When is cheap, cheap enough to bridge the digital divide?

Modeling Income Related Structural Challenges of Technology Diffusion in Latin America

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ABSTRACT:

The article presents a model that shows how income structures create diffusion patterns of Information and Communication Technologies (ICT). The model allows the creation of scenarios for potential cuts in access prices and/or required subsidies for household spending in Mexico, Uruguay, Brazil and Costa Rica. One analyzed scenario would require the reduction of ICT prices to as low as 4% of the current price levels (to US$0.75 per month), or alternatively, a subsidy as high as 6.2% of GDP (a figure equivalent to public spending on education plus health). Neither existing technological solutions nor existing financial mechanisms are sufficient to cope with this challenge. Alternatives are discussed.

Keywords: Information and Communication Technology ICT, digital divide, Internet, public access, household spending, Latin America, Mexico.

Introduction

The heated discussion about the digital revolution has already spanned two decades and is far from cooling down. It has been widely reported that the increased pervasiveness of digital Information and Communication Technologies (ICT) leads to significant contributions to development, including economic growth (e.g. Cole, 1986; Mody and Dahlman, 1992; Waverman, et.al., 2005; Indjikan and Siegel, 2005), democracy and transparency (e.g. Coleman, 2005; Banisar, 2006; Hilbert, 2009), education (e.g. Marshal and Taylor, 2006) and cultural development (Castells, 2004), among others. After a thorough and well-cited analysis, Castells (1998, p. 367) reaches the conclusion that "the generation of wealth, the exercise of power, and the creation of cultural codes came to depend on the technological capacity of societies and individuals, with information technologies as the core of this capacity."

The nature of the diffusion process of the related innovations resembles a well-known S-curve from centre-periphery, whereby the centre can be characterized as being more developed and the periphery as underdeveloped (e.g. Mahajan and Peterson, 1985; Rogers, 2003). The unfolding of the curve inevitably creates a divide between those that can first benefit from the innovation and those excluded. In the case of ICT diffusion patterns the term "digital divide" has been coined to describe the fact that some already use digital tools, while others are still deprived of access and the potential opportunities that follow from it (e.g. NTIA, 1995, 1999; OECD, 2001; ITU, 2009).

Both arguments together describe a double-edged sword. Technology is not only a parent of wealth and development (creates it), but also its child (stems from it). It has therefore the potential to spawn either a virtuous or vicious circle between existing or missing development and technology. The urgency to work on this challenge arises from the rapidly closing window of opportunity related to the dynamic between development and technological progress (e.g. Perez and Soete, 1988; Freeman and Louca, 2001). The excluded could either be armed with new empowering tools despite their unfavorable starting position or their relative situation could worsen while the benefits once more enable the already well-off to make headway.

This article focuses on the access dimension of the digital divide and analyzes the economic feasibility of providing universal ICT services. It presents a model that simulates the dynamic between access prices, eventual subsidies and ICT penetration rates, and as such allows the exploration of feasible options. A quick thought experiment sets the stage for the subsequent exercise: it has been claimed that a US$100 laptop would enable us to provide "one laptop per child" throughout the developing world (Negroponte, 2005). The World Bank reports that around 40% of the world population lives with less than US$2 per day. Optimistically estimating that they spend 2.7% of their income on communication (more on that in Figure 1), the poor would have US$20 per year available to spend on ICT (2*365*0.027). That would be enough to buy one US$100 laptop each fifth year. While this result does not sound too shocking, it has to be remembered that this person is not expected to spend another cent on any other form of communication during these five years (no letter post, not one phone call, etc) and still has not connected the laptop to any kind of network. Correspondingly, the scenario looks worse for the 15% of the world population living with less than US$1 per day. One alternative would be to call for public subsidies, providing free or at least cheap connectivity for the poor. How much would this cost? The other alternative would be to reduce prices even further. How cheap, is cheap enough to bridge the digital access divide?

