls, lower fixed costs, lower faults, and higher labor productivity (Estache *et al.* 2006, p. 7).

But developed and developing countries exhibit considerable differences. Estache *et al.* (2006) review in detail the cross-country studies as a prelude to their own study. Their study adds country political risk, including corruption, which will have an impact on private investment in the infrastructure

Access Pricing & Regulation

Regulatory authorities set the framework to determine access pricing. The impact of these frameworks has been researched in the industry. Contention exists among what framework is appropriate from an economic perspective. Since the bulk of the regulators, at least in Europe, have chosen some form of long run incremental cost (LRIC), and most of the balance of the countries has selected full allocated/distributed costs (FDC) (Nitsche and Wiethaus 2011)[5], the economic literature has

5 The authors, and others, have found difficulties with these methodologies because they are static, and do not reflect the realities of market behavior; however these methods are what are used in practice. See Alleman and Rappoport (2005) and Pindyck (2004) and the reference cited therein.

examined these questions in this context. One of the most recent studies, Nitsche and Wiethaus (2011), examines different types of access pricing approaches and how they affect investments and consumer welfare. They find a FDC approach

> … or a regulatory holiday induces highest investments, followed by risk-sharing and LRIC regulation. Simulations indicate that risk-sharing creates most consumer welfare, followed by regimes with fully distributed costs, regulatory holiday and long run incremental costs, respectively. Risk-sharing benefits consumers as it combines relatively high ex-ante investment incentives with strong ex-post competitive intensity." (Nitsche and Wiethaus 2011, p. 263).

Latin America's ICT Environment

Below the ICT environments of Latin America are illustrated. For clarity the countries of South America and Central America/Mexico[6] are displayed separately. The Caribbean countries are excluded from this review because of their size and uniqueness. The South America countries included are: Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay and Venezuela. French Guiana is excluded because its data is combined with France's statistics. The Central America and Mexico countries are: Costa Rica, El Salvador, Guatemala, Honduras, Mexico, and Nicaragua, and Panama. The International Telecommunication Union is the source of the data used below.[7] Ultimately Belize, Guyana, and Suriname were dropped in the modeling due to data limitations.

The traditional fixed-line telephone service has not grown nearly as fast as the mobile service. Indeed, the mobile service is a substitute for it, although the fixed-line does offer the opportunity to provide an Internet or even broadband internet services. Even in developing countries, individuals are "cutting-the-cords" – that is giving up their fixed-line in favor of cellular service (Banerjee *et al.* 2014).

Cellular-Mobile Service

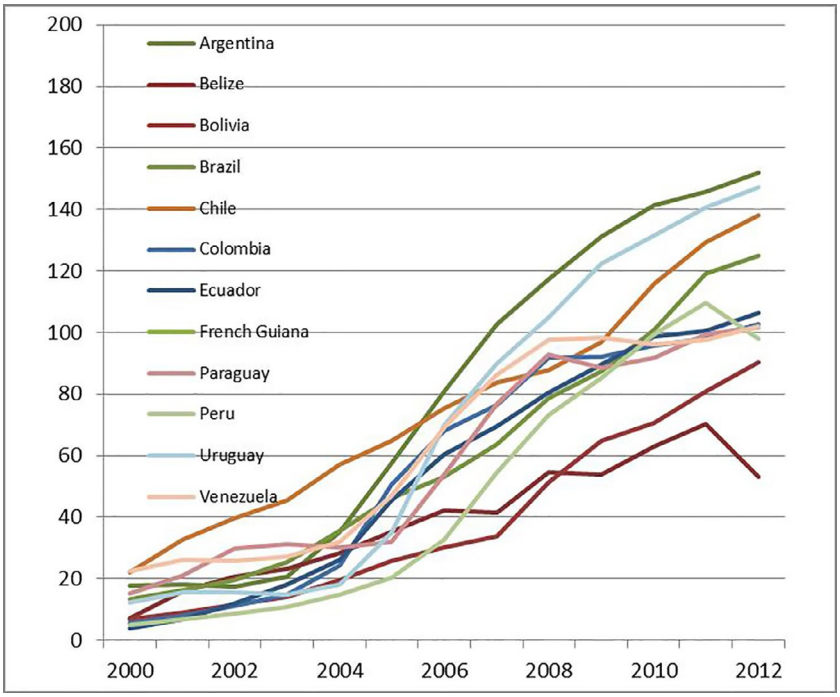
Figure 1 and Figure 2 clearly show that the growth of cellular telephone service has been spectacular. The average compound annual growth rates (CAGR) for the South American countries is over twenty percent (21.26 %) since 2000. Virtually all South American countries have 100 percent or better penetration. Several, much better: Argentina, Brazil Chile, and Uruguay have over 1.2 cellular phones for every inhabitant.[8]

6 Mexico is classified as North America, but we include it as part of Latin America.

7 We would like to thank Carlos Sánchez of IBEI for help in obtaining the access to the databases.

8 One has to be careful with these data since mobile phones are counted by the number of SIM cards, but many people will have only one phone and multiple SIM cards to take advantage of the rates of alternative carriers.

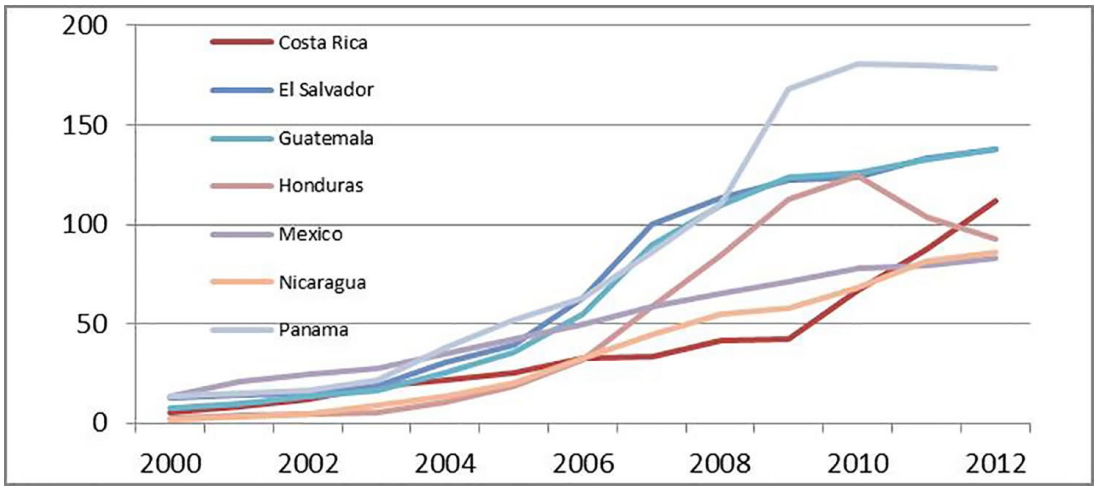
Figure 1. Mobiles per 100 inhabitants, South America



