

Determinants of Mobile Broadband Affordability: A Cross-National Comparison

Full Paper

1. Introduction

The potential, value, and relevance of information and communication technologies (ICTs) is no longer debatable. Past research, however, highlights differences in their availability in developed and developing countries. This phenomenon is known as the digital divide (Norris, 2001; Warschauer, 2004, Pick and Sarkar, 2015). Of the approximately 200 nations for which digital divide data are reported by the International Telecommunications Union (ITU), more than 135 of these have some mobile broadband Internet access (ITU, 2013). The troubling news in these recent data, however, is that in 25 of these countries the annual cost of mobile broadband service is more than a month's pay (i.e., more than 8.33% of the per capita income). Since mobile broadband technologies are becoming a critical means of communication and Internet access (World Bank, 2012), understanding the affordability and adoption of these technologies is an emerging area of research (García-Murillo and Rendón, 2009; Gruber and Koutroumpis, 2010; Lee, 2008; Lee, Marcu and Lee, 2011).

While digital divide 'theory' is not unified in definition or explanations of causes (Floridi, 2010, p. 108), it is generally accepted that there are digital "have's and have not's," many of whom are the economically poor and disadvantaged who cannot afford broadband services (Himma and Tavani, 2008). Part of our analysis will determine whether or not, and to what extent, measures of income and income inequality are related to mobile broadband affordability. Rogers (2003), Norris (2001), and van Dijk (2005) provide a conceptual basis from which we argue that the current state of technology diffusion does not meet access needs of potential users in societies, especially with respect to affordability. We therefore use technology diffusion theory to identify additional factors that affect broadband affordability. Without the presence, intervention, and collaboration of public and private actors in the broadband ecosystem, mobile broadband services will not be affordable for large segments of populations globally (van Dijk, 2005; Marsden, 2011). Based on both technology diffusion and digital divide literature, we identify key hypotheses to explain the relationship between a country's policy initiatives, regulation, government structure & processes, government performance (independent variables) and mobile broadband affordability (dependent variable). These hypotheses were tested using broadband affordability data from the 2013 International Telecommunication Union report (ITU, 2013). The hypotheses – discussed and operationalized below – allow us to answer the following research question: *What factors related to policy, regulation, government, and governance determine the affordability of mobile broadband in different countries?*

In answering this research question, we attempt to fill an important research gap and to address key global issues associated with ICT affordability. In fact, identifying factors that can improve the affordability of a technology that is so important to human development (i.e., mobile broadband) will be helpful for many stakeholders, including governments, policy makers, and public servants. Furthermore, understanding current gaps and limitations might assist service providers, promote investment, and also create or modify policy, law and regulation that make mobile broadband more affordable.

The remainder of this paper is organized as follows: The next section provides an overview of diffusion of innovation and digital divide theories, and then focuses on past literature on fixed and mobile broadband affordability and diffusion. Section 3 outlines the data and methods used in this study. In particular, we describe and operationalize the variables and show their link with prior literature. Section 4 presents and

analyzes the findings, while Section 5 discusses the implications of our findings and suggests avenues of future research.

2. Explaining variation in mobile broadband affordability

2.1 Diffusion of innovation theories and broadband

Why does the broadband digital divide persist, particularly in developing countries, while the global reach of mobile broadband services continues to expand? Innovation diffusion and digital divide theorists provide perspectives we use to inform our inquiry. For instance, Rogers (2003) argues that, using an S-curve model, early innovators and adopters are the first to embrace an innovation. In part because an innovation becomes more affordable, middle and late majority adopters then follow, increasing the acceptance rate. Moreover, so-called laggards are the last to buy in before a saturation point sets in - at which time the current technology can drop in price, market share, and attractiveness due to the next generation of technology. With regard to the digital divide, inhabitants of developing countries who cannot afford or are unable to access or use new technologies may still be excluded, even after the so-called saturation point of a technology is reached in more developed countries. Furthermore, a repeating cycle of innovation diffusion perpetuates the “rich get richer” phenomenon (van Dijk, 2005). Taking a step back, it is clear that innovations in the so-called global information society are in fact innovations at different levels of technological development distributed among highly stratified societies that both reflect and reinforce existing socioeconomic disparities (Norris, 2001). In addition, recent literature that criticizes Roger’s model suggests an interactive view of innovation that reflects the often unpredictable dynamics involving its diffusion (Swan et al. 2007; Swan and Scarbrough, 2005; Kietzmann, 2008). The interactive view suggests that innovation phases do not necessarily occur sequentially, but often in back-and-forth interactions. Think about what happens between the conception and implementation of an innovation: Software like Windows 95 or the first IOS for iPhone underwent major modifications before ‘stabilizing,’ and these modification were possible only because of their initial use by the public.