This article tackles both questions by following the outlined logic. It presents a model to simulate various scenarios. The exercise is carried out for four representative countries: Mexico, Uruguay, Brazil and Costa Rica. We start by finding a valid working definition of the digital divide for our purposes. As a second step we empirically justify our income-based model by looking at the importance of income distribution as a predictive variable for the digital divide. We then verify ICT spending per income level in the third section. The available resources for ICT in each income quintile can be understood as the potential market, which is then compared to the current cost of ICT access for each income segment. As a next step, we can quantify the gap between access prices, spending levels and actual ICT penetration rates per quintile, as done in the fourth section. Subsequently, we apply the model to analyze three exemplary future scenarios. The results show how much it would cost to bridge the digital divide or, alternatively, when cheap is cheap enough for the market to close the divide. For example, one scenario consists in bringing ICT access levels from below 20% for Internet and around 50% for telephony up to electricity penetration rates, which are currently above 95% in Latin America. In Mexico, for example, providing the economic possibility of ICT access to the poorest 20% of society would require to reduce current access prices of estimated US$244 per year down to US$35 per year (US$3 per month, or a price reduction down to 13%of current prices). In Brazil, the poorest 20% of the population counts with merely US$9 per year to spend on ICT (US$0.75 per month), implying the necessity to reduce current ICT prices down to 4% of its current level of US$220 per year. This is the economic reality of these income segments and the magnitude of the challenge to provide "one ICT access per child". Alternatively, a (direct or indirect) subsidy could be given to balance the purchasing power of these segments. In the case of Uruguay, this subsidy would need to be as high as 6.2% of GDP, which is equivalent to Uruguay's public spending on education plus health. This shows that the governments of developing countries (and their economies) currently do simply not posses the means to provide personalized access to all, even if they opted for the cheapest equipments. The article ends by discussing the odds in the light of this reality and explores complementary ways to bridge the digital divide. This includes the economic feasibility of sustainable public access to ICT, which has proven to be a viable way to reduce access prices by sharing the fixed costs of the technology. The income reality of the world's poor argues for the need of policy strategies that prepare for a long period in which public access will be the only viable access solution for significant parts of the developing world. However, the required financial mechanisms for such a period are currently not in place. The article ends by discussing innovative proposals in this regard.

How to define the digital divide?

The term "digital divide" is that rare breed of a new concept that has the ability to camouflage into the author's intended meaning, often leaving confusion or tedious semantic quarrels behind. It is usually defined as the divide between those included and excluded from the digital age, leaving lots of room for interpretation.

In general, distinctions can be made with regards to the group of users (countries or population segments), the kind of technology under consideration (mobile or fixed; voice or data; communication or computing, etc) and the stage of adoption. The most straightforward notions of the digital divide select a specific technological solution as a representation of the bulk of digital technologies (such as telephones or Internet subscription) and compare the amount of equipment or services between societies (international digital divide) or within different social segments of one society (domestic digital divide). Beyond this, different stages can be distinguished in the process of technology adaptation. In his traditional work on the "diffusion of innovations", Rogers (2003) has famously distinguished among five different stages of adoption. Statistical practitioners interested in measuring the nature of the digital divide have merged these five stages into three consecutive steps: ICT access, use and impact (OECD, 2002). Even though there might be a positive relation between the amount of ICT equipment, its usage and its impact, one of them does not automatically imply the next. The complexities in the steps from access to productive usage and from usage to impact have been widely discussed, such as in the productivity paradox of the 1980s or the new-economy hype of the late 1990s.

As a result of these distinctions many different proposals have been made on how to conceptualize the embracement of technology in each one the these stages and how they are related and intertwined with existing socio-economic and geo-spatial inequalities (e.g. Warschauer, 2003; Mossberger, et.al., 2003; van Dijk, 2006; Buys, et.al, 2009). The determinants of the divide can be assessed in each stage of the adoption process and with regards to all of the diverse existing technologies, or their combination. For example, access might depend on financial limitations, which also manifest themselves in geo-spatial requirements of infrastructure deployment, while productive usage will eventually depend on how the installed equipment is embraced, drawing the focus of attention to skills and motivations, among others. The final impact of the technology will ultimately be influenced by the purposeful application of the installed equipment, often requiring the readjustment of the general *modus-operandi* of the cultural and institutional setting, which leads to a complex dynamic of social change. Depending on the definition and the scope of the exercise, the results can be contradictory and either argue in favor of a rapidly closing digital divide (Compaine, 2001) or one that is still deepening (van Dijk, 2005).

The common feature of all studies is the inclusion of the access dimension of the divide, which might not be sufficient, but is a necessary first step. Without neglecting that the discussion of the digital divide can become much more complex, it will be enough for the scope of this paper to focus only on this indispensable dimension.

Regarding the access dimension it is important to distinguish "universal access" versus "universal service". United Nations International Telecommunications Union (ITU) defines that universal access implies that everyone in a population has access to publicly available communication network facilities and services, typically provided through such means as pay telephones, community telecentres and community Internet access terminals; while universal service focuses on promoting or maintaining universal connectivity of all households to public network facilities and services, and at affordable prices (ITU, 2007). Over the late 1990s, it seemed that the focus should turn to universal access, instead of pursuing the ambitious goal of universal service. However, the focus on universal service was revived by a couple of occurrences, including the mobile phone revolution, which had shown that it was possible to provide personalized services to most of the world's population (mobile phone penetration has reached 60 percent of the world's population in 2008), and by the discussion that has been unleashed by the "One Laptop per Child" initiative (Negroponte, 2005).