Similarly, Central America and Mexico (see Figure 2) have also seen spectacular growth in wireless. The average compound annual growth rates (CAGR) for these countries is nearly thirty percent (27.97 %) since 2000.

Panama has the lead in Central America with 1.8 wireless phones for every one inhabitant. But most of the others are above or near one mobile per person. Honduras, Mexico and Nicaragua are the stragglers: they have slightly under 100 mobile phones per 100 inhabitants (83, 93, and 86, respectively).

Figure 2. Mobiles per 100 inhabitants, Central America & Mexico



Internet Service

While the pattern for internet penetration is not as dramatic as wireless-mobile service, it has made significant progress over the last dozen years of growth. For South America – Chile, Uruguay and Argentina are above fifty percent of individuals with access to the Internet; many Central American countries are doing nearly as well. Figure 3 shows the growth of Internet per 100 inhabitants for South America and Figure 4 for Central America and Mexico.

Figure 3. Internet per 100 inhabitants, South America

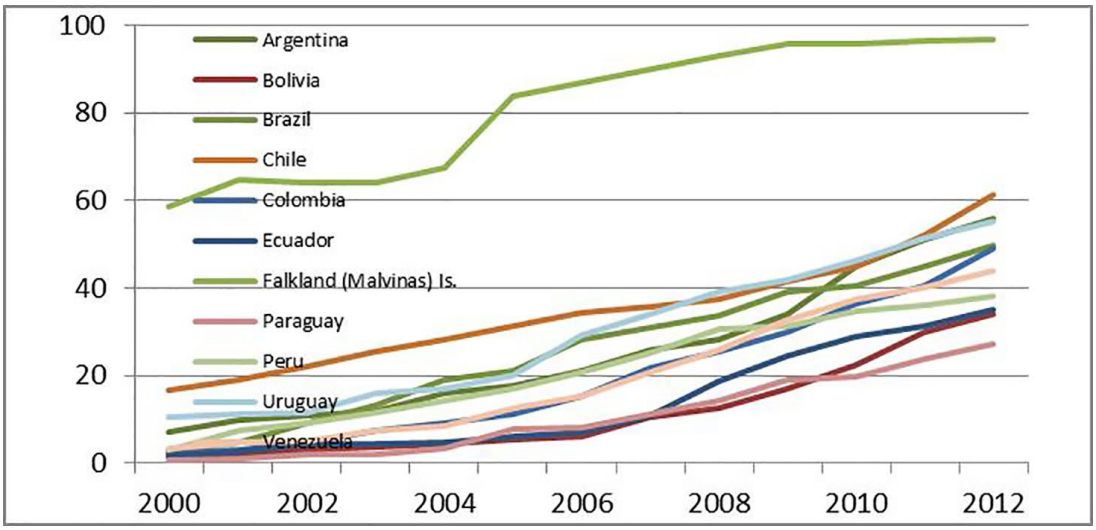
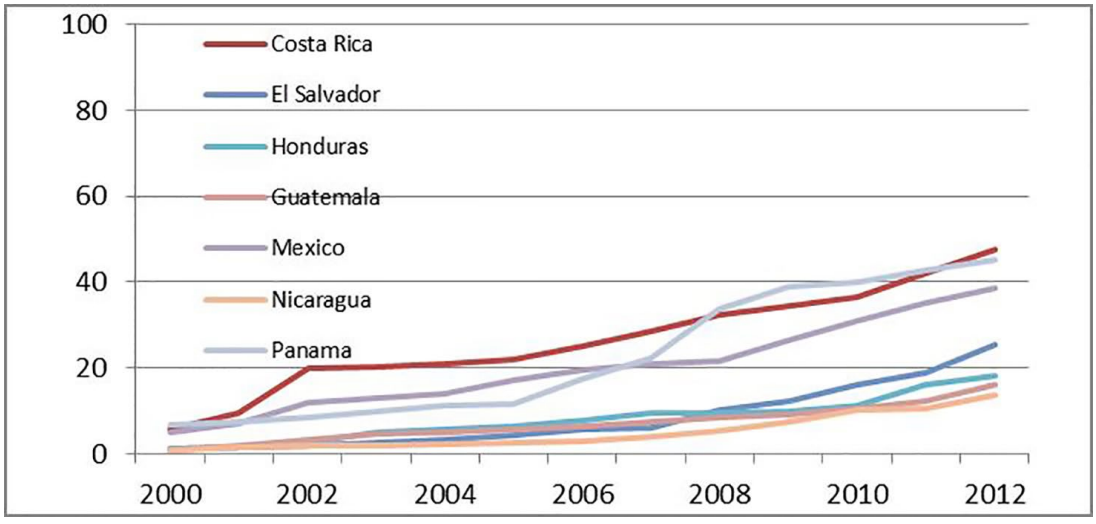


Figure 4. Internet per 100 inhabitants, Central America & Mexico.