Another critique of Rogers’ model was offered by van Dijk (2005), who critiqued while supporting the underlying logic of the S curve concept. Van Dijk (2005) argued that “there may be different S-curves for particular social categories of people” (p. 65), and that governments and targeted policies and regulation are necessary to enable “material access” and “skills access” to broadband applications and services. Both cross-national statistical studies and case studies from across the globe have shown that material access to ICTs has differed mainly on income (Chinn and Fairlie, 2007; Norris, 2001) and income inequality (Fuchs, 2009). Previous research on the broadband digital divide has focused on fixed line broadband in developed countries and the role of several factors in bridging this divide, including different forms of broadband industry competition (Atkinson, 2009; Cava-Ferreruela and Alabau-Muñoz, 2006; Distaso, Lupi and Manenti, 2006; Grosso, 2006; Lee, Marcu and Lee, 2011). While these studies and others, e.g. (Yates, Gulati and Weiss, 2010) provide insights into fixed broadband diffusion, there are only a handful of studies that explore mobile broadband.

2.2 Mobile broadband

We narrow the focus of this study to mobile broadband for two reasons: First, mobility can enable more widespread access to broadband (e.g., using smart-phones and other wireless devices); and second, less infrastructure is required to deploy mobile services. In spite of these advantages, however, there is very little affordable mobile broadband in developing countries to date (World Bank, 2012; ITU, 2013).

Even though data from the United Nations (2010) and ITU (2012, 2013) confirm that per capita income is an important driver of mobile broadband affordability and diffusion, factors other than income are at work. For instance, political structure and processes (Guillén and Suárez, 2005), and regulation and governance (Marsden, 2011; Waverman and Koutroumpis, 2011) have been found to be important

explanatory variables, in particular with respect to diffusion of narrowband and broadband Internet access.

Factors that have been shown to influence mobile broadband affordability and diffusion in developed countries include different forms of competition, level of income, fixed broadband price, national policy, standards, and infrastructure (Cabral and Kretschmer, 2007; Gruber and Koutroumpis, 2010; Lee, Marcu and Lee, 2011; Smith, 2010). Gruber and Koutroumpis (2010) argue that multiple wireless standards and various types of services using different technologies facilitate competing systems that can provide for increased and improved mobile services. With regard to public policy and competing standards, Cabral and Kretschmer (2007) found that mobile diffusion levels in the U.S. (where multiple standards are used) are similar to Europe (where mostly single standards are used). Cava-Ferreruela and Alabau-Muñoz's (2006) study of OECD countries found that technological competition, low costs of deploying infrastructure, and predisposition to invest in new technologies are key factors for fixed broadband access and use. Finally, Lee, Marcu and Lee's (2011) study showed that for 30 high-income OECD countries, having multiple standards in the market is associated with a high level of mobile broadband penetration.

Earlier studies in the literature, e.g. (Chinn and Fairlie, 2007; Norris, 2001; Rouvinen, 2006), focus primarily on gaps in access to and use of ICTs that predate but are closely related to mobile broadband, namely the Internet and mobile telephony. These studies show that competition to provide telecommunication services lowers the cost of access to ICTs, and that higher income results in higher usage of these services. Rouvinen (2006) found that market competition increases mobile telephony diffusion in developing and developed countries; but that standards competition hinders diffusion in the developing world.