In 2005, the MIT driven "One Laptop per Child" initiative announced the ambitious goal to produce a "$100 laptop" that would revolutionize education by being within reach of each child in the developing world. Due to various reasons, the plan did not accomplish its goal during the years to come (The Economist, 2008a). During 2008 the initiative announced a temporary "Give One, Get One" scheme in the developed world, encouraging people to pay US$ 399 for two of the laptops, one of which would be given to child in the developing world. The initiative set in motion a snowball effect that went far beyond the potential benefits of a single quick-fix solution. The chipmaker Intel swiftly announced an alliance with software giant Microsoft to commercialize their own education-oriented laptop, called Classmate. The Classmate was first to push the price under the US$ 300 mark and the "laptop war" has been raging ever since (The Economist, 2008b). The Indian government surprised everyone with the announcement of a "$10 laptop" in 2008, but quickly readjusted its target to the well-known US$100 mark (Ribeiro 2008). At the same time private market analysts saw this goal at least three years away, with an uncertain future (Gartner, 2008). Independent from the intricate details of the ongoing projects, it had become clear that price reduction of digital access equipment became a concern of mayor interest for policy makers and industry. The race is on and universal service had once again become the benchmark for bridging the digital divide.

In this paper we will contribute to this and related discussions by evaluating basic questions like if US$100 is actually low enough to provide "one laptop per child"? Is universal service a feasible goal in the mid-term, maybe in combination with public subsidies? Answering these specific questions does not provide coherent policy advice on how to bridge the access divide, but it grounds the current discussion on the reality of existing income structures in the developing world. The results provide normative guidelines to direct policy options, much in line with Seneca's logic that if one does not know to which port one is sailing, no wind is favorable[i]. It is beyond the scope of this article to identify the right winds to guide us from normative objectives to concrete ICT access solutions, as it is much further beyond our focus to explore how to get from access to optimal usage and real impact.

How important is income distribution for the digital divide?

Models are idealizations of reality. Because reality is too complex, models work on an elevated level of abstraction, selectively choosing to ignore parts of reality, while focusing on what is seen as the variables with the largest explanatory power. Modeling the access dimension of the digital divide is no exception and there are countless variables that define the domestic dynamic. In this section we will explore if it is justifiable to elaborate a model of the digital access divide that only focuses on income as an explanatory variable.

It has been shown that the same long established determinants of socio-economic inequality also define the digital divide, including income, education, skills, employment, geography, age, gender and ethnicity, among others (e.g. Cullen, 2001; Hilbert and Katz, 2003). In Latin America, the region that persistently shows the world's most skewed income distribution (ECLAC, 2008), it is not surprising that income structures is seen as the most influential attribute to explain access inequalities (Katz and Hilbert, 2003; Peres and Hilbert, 2009). Brazil for example, the region's largest country (with over 37% of the region's GDP and 34% of Latin America's population), has one of the most unequal income distributions. The richest 10% of society receive around half of the national income, while the second richest count with a 15% share, and the poorest decile has to manage with less than 1% of the available resources. Uruguay, one of the smallest countries of the region (.8% of the region's GDP and .6% of its population), has the most equal income distribution, with the richest 10% of the population receiving 37% of income, the second decile 15% and the poorest decile 2%.

Let us take a closer look at the importance of income as a determinant of access in Brazil and Uruguay. During recent years an effort has been made by national statistics institutes to incorporate ICT indicators into household questionnaires throughout Latin America (Olaya, 2008; Partnership, 2008). This now allows us to perform multivariate analysis on the determinants of variables like Internet access. For our purposes, discriminant analysis seems to be good choice among the various alternatives of multivariate analysis. It tests for a linear combination of variables, which –when appropriately weighted—will maximally discriminate between those who have access and those who do not have access[ii].

Taking the 2007 household survey of Brazil (OSILAC, 2009) the following 10 potential variables have been chosen to explain household Internet access: per capita household income per decile; personal level of education (without, primary, secondary, postsecondary and tertiary); household size (single and double vs. larger families[iii]); age (in groups from 5-14, 15-24, etc); current school or education enrollment; job category (in four broad groups[iv]); geographical region (urban vs. rural); installation of color TV in household[v]; gender (male-female); and last but not least, ethnicity (as auto-identification of belonging to an indigenous group or not[vi]). The results can be seen in Table 1, second column.