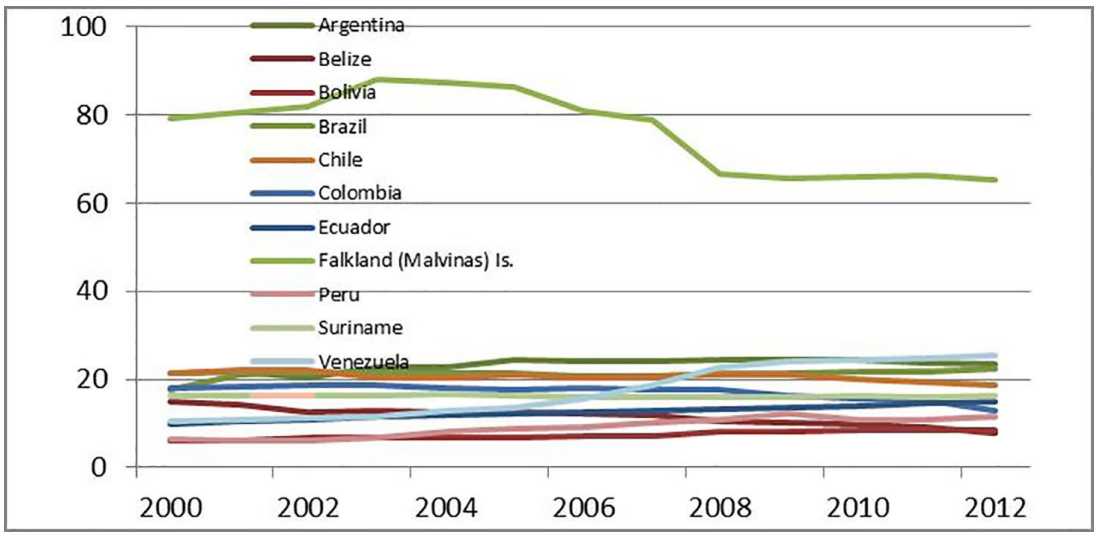


The laggards in South America are Paraguay and Belize, not yet reaching thirty percent (30%) penetration. Similarly, for Central America, El Salvador has not yet reached thirty percent (30%), Nicaragua and Honduras are even farther behind; they have not yet reached twenty percent (20%).

Fixed-Line Telephone Service

The pattern is very different for fixed-line telephone service. The penetration rates have decreased over time in many countries. This is due, no doubt, to the substitution of mobile for the fixed-line phone. These networks were not well developed and had low penetration, in part, due to the fact that they were not ubiquitous. Figure 5 shows how slow the growth of fixed line service has been; indeed, it has been negative for many countries of South America. The CAGR for these countries is less than one and a half percent (1.43 %) since 2000. Penetration rates are less than thirty percent and most are under twenty percent.[9]

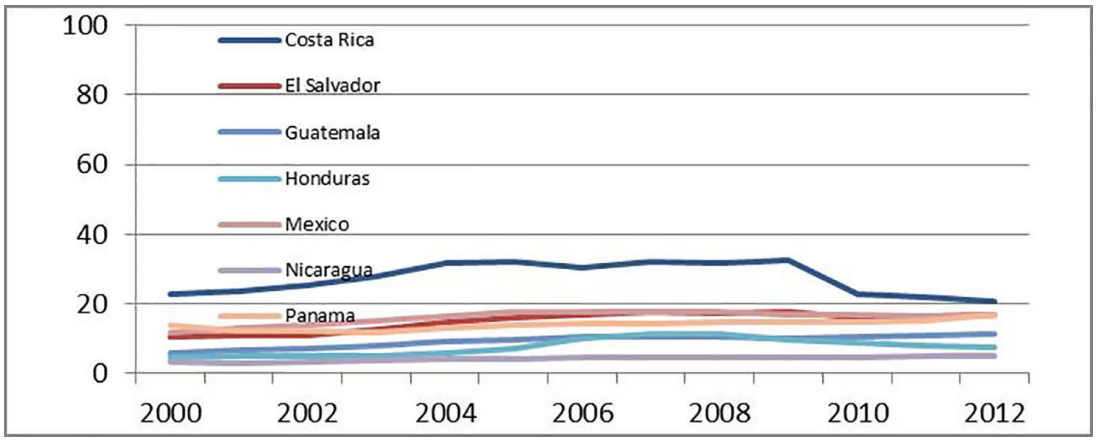
Figure 5. Fixed-lines per 100 inhabitants, South America.



A similar pattern is exhibited for Central America and Mexico. Figure 6 shows how slow the growth of fixed-line service has been for Central America and Mexico. The CAGR for these countries is just over three percent (3.06 %) since 2000 and under twenty percent penetration, some significantly under this.

9 Falkland (Malvinas) Islands is the exception with 65 % penetration.

Figure 6. Fixed-lines per 100 inhabitants, Central America & Mexico.



3. METHODOLOGY

The impact of ICT regulation on economic growth in selected Latin American Countries is examined following the *Waverman et al.* (2005) approach: an Annual Production Function (APF). This was based on the earlier work of Röller and Waverman (R-W) (2001). In addition *an* Endogenous Technical Change (ETC) model was explored based on Robert Barro's (1991) approach. In this framework the volatility of the economy during the period under study had to be taken into account. Data from selected countries of South and Central America and Mexico are used. As noted in the literature review, others have shown that ICT, most recently cellular mobile phone and broadband services, have an impact on economic growth as did fixed-line service in an earlier period. The question addressed in this paper is what is the impact of regulation?

As indicated earlier Internet and, particularly, mobile telephone services have grown spectacularly in the last decade. Privatizations have had time to settle and regulation has had time to mature. Thus, it is appropriate to examine their combined impact.

Data

The data set was obtained from several sources. The ICT data was gathered from the International Telecommunication Union's (ITU) World Telecommunications Indicators database. It is a rich source of ICT data and includes breakdowns of fixed, mobile, Internet subscribers, revenues, and other ICT data. It is updated annually (ITU 2014). This is the main foundation of the data set. The World Bank's World Development Indicators (WDI) database is used for basic data such as popula-

tion, GDP, and total labor force. The capital stock comes from the work of Berlemann and Wesselhöft (2012) who estimated aggregate capital stocks using the perpetual inventory method.[10] International Monetary Fund (IMF), World Economic Outlook Database (2014) is the principal source for the endogenous technical change estimation. Broadband prices are courtesy of Hernán Galperin as used in his paper (2013). The "strength" of regulation data is from the World Economic Forum *Global Competitiveness Report*. Gaps in the data left eight countries for the estimations with time period going from 2007 – 2011 with which to work. They are Argentina, Bolivia, Brazil, Ecuador, Peru, Venezuela, Costa Rica and Mexico. Because of data limitations in the remaining countries, various estimations are dropped for some years and some countries.