2.3 Gap identification and hypotheses

The literature review above shows that several factors have the potential to positively or negatively contribute to broadband affordability and diffusion. Policy initiatives, regulation, and the national context in which these are collectively reduced to practice are the most likely determinants of mobile broadband affordability. However, as previously noted, to our knowledge there are no previous cross-national studies that discuss all of these factors with respect to broadband affordability. Nor have previous cross-national studies focused on global diffusion of mobile broadband, one of the most important technological enablers for promoting economic development, social inclusion, and thus reducing the global digital divide (Warschauer, 2004; World Bank, 2012). We formulate two sets of hypotheses that draw from the literature on policy and regulation and a third set of hypotheses that shed light on factors related to political structure, government performance, and regulatory governance. In particular, here we focus on policy (hypotheses HP1a and HP1b), targeted regulation (hypotheses HR2a and HR2b), political structure and processes (HG3a), and also governance (hypotheses HG3b and HG3c). Specifically, our hypotheses are:

HP1a: The presence of competition to provide mobile telecommunication services increases a nation's mobile broadband affordability.

HP1b: Financial investment in the telecommunications sector increases a nation's mobile broadband affordability.

HR2a: Regulatory measures that engage governments in the telecommunication standards process increase a country's mobile broadband affordability.

HR2b: Regulatory measures that empower governments to manage licenses for telecommunication service providers increase a country's mobile broadband affordability.

HG3a: A more democratic political structure increases the affordability of mobile broadband services.

HG3b: Rule of law & control of corruption increase the affordability of mobile broadband services.

HG3c: The presence of a national independent telecommunications regulator increases the affordability of mobile broadband services.

While previous research provides rich detail on the connection between public policy initiatives and technological development as well as the challenges to realizing specific policy objectives, it is impossible to make any valid generalizations on the contribution that policy and other factors (both related and contextual) have on bridging the mobile broadband digital divide. In the next section, we operationalize the dependent and independent variables (see Section 3.1 and Sections 3.2 through 3.5). The subsequent section, Section 4, is devoted to testing the research hypotheses described above.

3. Data and methods

We test our hypotheses that national policy initiatives to promote ICTs, targeted regulation, and government structure, processes and performance increase mobile broadband affordability with OLS multiple regression analysis on data from 103 countries. Although mobile broadband price data were available for 108 countries, there were five countries with other missing data, which prevented these countries from being included in the log-linear regression model described in Section 4.

For this study, most secondary data were acquired from the United Nations (2010), World Bank (2010), and International Telecommunication Union (ITU) (2012, 2013) as these sources provide the most detailed and comprehensive cross-national information regarding broadband diffusion and price, and also factors that influence these variables.

3.1 Dependent variable

The indicator for mobile broadband affordability is the mobile broadband price sub-basket, as reported by the International Telecommunication Union for 2012 (ITU, 2013). This mobile broadband sub-basket is calculated as the average of two costs: the price of a 500 MB prepaid handset-based monthly plan and the price of a one GB postpaid computer-based plan, where each price is divided by the monthly per capita gross national income (GNI) to yield a “normalized” cost. The rationale behind this calculation is that prepaid mobile broadband plans dominate in less affluent countries whereas post-paid mobile broadband plans dominate in more affluent countries. Calculating an average sub-basket cost therefore allows policymakers and practitioners to compare costs between countries. Note also that this average cost measures the cost of mobile broadband services relative to each country’s average income, thus measuring the affordability of mobile broadband Internet access. The large number of countries with expensive mobile broadband services yields a long tail of large values in the distribution of the normalized costs derived from mobile broadband price sub-basket data. We therefore take the natural logarithm of the income-normalized mobile broadband cost to be the dependent variable in this cross-national study.

All independent variables used in the multiple regression analysis described in Section 4 were sampled from prior years (i.e., 2007-2010) (CIA, 2012; ITU, 2012; Kaufmann, Kraay and Mastruzzi, 2011; Pemstein, Meserve and Melton, 2010; United Nations, 2010; World Bank, 2010), reflecting the fact that their effects on mobile broadband affordability are delayed with respect to their value in a given year.