Tests for multicollinearity indicated a low level of multicollinearity[vii]. The overall test was significant (Wilks λ = .682, Chi-square = 3.44E7, df = 10, Canonical correlation[viii] = .564, p <. 001), but not very strong. The identified discriminant function accounted for 32% of the variance in Internet access. This is an acceptable degree of correlation, but shows that there must be other variables to explain who has and who does not have access to the Internet at home. Reclassification of people based on the newly identified function was quite successful: based on the identified function 78.5% of Brazilians were correctly reclassified into the original categories of having or not having home access. The most interesting result for our purposes is the importance of the income variable. The weights of the standardized canonical discriminant function (see Table 1) tell us how the ten original variables combine to make a new one that maximally discriminates between Brazilians who have and those who do not have household Internet access. We can interpret the standardized discriminant function coefficients as a measure of the relative importance of each of the original predictors. Income level (.753) is by far the strongest predictor for Internet access, followed by the level of education, household size and age.

Table 1: Results of discriminant analysis of household Internet access for the individual

	Standardized Canonical Discriminant Function Coefficients				
	Brazil 2007	Brazil 2005	Brazil 2002	Uruguay 2005	Uruguay 2007
Income per decile (p.c. of household)	.753	.743	.704	.799	.755
Education of person	.416	.487	.556	.423	.464
Household size (single/pair vs family)	.345	.305	.249	.431	.404
Age	.131	.167	.207	.084	.094
Enrollment in school/education	.115	.118	.117	.114	.122
Job category	.113	.077	.061	.026	.050
Color TV in household	.060	.117	.164	.038	.028
Geographical region (urban/rural)	-.073	-.007	.048	n.a	-.038
Gender	-.023	-.023	-.021	-.027	-.038
Indigenous ethnicity	.008	-.007	-.004	n.a	n.a.
	Strength of overall correlation				
Wilks lamba	.682	.712	.751	.708	.696
Canonical correlation	.564	.536	.499	.540	.522
Reclassification success	78.5%	81.2%	80.6%	79.4%	79.2%

Source: own elaboration; based on OSILAC, 2009

One might wonder if this result depends on a specific stage of the diffusion process and if these results change over time? The same exercise for Brazil 2005 and Brazil 2002 (see Table

1) shows that these results are pretty stable over time. In addition, discriminant analysis has been carried out for Uruguay 2005 and 2007 to verify that the identified tendency also holds for smaller countries with a more balanced income distribution (see Table 1).

Of course these results cannot automatically be generalized to other countries. They have been chosen on basis of available statistics and the exemplary nature of two dissimilar countries. Table 1 reveals that the level of education also turns out to be an important variable and it remains to be seen what role it –and other variables—play in different countries and with regard to other grouping variables (such as Internet usage instead of plain access). Notwithstanding, these indicative results provide evidence that ICT access is significantly influenced by income distribution. These results give us enough justification to opt for a simplified model that simulates the complex dynamic of the closing digital divide exclusively in terms of income distribution. Such reduction of reality will surely not be perfect, because, as we have seen, there are other important explanatory variables. However, models are always an abstraction of reality and the presented results show that income is the single variable with the greatest predictive potential.