Estimation/Results
Annual production function

A three-equation modification of the Röller-Waverman approach is used in the estimation of the Annual Production Function model. The summary of the results are shown in Tables 1 to 3. The details are in the Appendix.

The first equation, Output, estimates the level of output (GDP) as a function of the total physical capital stock net of ICT capital, the total labor force, and the mobile penetration rate. All of the variables are in natural logarithms hence the coefficients can be interpreted as elasticities. The sum of the coefficients of the capital stock and labor force are approximately one (0.954), indicating a slight decline in returns to scale, but consistent with constant returns-to-scale.

Table 1. Output equation (the natural log of real GDP in constant 2005 $US).

Variable	Coefficients	t-Statistic
Capital	0.287	2.924
Labor	0.667	4.403
Mobile Penetration	0.064	4.778

The Output Model's sum of capital and labor coefficients is ~ 0.95 – consistent with the literature – and constant returns-to-scale. Mobile penetration has a small, but positive impact – a ten percent increase in mobile penetration contributes 0.6 percent to GDP growth. All of the variables are significant.

10 Available at http://www.hsu-hh.de/download-1.5.1.php?brick_id=552HQnG7mehYlNnS [1.05.2014]

The second equation, Demand, estimates the level of mobile telecoms penetration as a function of GDP per capita, the price of mobile service (calculated from mobile revenue per mobile subscriber), internet penetration, the fixed-line price (which is fixed-line revenue per fixed-line subscriber) and education expenses as a percent of Gross National Income (GNI).

Table 2. Demand estimation (the natural log of mobiles per 100).

Variable	Coefficients	t-Statistic
Mobile Price	-0.405	-3.674
GDP per Capita	3.584	9.744
Education	0.836	3.769
Internet Penetration	0.383	4.549
Telephone Prices	0.058	0.755

The Demand Model's own price elasticity is – 0.405[11]; education expenditures impacts demand – ten percent increase in education expenditure will increase demand by 8.4 percent; income elasticity is high at 3.584, but this may be due to trends. Internet penetration influences demand as well; it has a synergy with cellular services – for every increase in internet penetration; this will lead to nearly a four percent (3.8%) increase in the demand for mobile service. All of these coefficients are significant. The cross-price elasticity with fixed telephony is 0 .058, but not significant.
The last equation, "Investment" is the change in mobile penetration each year as a function of mobile prices, regulation and telephone prices. The first two variables are of the correct sign -- the increase in mobile prices will induce more investment – and the weaker the regulation (the higher the value and the less regulatory burden) the more incentive to invest. However, these variables only border on significance. The telephone price coefficient, as in the other equations, is not significant. Give the low level of penetration in these countries, this is not surprising.

Table 3. "Investment" Equation (the natural log of the difference of mobiles per 100).

Variable	Coefficients	t-Statistic
Mobile Price	0.432	1.238
Regulation	0.845	1.380
Telephone Price	-0.029	-0.168

11 As mobile becomes more important over time one would expect the price elasticity to fall.

The positive mobile price coefficient of 0.432 indicates that the higher price for mobile services, the more will be invested in this area. The regulation coefficient is positive and is almost significant at the 10% level. This positive coefficient on regulation is expected (the higher the value, the less regulatory burden).

Other estimation methods were investigated – instrumental variables and simultaneous equation methods, but they did not improve the estimates. Appealing to Occam's razor, the simpler model was used.

Endogenous technical change

The growth equation approach of Barro (1991) is used in the estimation of the Endogenous Technical Change (ETC) model. The summary of the results are shown in Table 4. The details are in the Appendix.

The volatility of the economy during the period under study is reflected in the importance of the percentage changes in imports, the percent of borrowing, and real GDP in purchasing power parity (PPP) in 2005 dollars. Percentage change in exports is also important. All of the other coefficients are significant at the 0.01 level or better except for the change in mobile penetration.

The ETC model is not sensitive to changes in mobile penetration. The other variables in the model overpower any effect that the former has. More research is required in this area.

Table 4. Annual Rate of GDP Growth.

Variable	Coefficients	t-Statistic
Percentage change in Imports	0.0013	6.299
Change in Telephone Penetration	0.0071	2.473
Percentage change in Exports	0.0013	2.059
Borrowing as a percent of GDP	0.0028	2.463
Real GDP in Purchasing Power Parity, 2005	.0000	2.427
Change in Mobile Penetration	0.0002	0.501

3. CONCLUSION

This paper attempts to empirically evaluate the impact of regulation in selected Latin American countries. The results are only suggestive, but not conclusive – that weaker regulation supports investment in the ICT sector due to higher prices for the service.

With the limitations on the data, we have not been able to address some of the other significant issues. What has been the impact of the reforms twenty-plus years after they have been implemented? Were privatizations a success? Were regulatory instruments adequate for social control of the industry? What most comports with competitive practices? What will be their impact on consumer, entry, and investment? Overall, what lessons can be learned from the last two decades? These questions remain for future research.

REFERENCES

Alleman, James; Carl Hunt, Donald Michaels, Milton Mueller, Paul Rappoport, and Lester Taylor. 1991. *Telecommunications and Economic Development*: Empirical Evidence from Southern Africa. Available at www.colorado.edu/engineering/alleman/print_files/soafrica_paper.pdf [21.03.2014].

Alleman, James, Gary Madden and Hak Kim. 2008. Real Options Methodology Applied to the Information and Communications Technology Sector: A Survey. *Communications & Strategies*, 70 (2): 27-44. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1354094 [3.04.2014].

Alleman, James and Eli Noam. 1999. T*he New Investment Theory of Real Options and Its Implications for Telecommunications Economics*, Regulatory Economics Series, Kluwer Academic Publishers, Boston, MA, pp. i-xi, 1-280 http://books.google.com/books?id=z08plXnHVjkC&printsec=frontcover [3.04.2014].