3.2 Policy

We test hypotheses HP1a and HP1b using two different variables, calculated for each of the countries, which together reflect policy initiatives important to mobile broadband. The first is a specific indicator of competition to provide mobile telecommunication services. The second is a measure of financial investment in ICTs shared by the private sector, the public sector, and consumers.

We use a dummy variable to measure competition in the mobile telecommunications sector. Specifically, the level of competition in this sector is coded as follows:

“1” if there is full or partial competition to deliver mobile telecommunication services; and
“0” otherwise.

2010 data for this variable were obtained from the ITU’s ICT Eye database (ITU, 2012).

We reviewed a number of indicators in the World Bank’s World Development Indicators (WDI) database that could measure the financial investment and economic activity within and around the telecommunications sector (World Bank, 2010). No single indicator provided a comprehensive picture of investment and related activity, but focused on only a small segment of such investment. To address this concern, we constructed an additive index of seven indicators of a nation’s investment related to technological development. These seven indicators are: Telecommunications revenue (as a percentage of GDP); ICT expenditures (as a percentage of GDP); telecommunications investment (as a percentage of revenue); research & development spending (as a percentage of GDP); natural log of international Internet bandwidth (bits per second per person); high-technology exports (as a percentage of manufacturing exports); and, computer, communications and other services (as a percentage of service exports).

Of the nearly 240 variables available in the WDI database, we selected these seven because of their connection to financial investment and induced economic activity in information or communication technology. Because most of the benefits of such investment may not be realized until a few years into the future, we measure investment over a number of years by averaging the data available between 2000 and 2007. Once averages were computed for each indicator, we computed an aggregate *financial investment index* based on an average in the form of *Z*-scores of the seven indicators for each country.

3.3 Regulation

We test hypotheses HR2a and HR2b using two dummy variables, sampled for each of the countries, which together reflect important regulatory measures. The first variable is whether or not technical standards are regulated by the central government (Funk and Methe, 2001). The second is whether or not the government has the authority to grant and maintain telecommunication licenses (Gruber and Verboven, 2001). Data indicating whether or not each country’s government had these regulatory measures in place in 2010 were obtained from the ICT Eye database (ITU, 2012). These indicator variables were coded “1” if the respective measure was employed by the national regulatory authority or sector ministry and “0” if it was not.

3.4 Government and governance

We test hypotheses HG3a, HG3b & HG3c using three variables chosen to capture and distinguish the impact of government structure and government performance (i.e., processes and governance) on mobile broadband affordability.

To account for the impact of political (or government) structure and a culture of democratic politics, we included the Unified Democracy Scores (UDS) for 2008 as an independent variable. The UDS is derived through a Bayesian latent variable approach and draws from 10 frequently used indicators of democracy (e.g., Polity IV and Freedom House) to produce a single composite scale (Pemstein, Meserve and Melton, 2010).

We use the rule of law and control of corruption indicators from the Worldwide Governance Indicators (WGI) project (Kaufmann, Kraay and Mastruzzi, 2011) to assess governance practices in each country. These indicators of national governance measure perceptions by experts in the public and private sectors and NGOs worldwide and also citizens in individual countries regarding the ability of a nation’s

government to govern according to the law and control political corruption. Rule of law and control of corruption, in combination, have been shown in many cases to be essential for having national policy (e.g., see HP1a and HP1b) and regulation (e.g., HR2a and HR2b) be effective in advancing private sector development. This has been demonstrated for telecommunications policy and law in both the pre-Internet era (Levy and Spiller, 1996) and the Internet era (Waverman and Koutroumpis, 2011). Since these WGI variables are standardized, we use a simple average to combine them.

A more specific indicator of sound governance in the ICT policy sphere is the presence or absence of an independent national regulatory authority for telecommunications. Data indicating whether or not a country had such a national regulatory authority for telecommunications in 2010 were again obtained from the International Telecommunication Union's ICT Eye database (ITU, 2012). This variable was coded "1" if an independent authority was present in that year and "0" if it was not. In 2010, 64% of the countries had established an independent national regulatory authority for telecommunications.