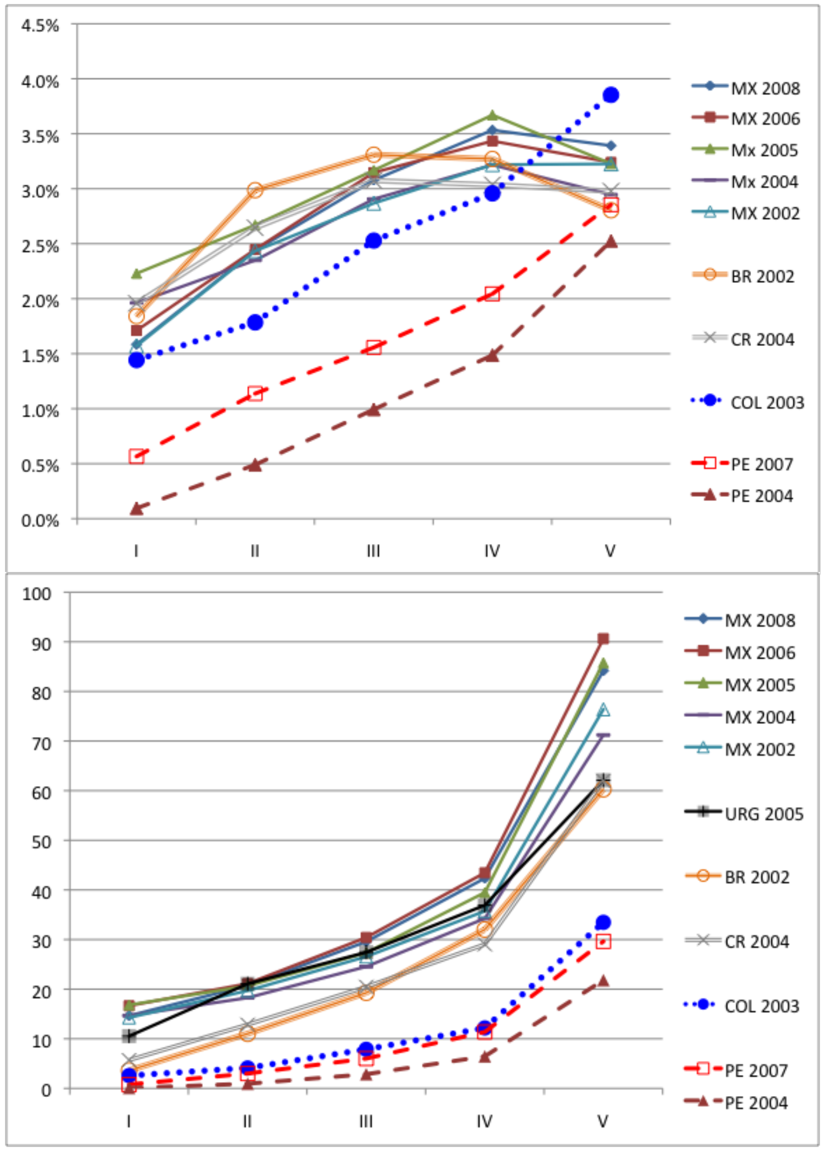
How much resources are available for ICT?

Official consumer and household spending questionnaires are scarce and valuable treasures for research in the developing world. Mexico, as a member of the statistics-savvy OECD, stands out as an exception. It has been possible to collect and harmonize some specific years for other countries as well (see Figure 1). The first thing that meats the eye when looking at Figure 1 is that spending unequivocally differs among income segments (here presented in quintiles; I: lowest income 20% of population; V: highest income 20%).

The top of Figure 1 shows a contradictory story with regard to the elasticity of household spending on communications. Traditionally consumption goods are either defined as 'necessity goods' or 'luxury goods', going back to Engel's (1857) pioneering work. Food is the prototype of a necessity good. Everybody needs to spend a comparable amount on it, implicating that the poor will end up spending a larger part of their total income on it. A luxury good, on the contrary, is characterized by elastic spending patterns, implying that the rich will spend significantly more on it than the poor, who do not depend on this good to satisfy their most basic needs. The top of Figure 1 shows that communication seems to be a luxury good for Peru and Colombia, which is in agreement with more specific research about this question in these countries (Gamboa, 2007; Aguero, 2008), while it seems to have some characteristics of a necessity good for the other countries (especially in the richest segments), which is also in agreement of previous research on those countries (Ureta, 2005). Is communication a luxury or a necessity?

The solution of this riddle can be found at the bottom graph of Figure 1. It shows that Peru and Colombia (with respective Gross-National-Income per capita of US$3,990 and US$4,660 in 2008) spend noticeably less in absolute value on communications than Costa Rica (GNI p.c.: US$6,060), Brazil (GNI p.c.: US$7,350), Uruguay (GNI p.c.: US$8,260) and Mexico (GNI p.c.: US$9,980). ICT are tradable goods and therefore are not much subject to price variations among different countries. This is different from non-tradable services, such as teaching for example. A teacher in Peru might cost considerably less than a teacher in Mexico. Not so for ICT. On the contrary, it can often be seen that ICT is cheaper in rich countries (which often produce them and have larger and frequently more competitive markets), than in poor countries (which have small markets and import the equipment). As a result, ICT spending is tied to absolute, not relative levels of spending. It seems that a certain saturation threshold has only been reached when household expenditure rises up to US$30-40 per month, making that roughly US$10 per person (see income segment IV of Costa Rica, Brazil and Mexico in both graphs). Before reaching this level, consumer continue to keep spending whatever they have available. In other words, the Figures suggest that communication spending below US$10 per person per month seems to be a necessity (for these years and these countries), while everything above appears to be an additional luxury.