Alleman, James and Paul Rappoport. 2005. Regulatory Failure: Time for a New Policy Paradigm. Communications & Strategy, 60 (4): 105-123. Reprinted in *Government Policy and Marketing Strategy*, Institute of Chartered Financial Analysts of India. Kolkata, India. 2008. http://ideas.repec.org/p/pra/mprapa/2517.html [3.04.2014].

Banerjee. Aniruddha, Paul N. Rappoport and James Alleman. 2014. Forecasting Video Cord-Cutting: The Bypass of Traditional Pay Television. In Springer Verlag. James Alleman, Áine Ní-Shúilleabháin and Paul Rappoport (Eds). *Demand for Communications Services – Insights and Perspectives: Essays in Honor of Lester D. Taylor*, Series editor, Darcy Gerbarg. http://www.springer.com/economics/economic+theory/book/978-1-4614-7992-5 [3.04.2014].

Barro, Robert J. 1991. Economic Growth in a Cross Section of Countries. *The Quarterly Journal of Economics*, 106 (2): 407-443.

Baudrier, Audrey. 2001. Independent Regulation and Telecommunications Performance in Developing Countries. University of Paris Panthéon-Sorbonne Working Paper. Paris.

Berlemann, Michael and Jan-Erik Wesselhöft. 2012. Estimating Aggregate Capital Stocks Using the Perpetual Inventory Method – New Empirical Evidence for 103 Countries. Helmut Schmidt University, Department of economics Diskussionspapierreihe/Working Paper Series No. 125, October, Hamburg. Available at http://www.hsu-hh.de/download-1.5.1.php?brick_id=OrPXSBiIjjS4SZ24 [1.05.2014].

Bourreau, M., Cambini, C., and Hoernig, S. 2013. *Geographic Access Rules and Investments*. Available at http://cadmus.eui.eu/handle/1814/26678

Braeutigam, Ronald R. 1989. Optimal Policies for Natural Monopolies. In Richard Schmalensee and Robert Willig (Eds). *Handbook of Industrial Organization*. Amsterdam: Elsevier .

Brynjolfsson, Erik. 1993. Communications of the ACM. 36 (12): 66-77, December. New York, NY

Brynjolfsson, Erik and Hitt, L. M. 1995. Information technology as a factor of production: the role of differences among firms. *Economics of Innovation and New Technology*, 3(3): 183-200.

Brynjolfsson, Erik and Hitt, L. M. 2000. Beyond computation: Information technology, organizational transformation and business performance. *The Journal of Economic Perspectives*: 23-48.

Cambini, C., Jiang, Y. 2009. Broadband investment and regulation: A literature review. *Telecommunication Policy*, 33: 559–574.

Cardona, M., Kretschmer, T. and Strobel, T. 2013. ICT and productivity: conclusions from the empirical literature. *Information Economics and Policy*, 25: 109-125.

Chinn, M., and Fairlie, R. 2007. The determinants of the global digital divide: Across-country analysis of computer and Internet penetration. *Oxford Economic Papers*, 59 (1): 16–44.

Chisari, Omar, Antonio Estache, and Carlos Romero. 1999. Winners and Losers from Privatization and Regulation of Utilities: Lessons from a General Equilibrium Model of Argentina. *World Bank Economic Review*, 13 (2): 357–378.

Chunrong Al and Salvador Martinez and David Sappington. 2004. Incentive Regulation and Telecommunications Service Quality. *Journal of Regulatory Economics*, 26 (3): 263-285. http://ideas.repec.org/a/kap/regeco/v26y-2004i3p263-285.html [1.5.2014].

Crandall, R.W., Lehr, W., and Litan, R. 2007. The effects of broadband deployment on output and employment: Across-country analysis of US data. Issues in Economic Policy, No. 6, The Brookings Institution, Washington, D.C. Retrieved from http://www.brookings.edu/papers/2007/06labor_crandall.aspx

Czernich, S, N., Falck, O., Kretschmer, T., and Wössmann, L. 2009. Broadband infrastructure and economic growth. CESifo Working Paper Series No. 2861. http://papers.ssrn.com/sol3/Delivery.cfm/SSRN_ID1516232_code459177.pdf?abstractid=1516232&mirid=1 [13.04.2014].

Czernich, S; Falck, O.; Kretschmer, T. and Woessman, L. 2011. Broadband infrastructure and economic growth. *The Economic Journal*, 121 (552): 505-532.

Dutz. Mark A., Jonathan M. Orszag and Robert D. Willig. 2012. The Liftoff of Consumer Benefits from the Broadband Revolution. Review of Network Economics, 11 (4) www.degruyter.com/view/j/rne.2012.11.issue-4/1446-9022.1355/1446-9022.1355.xml?format=INT [14.02.2014].

Economides, Nicholas and Joacim Tåg. 2012. Network neutrality on the Internet: A two-sided market analysis. Information Economics and Policy, 24 (1): 91–104.

Eisenach, Jeffrey. 2014. Australia's failed experiment in government-owned broadband. http://www.techpolicydaily.com/communications/australias-failed-experiment-government-owned-broadband/#sthash.t7XV408M.dpuf [14.05.2014].

Estache, Antonio; Ana Goicoechea; and Marco Manacorda. 2006. Telecommunications Performance, Reforms, and Governance. World Bank Policy Research Working Paper 3822, January.

Estache, Antonio, Andres Gomez-Lobo, and Danny Leipziger. 2001. Utilities Privatization and the Poor: Lessons and Evidence from Latin America. *World Development*, 29 (7): 1179–1198.

Estache, Antonio, Manacorda, Marco, and Valletti, Tommaso. 2002. Telecommunications reforms, access regulation, and Internet adoption in Latin America. *Economica*, 2: 153-217.

Estache, Antonio, Quentin Wodon, and Vivien Foster. 2002. *Accounting for Poverty in Infrastructure Reform: Learning from Latin America's Experience*. Washington: World Bank.

Fink, Carstenm Aaditya Mattoo, Randeep Rathindran. 2002. An Assessment of Telecommunications Reform in Developing Countries. World Bank Policy Research Working Paper 2909.