3.5 Control variables

We include three control variables in our regression model that have a theoretical link to ICT affordability or an empirical link shown in previous research.

Previous cross-national studies of technology adoption have assumed that countries with an affluent population will be in a stronger position to spend more on emerging ICT technologies. Furthermore, people who have a higher level of income are more likely to demand that more services be made available over the Internet (van Dijk, 2005). We use the United Nations' Income Index for 2010 (United Nations, 2010) to capture the impact of the affluence of a nation's citizens on the dependent variable in our regression model.

Nations that have less of a disparity among its citizens in income, and the distribution of other resources, more generally, also should have less of a disparity in access to mobile broadband service and other forms of ICTs. Past research shows income inequality does predict inequalities in Internet access and use (Fuchs, 2009). We measure the level of income inequality with the commonly-used Gini coefficient (Dorfman, 1979). These data were obtained from *The CIA World Factbook* [see <https://www.cia.gov/library/publications/the-world-factbook/>] (CIA, 2012)] and (United Nations, 2010).

The first control variable (the UN Income Index) measures one of two important factors that are central to van Dijk's theory of the digital divide, namely *material access* to ICTs. The second factor, the skills necessary to use ICTs, or *skills access* to ICTs, is included in the third control variable, the United Nations Education Index (United Nations, 2010). We use this variable to capture the effect of the level of education within a given country in our regression model.

4. Data analysis: Mobile broadband affordability

The results of the multiple regression analysis of the log-transformed value for the mobile broadband price sub-basket based on two policy variables, two regulatory variables, and government structure and performance variables, as well as three control variables, are reported in Table 1. The ten independent variables sampled for 103 countries together explain 81.6% of the variance in mobile broadband affordability.

The first seven rows of data in Table 1 report the coefficients for variables specific to policy (HP1a & HP1b), regulation (HR2a & HR2b), and political structure, government and governance (HG3a, HG3b & HG3c). Since the dependent variable has been log-transformed, the unstandardized beta coefficients (***b***) should be interpreted as the percentage change in the dependent variable associated with a .01-unit change in the independent variable. Thus for a one-unit increase, the percentage change would be $100 * b$ (see, for example, <http://www.ats.ucla.edu/stat/>).

The first row of data reports the coefficients for the mobile telecommunications competition variable (ITU, 2012). The coefficients are statistically significant at the 0.01 level, which suggests that countries that encourage greater competition have access to more affordable broadband services. Privatization and competition in the computing and communication sectors can create a highly favorable environment for lower prices. In such an environment, mobile service providers deploy more efficient telecommunications infrastructure to connect users to the Internet and consumers are able to purchase superior products and services.

Independent Variables	Unstandardized Coefficients		Standardized Coefficients	Secondary Data Sources
	<i>b</i>	<i>Std. Error</i>	Beta	
Mobile telecom competition (HP1a 1=full or partial competition)	-594 ***	<i>.206</i>	-.132 ***	(ITU, 2012)
Financial investment index (HP1b)	.345 **	<i>.163</i>	.107 **	(World Bank, 2010)
Technical standards development (HR2a 1=present)	-.263	<i>.205</i>	-.058	(ITU, 2012)
Telecom licensing (HR2b 1=present)	.185	<i>.188</i>	.046	(ITU, 2012)
Democratic political structure (HG3a)	-.044	<i>.103</i>	-.027	(Pemstein, Meserve and Melton, 2010)
Rule of law & control of corruption (HG3b)	.021	<i>.109</i>	.015	(Kaufmann, Kraay and Mastruzzi, 2011)
Independent telecom regulator (HG3c 1=present)	-.151	<i>.154</i>	-.048	(ITU, 2012)
Affluence (UN Income Index)	-6.491 ***	<i>.657</i>	-.818 ***	(United Nations, 2010)
Income inequality (Gini coefficient)	.022 ***	<i>.007</i>	.159 ***	(CIA, 2012; United Nations, 2010)
Education (UN Education Index)	-.639	<i>.609</i>	-.076	(United Nations, 2010)
(Constant)	5.734 ***	<i>.632</i>		
Dependent variable: Natural log of income-normalized broadband price. N = 103; Adjusted R ² = 0.816; Std. Error of the Estimate = 0.573. Bold entries are unstandardized (b) & standardized (Beta) OLS regression coefficients; standard errors are in italics; *** p < .01, ** p < .05, * p < .10.				