Figure 1: Monthly household spending on communication, as % of total spending (top) and as absolute values in current US$ (bottom)



Source: own elaboration; based on INEGI (2000-2009), Encuesta Nacional de Ingresos y Gastos de los Hogares.2000-2005 en Mexico; INE (2006), Encuesta National de Gastos e Ingresos de los Hogares 2005-2006 en Uruguay; IBGE (2003), Pesquisa de Orçamentos Familiares 2002-2003 Brasil; INEC (2006), Encuesta Nacional de Ingresos y Gastos de los Hogares 2004 en Costa Rica; DANE (2004), Encuesta de Calidad de Vida del 2003 en Colombia; INEI (2004-2007), Encuesta Nacional de Hogares en el Peru.

How much does ICT access currently cost?

The spending figures give us a rough idea about the size of the potential market. Having quantified the demand side of ICT, we now need some figures from the supply side, in other words the price of ICT. This has to start with a definition of what ICT actually are.

The technological system that is generally referred to as ICT merges several previously separated evolutionary paths into one technological system. Traditional broadcasting technologies, such as radio and television, communication systems, such as the telephone, as well as storage devices, such as music players, and of course computing equipment make part of the dynamic that is often referred to as ICT-convergence. The current introduction of digital television is an epitome for how a traditional unidirectional information-disseminating technology is merging with bi-directional communication systems, while increasing its data processing capacities by adding different hardware and software solutions. Another example is third and forth generation mobile phones (3G and 4G), in which the telephony communication system is upgraded to include broadband Internet services and software applications. Eventually, digital TV and mobile Internet will also merge into a single technological system, becoming part of the network of networks (the 'Inter-net'), leading to all sorts of fixed or mobile solutions, for individual or collective use, with a specific resolution, bandwidth and storage capacity, blurring the traditional borderlines between broadcast, telecommunication and computation. The downside of this high-speed technological progress is that every new technological innovation reopens the digital abyss, constantly resulting in new inequalities between those who possess more and better information and communication processing capacities and those with lower ones. The digital divide becomes a moving target, and on top of that, one that moves at the rhythm of a technology that moves faster than anything we have seen in history so far (e.g. Hilbert and Cairo, 2009).

In this sense, much more pronounced than with other challenges of technology penetration, the digital divide is not only wide or narrow, but is also deep or shallow. Actually, as the extraordinarily fast innovation cycle persistently emphasizes qualitative differences, the digital divide will never be "closed" in a uniform sense. Some people will always have more information processing capacity than others. However, we are able to build a bridge over even the deepest abyss. "Bridging" the digital divide means therefore that every member of the so-called Information Society has continuous access to sufficient resources to be able to maintain minimum connectivity with its peers. The result is the challenge of constantly defining the terms "sufficient" and "minimum". Such reasoning has led to the concept of "digital poverty," with segments of society being below the dynamically evolving digital poverty line, and others above (Galperin and Mariscal, Eds, 2007).

Considering the dynamics of multiple access solutions and their short innovation cycles, it seems advisable not limit our analysis of the digital divide to a specific technology. Rather, we should consider connectivity as access to a combination of technologies, an 'ICT access packet', that allows people to communicate and to process information through digital means, leaving the technological implementation to individual choices and later policy considerations. Consequently, bridging the digital divide would mean that a minimum ICT access packet would be in reach for everybody, still conceding that some will always continue to have more connectivity than others.

Keeping in mind that our goal is to estimate the amount of resources dedicated to ICT, independently of future technological implementation, we nevertheless have to start with what is currently seen as the standard 'ICT access packet' to get a feeling for what is right now being spent on it. This can be done by reviewing current penetration rates of different ICT and include the most popular solutions into our packet. The most popular ICT access solutions in Latin America are fixed-line telephony (70% of all households in 2007), mobile phones (70% of all individuals), personal computers[ix] (45% of all households) and Internet (17% of all households) (OSILAC, 2007). We will stick to those four main technologies. We suppose that all members of the household share the fixed-line, as well as the computer and the Internet access. This inevitably favors the low-income segments, as low-income families tend to be larger in general (on average the household size of the poorest quintile in Latin America is around 4.5 members, while a household in the richest quintile counts with 2.5 members) (CEPALSTAT, 2009).

Table 2 shows annual ICT access prices for Mexico 2002, Mexico 2007, Uruguay 2005, Brazil 2003, and Costa Rica 2004, as national average and per income quintile. These numbers could easily have been obtained for more countries, but only these cases also count with the necessary household spending surveys and the related penetration rates (which we will need in the subsequent steps). Having said this, the final selection of these cases was determined by the availability of all necessary variables in the respective household questionnaires (OSILAC, ICT statistical information system, 2009), together with the availability of household spending statistics. Luckily these countries are relatively representative for the diversity of the region, being one large and one small country from South- and Meso-America in each case. Income levels of these countries vary from Costa Rica (GNI: US$6,060), Brazil (US$7,350), Uruguay (US$8,260) to Mexico (US$9,980) and are therefore almost exactly span the upper half of the region's income diversity. Unfortunately it is typical that poorer countries do not count with detailed statistical information to include them in these kinds of exercises.