Foster, Vivien; Maria Caridad Araujo. Does infrastructure reform work for the poor? A case study from Guatemala. WPS3185. econ.worldbank.org/external/default/main?pagePK=64165259&theSitePK=469382&piPK=64165421&menuPK=64166093&entityID=000160016_20040129113807 [10.03.2014].

Galperin, Hernán. 2013. Broadband Prices in Latin America and the Caribbean: 2013 Report. Working Paper # 15, Universidad de San Andrés (Argentina). Available at: http://ssrn.com/abstract=2341758 [1.05.2014].

García Zaballos, Antonio; Rubén López-Rivas. 2012. *Socioeconomic Impact of Broadband in Latin American and Caribbean Countries*. Inter-American Development Bank, November. http:\www.iadb.org\document.cfm?id=37257082 [10.03.2014].

Gasmi, Farid, Jean Jacques Laffont, and William Sharkey. 2000. Competition, Universal Service and Telecommunications Policy in Developing Countries. *Information Economics and Policy*, 12 (3): 221–248.

Greenstein, Shane, and McDevitt, R. 2009. The broadband bonus: Accounting for broadband Internet's impact on US GDP. National Bureau of Economic Research Working Paper No. 14758. http://www.nber.org/papers/w14758 [24.03.2014].

Greenstein, Shane; Ryan McDevitt. 2012. Measuring the Broadband Bonus in Thirty OECD Countries. In Greenstein, S. and R. McDevitt (Eds). Measuring the Broadband Bonus in Thirty OECD Countries. *OECD Digital Economy Papers*, No. 197, OECD Publishing. http://dx.doi.org/10.1787/5k9bcwkg3hwf-en [29.03.2014].

Gutierrez, Luis, and Sandy Berg. 2000. Telecommunications Liberalization and Regulatory Governance: Lessons from Latin America. *Telecommunications Policy*, 24 (10–11): 865–884.

Henze, Bastian, Charles Noussair und Bert Willems. 2012. Regulation of network infrastructure investments: an experimental evaluation. *Journal of Regulatory Economics*, 42: 1–38.

Hill, Alice, Abdala, and Manuel Angel. 1993. Regulation, institutions, and commitment: privatization and regulation in the Argentine telecommunications sector. World Bank Working Paper 1216, November. www-wds.worldbank.org\servlet\WDSContentServer\WDSP\IB\1993\11\01\000009265_3961005141505\Rendered\PDF\multi_page.pdf [6.03.2014].

Inter-American Development Bank. 2013. Regional Central American Broadband Network (RG-T2242) Pre-Feasibility Studies Related to the Deployment: Market Study Terms of Reference, Annex II – RG-T2242, 24 January. idbdocs.iadb.org\wsdocs\getdocument.aspx?docnum=37416976 [8.05.2014].

International Monetary Fund. 2014. *World Economic Outlook Database*. April. www.imf.org/external/pubs/ft/weo/2014/01/weodata/index.aspx [11.05.2014].

International Telecommunication Union (ITU). 2013. *Trends in Telecommunications Reform*. http://www.itu.int/pub/D-REG-TTR.14-2013 [15.04.2014].

International Telecommunication Union (ITU). 2014. *ICT Statistics Home Page*, www.itu.int/en/ITU-D/Statistics/Pages/default.aspx [15.04.2014].

International Telecommunication Union (ITU). 2013. *All in the State of Broadband: Universalizing Broadband*. A Report by the Broadband Commission, September. [19.03.2014].

Jung, Juan. 2014. Regional inequalities in the impact of broadband on productivity: Evidence from Brazil. IBEI Working Paper 47.

Katz, Michael L., and Carl Shapiro. 1985. Network Externalities, Competition, and Compatibility. *American Economic Review*, 75 (3): 424–440.

Katz, Raul L. 2009a. Estimating broadband demand and its impact in Latin America. Paper presented at the 3rd ACORN-REDECOM Conference, May 22–23, Mexico City, Mexico.

Katz, Raul L. 2009b. La Contribución de las tecnologías de la información y las comunicaciones al desarrollo económico: propuestas de América Latina a los retos económicos actuales. Madrid, España: Ariel.

Katz, Raul L. 2009c. The economic and social impact of telecommunications output: a theoretical framework and empirical evidence for Spain. *Intereconomics* (1) January/February.

Katz, Raul L. and Suter, S. 2009. Estimating the economic impact of the broadband stimulus plan. Columbia Institute for Tele-Information Working Paper.

Katz, Raul L., Waterlaus, S., Zenhäusern, P. and Suter, S. 2009. The Impact of Broadband on Jobs and the German Economy. Columbia Institute for Tele-Information Working Paper.

Keller, Wolfgang. 2001. International Technology Diffusion. Working Paper 8573. Cambridge, Mass.: National Bureau of Economic Research.

Kessides, Ioannis. 2003. *Infrastructure Regulation: Promises, Perils, and Principles*. Washington DC

Kiiski, Sampsa, and Matti Pohjola. 2001. Cross-Country Diffusion of the Internet. Discussion Paper 11/2001. Helsinki: United Nations and World Institute for Development Economics Research (WIDER).

Krämer, J., Niklas Horstmann, and Daniel Schnurr. 2014. Behavioral Approach Towards NGAN Regulation: Experimental Evaluation of Regulatory Institutions. February 05 (manuscript).

Krämer, J. and Vogelsang, I. 2012. Co-investments and tacit collusion in regulated network industries: Experimental evidence. http://ssrn.com/abstract=2119927 [10.04.2014].

Koutroumpis, P. 2009.The economic impact of broadband on growth: A simultaneous approach. *Telecommunications Policy*, 33: 471–485.

Laffont, Jean Jacques, and Jean Tirole. 1998. Network Competition: Overview and Nondiscriminatory Pricing. *RAND Journal of Economics*, 29 (1): 1–37.

Laffont, Jean Jacques, and Jean Tirole. 2000. *Competition in Telecommunications*. MIT Press.

Laffont, Jean Jacques, and Jean Tirole. 2001. Global Price Caps and Regulation of Access. *Brazilian Review of Econometrics*, 2 (1): 115–146.

Leal, Rodrigo Lima Verdem and Claudio de Almeida Loural. 1999. ICT and Telecommunications: Sectorial Transformation and Public Policy Agenda. Fundação CPqD.