Table 1. Multiple Regression Analysis Explaining Mobile Broadband Affordability

The coefficients for the financial investment index are statistically significant at the 0.05 level, but not in the direction that we anticipated. Instead of decreasing mobile broadband cost, we find that more

financial investment in telecommunications increases the cost of mobile broadband services to subscribers. When holding all other variables constant, a 0.10 unit increase in a country's financial investment index increases the cost of mobile broadband services by 3.5% ($b = .345$). A country that has the mean value (-0.043) on the financial investment index would have a cost that is approximately 61% higher than a country that has the minimum investment index (-1.808). And a country that has the maximum value (1.742) would have a cost that is about 62% higher than a country with the mean value. It is clear that greater financial investment in previous years (2000-2007) means subscriptions to mobile broadband are more expensive in 2012 (ITU, 2013). In sum, there is compelling support for hypothesis HP1a and evidence that refutes hypothesis HP1b. More affordable mobile broadband is associated with competition to provide mobile broadband services. However, more costly mobile broadband is associated with greater financial investment in ICTs in previous years, even after a lag of five or more years.

The coefficients in the third and fourth rows show no relationship between either technical standards development or telecommunications licensing and less costly mobile broadband. Likewise, the coefficients in rows five through seven show no relationship between either political structure and processes, regulatory structure, or rule of law & control of corruption, and mobile broadband cost. In sum, there is neither support for our hypotheses suggesting that regulation impacts mobile broadband (HR2a & HR2b) nor our hypotheses for political structure, government, and governance (HG3a, HG3b & HG3c). Based on our findings for policy initiatives described earlier, what matters more appears to be how and to what extent public policy is working in practice to serve the public interest by moderating the price of mobile broadband services.

Rows eight through ten capture the effects of our control variables. Increasing levels of income has a substantial and favorable effect on the cost of mobile broadband services. A .01-unit increase on the Income Index decreases the cost of mobile broadband by about 6.5% when controlling for all other variables. The coefficients for the United Nations Income Index are statistically significant at the .01 level. Countries with a more affluent population may face a greater demand for broadband access to the Internet. The data suggest that the public and private sectors have begun to respond to meet this demand. Moreover, the standardized beta coefficient (**Beta** = -.818) shows that the level of income is the most important factor in explaining mobile broadband cost in these countries. We believe that there are both demand- and supply-side reasons for this finding. On the demand side, per capita income is used both to normalize mobile broadband price in the ITU data (to yield affordability, as described in Section 3.1) and to calculate the Income Index, which causes an inverse relationship between mobile broadband affordability and the Income Index. On the supply side, we expect that mobile telecommunication service providers are more likely to enter more affluent national and regional markets and compete for market share, in part based on the price of services, especially before diffusion in the population approaches saturation.

As the coefficients in the ninth row show, there is a strong and statistically significant relationship between income inequality and mobile broadband cost. When holding all other variables constant, a one-unit decrease in a country's Gini coefficient decreases a country's mobile broadband cost by 2.2%. A country that has the mean value (40.1%) on the Gini scale would have a cost that is approximately 37% higher than a country that has the minimum Gini coefficient (23.0%), e.g., Sweden. And a country that has the maximum value (65.8%), e.g., Seychelles, would have a cost that is about 56% higher than a country with the mean value. These findings complement work by Fuchs (2009), who showed that income inequality is a significant factor in determining diffusion of narrowband Internet.

The coefficients for the last variable — the UN Education Index — are not statistically significant. While higher overall levels of income and lower differences in income both increase the affordability of mobile broadband, the same cannot be said of higher levels of education. Thus, promoting economic growth in

general may be the most effective means for bridging the mobile broadband digital divide in less affluent countries.