The underlying methodology of Table 2 follows generally accepted assumptions. For the calculation of the price of fixed line telephony we stick to the methodology proposed by the United Nations International Telecommunications Union (ITU, 2009) and the World Bank's "price basket for residential fixed line", which capture the average monthly cost of a basic local fixed residential telephone service (in our case divided by the average household size per income quintile), plus 30 three-minute local calls per month to the same (fixed) network (15 peak ad 15 off-peak calls). For mobile telephony we include 30 one-minute outgoing calls per month (15 on-net and 15 off-net, that is to a network of the same and a different operator). ITU reports mobile tariffs for prepaid cell-phones. This is justified not only because the overwhelming majority of mobile phone users in the developing world uses prepaid phones instead of fixed contracts (in Mexico 95% of all mobile phone users; in Uruguay 85%), but because they are often the only payment method available to low-income users who might not have a regular income and will thus not qualify for a postpaid subscription based service. For Internet services it was decided to opt for the price of a 256 kbit/s connection for the household. This is the lowest non-dial-up connectivity usually available. It was decided not to opt for dial-up because this would have required an estimation of usage minutes and because dial-up option have become much more expensive per person than low-cost dedicated services, such as through a telephone line with DSL[x]. The price of this connection is divided by household size per income quintile. Last but not least, a USD 500 computer is chosen which would be in use for three years (which is seen as the average industry standard for computer obsolescence). This refers to some of the cheapest industry offers in the region[xi] (Laplane, et.al. 2007). It is assumed that the entire household also shares the computer.

Table 2: Annual ICT prices per inhabitant in US$, national average and per income quintile

MEXICO 2002	National	I	II	III	IV	V
Fixed-line telephony	103.8	93.3	99.4	102.6	109.2	120.0
Mobile phone	99.1	99.1	99.1	99.1	99.1	99.1
Internet	155.0	121.6	140.9	151.2	172.2	206.6
Personal Computer	41.7	32.7	37.9	40.7	46.3	55.6
TOTAL PACKET yearly	399.5	346.6	377.2	393.5	426.7	481.2
MEXICO 2007	National	I	II	III	IV	V
Fixed-line telephony	94.0	83.1	89.7	94.0	100.8	112.4
Mobile phone	57.3	57.3	57.3	57.3	57.3	57.3
Internet	111.5	84.8	100.9	111.5	128.4	157.0
Personal Computer	43.9	33.3	39.7	43.9	50.5	61.7
TOTAL PACKET yearly	306.7	258.5	287.6	306.7	337.1	388.4
URUGUAY 2005	National	I	II	III	IV	V
Fixed-line telephony	69.4	57.9	67.2	73.4	80.4	84.9
Mobile phone	133.7	133.7	133.7	133.7	133.7	133.7
Internet	208.8	142.4	195.8	232.0	272.4	298.3
Personal Computer	55.6	37.9	52.1	61.7	72.5	79.4
TOTAL PACKET yearly	467.5	371.8	448.7	500.9	559.0	596.3
BRAZIL 2003	National	I	II	III	IV	V
Fixed-line telephony	58.6	50.2	54.7	62.1	63.4	69.7
Mobile phone	85.7	85.7	85.7	85.7	85.7	85.7
Internet	102.2	79.5	91.7	111.8	115.4	132.5
Personal Computer	47.6	37.0	42.7	52.1	53.8	61.7
TOTAL PACKET yearly	294.1	252.5	274.9	311.7	318.3	349.6
COSTA RICA 2004	National	I	II	III	IV	V
Fixed-line telephony	20.4	19.3	19.3	19.3	20.7	23.6
Mobile phone	21.8	21.8	21.8	21.8	21.8	21.8
Internet	150.2	139.0	139.0	139.0	154.4	185.3
Personal Computer	45.0	41.7	41.7	41.7	46.3	55.6
TOTAL PACKET yearly	237.4	221.7	221.7	221.7	243.2	286.2

Source: own elaboration; based on ITU, World Telecommunications Database, 2009

These numbers therefore represent our 'ICT access packet', adjusted to family size per income segment. Realistically looking at the chosen services, this packet is rather at the very low end, meaning that it represents a minimum packet for somebody who would like to claim to be a full-fledged member on an "Information Society". Of course, an individual could make much more than one 3 minutes fixed-line call per day, or could easily spend more than one daily minute on the cell-phone. We will look at these possible variations in the following section.