Madden, Gary and Savage, Scott J. 1998. CEE telecommunications investment and economic growth. *Information Economics and Policy*, 10 (2): 173–195.

Mattoo, Aaditya; Nielson, Julia; Nordas, Hildegunn Kyvik. econ.worldbank.org/external/default/main?pagePK=64165259&theSitePK=469382&piPK=64165421&menuPK=64166093&entityID=000442464_20130411152828 [10.03.2014].

Mourougane, Annabelle and Mauro Pisu. 2011. Promoting Infrastructure Development in Brazil. OECD Economics Department Working Papers, No. 898, OECD Publishing. http://dx.doi.org/10.1787/5kg3krfnclr4-en [31.03.2014].

Nitsche, R., and Wiethaus, L. 2011. Access regulation and investment in next generation networks – A ranking of regulatory regimes. *International Journal of Industrial Organization*, 29 (2): 263-272.

Pindyck, R. 2004. Mandatory Unbundling and Irreversible Investment in Telecom Networks. NBER Working Paper No. 10287.

Röller, Hendrik, and Leonard Waverman. 2001. Telecommunications Infrastructure and Economic Development: A Simultaneous Approach. *American Economic Review*, 91 (4): 909–923.

Samarajiva, R., and Lucas, R. 2010. Improving measurement of progress toward Target 10 of the World Summit on Information Society (WSIS). Paper presented at the Eighth World Telecommunication/ICT Indicators Meeting (WTIM), November 24–26, Geneva.

Sluijs, Jasper P. Florian Schuett, and Bastian Henze. 2011. Transparency regulation in broadband markets: Lessons from experimental research. *Telecommunications Policy*, 35: 592-602.

UNRISD Discussion Paper No. 116, October. 1999. digitalknowledgecentre.in/files/2012/02/ICTs-and-Social-Development-The-Global-Policy-Context.pdf [6.03.2014].

Valletti, Tommaso M., and Antonio Estache. 1999. The Theory of Access Pricing: An Overview for Infrastructure Regulators. Policy Research Working Paper 2097. Washington: World Bank.

Valletti, Tommaso M., Steffen Hoernig, and Luis Pita Barros. 2002. Universal Service and Entry: The Role of Uniform Pricing and Coverage Constraints. *Journal of Regulatory Economics*, 21 (2): 169–90.

Van Reenen, J., Bloom, N., Draca, M., Kretschmer, T., and Sadun, R. 2010. The economic impact of ICT. SMARTN.2007/0020FINALREPORT, Centre for Economic Performance, London School of Economics. http://ec.europa.eu/information_society/eeurope/i2010/docs/eda/econ_impact_of_ict.pdf [14.03.2014].

Van Reenen, J., Bloom, N., Draca, M., Kretschmer, T., Sadun, R., Overman, H., M. Schankerman. 2010. The Economic Impact of ICT. Final Report, London: Centre for Economic Performance, London School of Economics.

Wallsten, Scott 2008. Understanding international broadband comparisons. WorkingPaperSeries, TechnologyPolicyInstitute,StanfordUniversity.Retrieved from http://ssrn.com/abstract=1136831S

Wallsten, Scott. 2001. An Econometric Analysis of Telecom Competition, Privatization and Regulation in Africa and Latin America. *Journal of Industrial Economics* 49 (1): 1–19.

Waverman, Leonard and Pantelis Koutroumpis. 2011. Benchmarking telecoms regulation – The Telecommunications Regulatory Governance Index (TRGI). *Telecommunications Policy*, 35 (5): 450-468.

Waverman, Leonard, Meloria Meschi, Melvyn Fuss. 2005. Impact of Telecoms on Econ Growth in Developing Countries. The Vodafone Policy Paper Series, Number 2, March. www.vodafone.com/content/dam/vodafone/about/public_policy/policy_papers/public_policy_series_2.pdf [18.03.2014].

Vu, Khuong M. 2011. ICT as a source of economic growth in the information age: Empirical evidence from the 1996–2005 period. *Telecommunications Policy*, 35: 357-372. http://scholar.google.es/scholar_url?hl=en&q=http://www.unipu.hr/uploads/media/1-s2.0-S030859611100022X-main.pdf&sa=X&scisig=AAGBfm0N2uFZqbaMPL7RiFGlzToGk2l8YA&oi=scholarr&ei=sqkhU7-PEO_60gXbmICAAw&ved=0CC0QgAMoATAA [14.03.2014].

World Development Indicators. 2012. data.worldbank.org/data-catalog/world-development-indicators/wdi-2012 [18.03.2014].

APPENDIX

I. Production function method

Table 5 lists the variables used the production function estimations and their description.

Table 5. Variable description, Annual Production Function.

Variable	Description
l_	Indicates the natural log of the variable
l_d_	Indicates difference in variables between time e. g. Xt – Xt-1
Education	Education expenditure
INTERNET_Pen	Internet per 100 inhabitants
K	Physical Capital Stock
MPEN_RATE	Mobiles per 100 inhabitants
mprice	Price of Mobile Service (Revenue/telephones)
Regulation	Global Competitiveness Index: Burden of government regulation
RGDPPP_US_2005_1	Real Gross Domestic Product per capita in 2005 dollars
TEL_Price	Price of Telephone Service (Revenue/ telephones)
TLF	Total Labor force

The three equation model estimated is:

Output

ln(RGDP_US_2005) = a1. + a2.ln(TLF) + a3.ln(K) + a4 .ln(MPEN_RATE) + u

Demand

ln(MPEN_RATE)= b0 + b1.ln(TEL_Price) + b2.ln(mprice) + b3.ln(RGDPPP_US_2005t-1)
+ b4.ln(INTERNET_Pen) + b5.(education)+ u

"Investment"

ln(MPEN_RATEt) – ln(MPEN_RATEt-1) = c0 + c1.ln(mprice) + c2.ln(TEL_Price)
+ c3.(regulation) + u

The detailed results of the estimations are listed below.