4.1 Goodness of fit and multicollinearity

Because the adjusted R^2 in Table 1 was so high, we investigated to what extent multicollinearity was present in the multiple regression model summarized in this table. There were three variables in this model that had large variance inflation factor (VIFs); rule of law & control of corruption (our WGI governance variable) had a VIF of 3.5, affluence (the Income Index) had a VIF of 3.8, and education had a VIF of 2.9 in our log-linear regression model, which had a mean VIF of 2.0. Maximum VIFs that are greater than five to ten are considered cause for concern, however, this threshold depends on many factors including the characteristics of the data set. We therefore examined cross-correlations between the independent variables in our model. The correlation between income and WGI governance and income and education for the countries in our data set was high, i.e. 0.75 and 0.78, respectively. Even education and governance had a moderate-to-high correlation coefficient of 0.61.

In an attempt to distinguish between the effects of WGI governance, income, and education, we estimated three different regression models with eight independent variables instead of the 10 shown in Table 1. In each of these regression models, we eliminated two of high-VIF variables, but kept the third. We observed three interesting things about these models. First, in all three models the VIFs decreased to have maximum values less than 2.1 and mean values less than 1.4 (both found in the model that included rule of law & control of corruption as a measure of public-sector governance). Second, in each model, the high-VIF variable in Table 1 – rule of law & control of corruption, affluence, and education – had the largest standardized coefficient in the model. Thus, in addition to exhibiting moderate-to-high or high cross-correlation, when considered separately from each other, these variables each had a strong and significant impact on mobile broadband affordability. Third, as in Table 1, income inequality was the second most important variable because it was associated with the second largest standardized coefficient in each of these models.

Of the four models of mobile broadband affordability estimated in this study, the one with the largest coefficient of determination, with an adjusted R^2 of 0.816, was the 10-variable model presented in Section 4. The model with the smallest coefficient of determination (0.482) was the 8-variable model that included WGI governance, but excluded income and education.

In sum, it is clear that income and income inequality are the most important factors in determining mobile broadband affordability. However, it is not possible to precisely distinguish the effects of income, education, and WGI governance using our data set. Although beyond the scope of this study, it is likely that the findings summarized in Section 4 (and Table 1) overstate the coefficient of determination and the role of income, and understate the role of education and governance, in determining mobile broadband affordability. The diffusion of innovation theories described in Section 2 suggest that income *and* education should both have an impact on affordability of ICTs (Norris, 2001; Pick and Sarkar, 2015; Swan and Scarbrough, 2005; van Dijk, 2005). Likewise, case studies (Levy and Spiller, 1996) and empirical evidence (Waverman and Koutroumpis, 2011) suggest that rule of law & control of corruption should also matter, however, we were only able to provide empirical evidence for these connections in models that excluded the Income Index (United Nations, 2010).

5. Implications, conclusions, and future work

Our research assesses the impact of policy, regulation, political structure, and public sector performance on mobile broadband affordability. We showed that countries that encourage competition among telecommunication service providers and have less income inequality have greater material access to mobile broadband services (van Dijk, 2005). Specifically, these two factors have a positive and significant

relationship with the income-normalized price of mobile broadband services (ITU, 2013). We also found that more financial investment in telecommunications increases the price of mobile broadband services. It is clear that greater financial investment in previous years means subscriptions to mobile broadband are more expensive in 2012, especially in developing countries. This suggests that service providers are still recouping the cost of deploying the infrastructure necessary to provide mobile services, and have likely not yet achieved the economy of scale required for the price of mobile broadband to begin to fall. Two additional findings also demonstrate that accepted regulatory practices that can improve diffusion of mobile services do not directly affect their affordability. First, we showed that the practice of granting and maintaining licenses for telecommunication service providers appears to have no effect on mobile broadband affordability. Second, we presented evidence that it is not necessary for national governments in to engage directly in the development of technical standards, but instead to depend on private sector activities moderated by government agencies in other countries. For this evidence to be conclusive, however, a more in-depth investigation of telecommunications licensing and standards development for mobile broadband and related ICTs is needed.