Output equation

Gross domestic Product, Logarithm of
156 observations, included 13 cross-sectional units, time-series length = 12
Dependent variable: l_ RGDP_US_2005

	Coefficient	Std. Error	t-ratio	p-value	
Const	6.51694	2.54798	2.5577	0.01160	**
l_TLF	0.66739	0.151563	4.4034	0.00002	***
l_K	0.287371	0.0982785	2.9240	0.00403	***
l_MPEN_RATE	0.063925	0.0133785	4.7782	<0.00001	***

Mean dependent var	24.67745	S.D. dependent var	1.654669
Sum squared resid	0.455369	S.E. of regression	0.057032
R-squared	0.998927	Adjusted R-squared	0.998812
F(15, 140)	8688.837	P-value(F)	1.0e-199
Log-likelihood	233.8929	Akaike criterion	-435.7858
Schwarz criterion	-386.9881	Hannan-Quinn	-415.9663
Rho	0.761276	Durbin-Watson	0.470186

Test for differing group intercepts -
Null hypothesis: The groups have a common intercept
Test statistic: F(12, 140) = 344.926
with p-value = P(F(12, 140) > 344.926) = 1.58505e-97

Demand Equation

Mobile Penetration, Logarithm of
96 observations, included 8 cross-sectional units, time-series length = 12
Dependent variable: l_MPEN_RATE

	Coefficient	Std. Error	t-ratio	p-value	
Const	-23.8758	3.31101	-7.2110	<0.00001	***
l_TEL_Price	0.0583081	0.0772044	0.7552	0.45224	
l_ mprice	-0.405087	0.110264	-3.6738	0.00042	***
l_ RGDPPP_ US_2005_1	3.58396	0.367803	9.7442	<0.00001	***
l_ INTERNET_ Pen	0.382788	0.0841447	4.5492	0.00002	***
l_ education	0.836382	0.221923	3.7688	0.00031	***

Mean dependent var	3.597670	S.D. dependent var	0.879910
Sum squared resid	6.211235	S.E. of regression	0.273558
R-squared	0.915554	Adjusted R-squared	0.903345
F(12, 83)	74.98996	P-value(F)	2.68e-39
Log-likelihood	-4.794651	Akaike criterion	35.58930
Schwarz criterion	68.92583	Hannan-Quinn	49.06447
Rho	0.648592	Durbin-Watson	0.526884

Test for differing group intercepts -
Null hypothesis: The groups have a common intercept
Test statistic: F(7, 83) = 33.0546
with p-value = P(F(7, 83) > 33.0546) = 1.74527e-21

Investment equation

Mobile Penetration, Logarithm of
42 observations included 6 cross-sectional units, time-series length = 7
Dependent variable: d_l_MPEN_RATE

	Coefficient	Std. Error	t-ratio	p-value	
Const	-2.83557	2.46266	-1.1514	0.25783	
l_ mprice	0.430779	0.347844	1.2384	0.22430	
l_ TEL_Price	-0.0293396	0.174655	-0.1680	0.86762	
l_ regulation	0.845205	0.612607	1.3797	0.17696	

Mean dependent var	0.001606	S.D. dependent var	0.368809
Sum squared resid	4.672476	S.E. of regression	0.376285
R-squared	0.162159	Adjusted R-squared	-0.040953
F(8, 33)	0.798371	P-value(F)	0.608172
Log-likelihood	-13.47983	Akaike criterion	44.95966
Schwarz criterion	60.59869	Hannan-Quinn	50.69198
Rho	-0.269747	Durbin-Watson	2.321947

Test for differing group intercepts -
Null hypothesis: The groups have a common intercept
Test statistic: F(5, 33) = 1.22194
with p-value = P(F(5, 33) > 1.22194) = 0.320853

Endogenous Technical Change (ETC)

The detailed results of the ETC estimation are listed below. Table 5 lists the variables used the ETC estimation and their description.

Table 6. Variable descriptions, ETC.

Variable	Description
d_	Indicates difference in variables between time e. g. Xt – Xt-1
borrow_GDP	Borrowing as a percent of GDP
d_MPEN_RATE	Difference in Mobiles per 100 inhabitants i. e. MPENt – MPENt-1
d_Tel_pen	Difference in Tel_pen i. e. Tel_pen t – Tel_pen t-1
GDPGR	Annual Growth Rate of Gross Domestic Product
PC_imports	Percentage change in imports
PC_exports	Percentage change in exports
RGDPPP_US_2005_1	Real Gross Domestic Product per capita in 2005 dollars
RGDPPP_US_2005_1	Real Gross Domestic Product per capita in 2005 dollars

The ETC equation estimated is:
GDPGR = a1. + a2.(d_MPEN_RATE) + a3.(d_Tel_pen) + a4 .(PC_exports) + a5 .(PC_imports) + a6.(borrow_GDP) + a7 .(RGDP_US_2005) + u

Annual Growth of Gross Domestic Product

110 observations
Included 11 cross-sectional units
Time-series length = 10
Dependent variable: GDPGR

	Coefficient	Std. Error	t-ratio	p-value	
Const	-0.0445471	0.0276778	-1.6095	0.11090	
d_MPEN_RATE	0.000224237	0.000448046	0.5005	0.61792	
d_Tel_pen	0.00705454	0.00285275	2.4729	0.01522	**
PC_exports	0.000897952	0.000436975	2.0549	0.04269	**
PC_imports	0.00131975	0.000209557	6.2978	<0.00001	***
borrow_GDP	0.00275606	0.00111893	2.4631	0.01561	**
RGDPPP_US_2005	1.51866e-05	6.25649e-06	2.4273	0.01714	**

Mean dependent var	0.038960	S.D. dependent var	0.047056
Sum squared resid	0.083473	S.E. of regression	0.029959
R-squared	0.654154	Adjusted R-squared	0.594654
F(16, 93)	10.99413	P-value(F)	3.32e-15
Log-likelihood	239.0208	Akaike criterion	-444.0416
Schwarz criterion	-398.1334	Hannan-Quinn	-425.4210
Rho	0.128328	Durbin-Watson	1.502331

Test for differing group intercepts -
Null hypothesis: The groups have a common intercept
Test statistic: F(10, 93) = 1.68596
with p-value = P(F(10, 93) > 1.68596) = 0.0955729