This is the first cross-national study of mobile broadband to assess the impact of regulation and public sector performance using a broad range of indicators. Previous studies have relied on single indicators, e.g. (García-Murillo and Rendón, 2009), and, thus, omitted measurement of important public sector activities. It was surprising, however, that neither political structure and processes, nor regulatory structure and regulations had an impact on a country's mobile broadband affordability since there were strong theoretical reasons for expecting this to be the case (e.g., see Norris, 2001; van Dijk, 2005; Warschauer, 2004). It is therefore unlikely that the promise of mobile broadband will become a reality in laggard nations without transformations in national strategy and public policy. Because the policy initiatives we evaluated are intended to support the ICT sector as a whole and telecommunication industries more specifically, some of these initiatives, e.g., competition among telecommunication service providers, will have a positive impact on mobile broadband affordability.

One important limitation of this study, however, is that the coefficient of determination of our regression models explains between 48% and 82% of the variation in mobile broadband affordability. This means there is an opportunity for new or improved models to explain between 18% and 52% of this variation. Additional analysis (see Section 4.1) suggests that developing and testing alternative independent variables for technical standards, governance, affluence, and education is a promising place to start. For example, Pick and Sarkar (2015) use socioeconomic and governance data from other sources, e.g. The World Economic Forum, in their analysis of global digital divides and how they are changing. The Human Development Reports, e.g. (United Nations, 2010), publish measures such as the Human Development Index, the Inequality-Adjusted Human Development Index, Multidimensional Poverty Index, etc., any of which could be incorporated into an improved model for determining mobile broadband affordability.

There are of course other factors that contribute to understanding the affordability of mobile broadband services across the globe. There may be more precise activities or norms within the public sector that explain greater access to mobile broadband that also can be measured. Wilson and Wong (2006), for example, demonstrate the importance of "information champions" in explaining variation in Internet access and use across African states. The appointment of a chief information officer could indicate an even stronger commitment by a nation to advancing the use of emerging ICTs. External leadership also may influence transformations in the public sector. Finnemore (1993) shows how the United Nations Educational, Scientific, and Cultural Organization (UNESCO) provided valuable educational assistance to nations in creating science bureaucracies after World War II. Nations can learn from each other as well, and there are studies which suggest that governments adopt policy innovations from nations seen as their socio-cultural peers and from neighboring states that have demonstrated past success with new policies (Simmons and Elkins, 2004).

Still, the global broadband digital divide characterized by inequalities in fixed line broadband Internet affordability seems to be perpetuating in mobile broadband affordability, and this supports Rogers' theory of diffusion of innovation – the linearity of his model is clearly illustrated by these similarities between fixed and mobile broadband affordability. However, HP1a was supported but HP1b was refuted, and one could argue that this reflects the more interactive view of innovation (e.g., Swan et al. 2007). Competition and financial initiatives can be undertaken by national policymakers in very different ways (more or less innovative); therefore the (positive) effects of such initiatives might be seen only in the long-term, as back-and-forth interactions might be needed between stakeholders. An additional takeaway of our paper is that innovation processes (especially those involving its diffusion) are often unpredictable and don't always follow a simple 'rule' [as Rogers (2003) suggests]; our results, by partially supporting Rogers' linear model and partially Swan et al.'s interactive model are illustrative of the complexity of diffusion processes involving broadband affordability.

Our findings shed light on the complex nature of innovation processes, and theoretically contribute to prior literature by demonstrating that affordable mobile broadband is driven first and foremost by policy. In turn, policy can help create or improve effective regulatory measures and eliminate or modernize ineffective regulation. For strategy, policy and regulation to produce favorable outcomes, they should be reduced to practice with the appropriate political structure and sound public-sector governance. Finally, we believe the empirical findings in this study can guide decision makers in capitals across the globe to take an active role in improving public sector performance, and also developing a healthy ICT sector. If properly guided, such changes should reduce inequalities in access to mobile broadband services and thereby allow the ongoing information and communication revolution to improve the lives of those in developing countries who have yet to benefit.

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