How does income distribution create ICT diffusion patterns?

One way to check the validity of the estimations for our 'ICT access packet' is to multiply the prices with the penetration rates of those technologies, which should give us the amount of the respective ICT spending. If it turns out that this multiplication results 1:1 with the identified spending figures, it has been proven that our price estimations are accurate. If the result of the multiplication turns out to be below actual spending, the conclusion would be that individuals actually spend more on ICT than defined by our minimum 'ICT price packet'. For example, broadband connectivity could be increased far beyond 256 kbps (1000-4000 kbps connections are commercially available in these countries), while standard personal computers can easily cost up to US$1500-3000. If the multiplication of price levels with penetration rates would turn out to be above actual spending levels, it could be concluded that our packet is overestimated. In other words, in these cases users spend less than 3 minutes per day on the fixed-line or less than one minute per day on their mobile phone (for example by having a non-charged prepaid phone). The existence of prepaid mobile phones that are only used sporadically has been reported frequently in the developing world (e.g. Galperin and Mariscal, 2007). Another explanation for the overestimation of our packet might be that computers are not modernized every three years. It is not unusual to find 10-15 year old PCs and recycled computers throughout the developing world (e.g. REALC, 2009).

ICT penetration rates per income quintile can be seen in Table 3. Once again, the chosen countries include Mexico 2002, Mexico 2007[xii], Uruguay 2005, Brazil 2003 and Costa Rica 2004.

Table 3: ICT penetration rates per inhabitant; Affordable portion of 'ICT access packet'; national average and per income quintile

MEXICO 2002	National	I	II	III	IV	V
Fixed-line telephony	0.45	0.24	0.33	0.47	0.58	0.76
Mobile phone	0.25	0.18	0.24	0.29	0.31	0.27
Internet	0.07	0.01	0.02	0.04	0.12	0.22
Personal Computer	0.16	0.04	0.07	0.12	0.24	0.43
How much of the 'ICT access packet' can be bought: [indiv.spending] / ∑[penetration rate * price]	1.03	0.80	0.87	0.88	0.95	1.64
MEXICO 2007	National	I	II	III	IV	V
Fixed-line telephony	0.55	0.41	0.46	0.55	0.66	0.81
Mobile phone	0.60	0.34	0.54	0.67	0.72	0.91
Internet	0.12	0.03	0.05	0.09	0.13	0.44
Personal Computer	0.25	0.10	0.16	0.21	0.28	0.63
How much of the 'ICT access packet' can be bought: [indiv.spending] / ∑[penetration rate * price]	0.95	0.59	0.71	0.86	1.11	1.49
URUGUAY 2005	National	I	II	III	IV	V
Fixed-line telephony	0.73	0.48	0.75	0.85	0.91	0.98
Mobile phone	0.33	0.32	0.33	0.33	0.34	0.36
Internet	0.14	0.01	0.06	0.15	0.26	0.51
Personal Computer	0.24	0.05	0.16	0.29	0.42	0.62
How much of the 'ICT access packet' can be bought: [indiv.spending] / ∑[penetration rate * price]	0.76	0.39	0.69	0.77	0.88	1.07
BRAZIL 2003	National	I	II	III	IV	V
Fixed-line telephony	0.50	0.16	0.37	0.55	0.73	0.89
Mobile phone	0.39	0.13	0.27	0.38	0.54	0.79
Internet	0.11	0.00	0.01	0.04	0.14	0.46
Personal Computer	0.15	0.01	0.03	0.08	0.21	0.55
How much of the 'ICT access packet' can be bought: [indiv.spending] / ∑[penetration rate * price]	0.84	0.47	0.71	0.92	0.98	1.13
COSTA RICA 2004	National	I	II	III	IV	V
Fixed-line telephony	0.66	0.42	0.56	0.66	0.75	0.86
Mobile phone	0.45	0.17	0.28	0.39	0.55	0.80
Internet	0.21	0.01	0.04	0.09	0.21	0.57
Personal Computer	0.25	0.06	0.10	0.16	0.34	0.57
How much of the 'ICT access packet' can be bought: [indiv.spending] / ∑[penetration rate * price]	1.34	1.08	1.42	1.50	1.28	1.41

Source: own elaboration; based on OSILAC, 2009.

Table 3 also shows the result of the ratio between the average US$ spending per household member and the sum of the individual price of our 'ICT access packet' multiplied with the respective penetration rate (comparing real and expected spending). The national figures show that our price estimations have been quite reasonable. In the case of Mexico 2002, our estimations have only been 3% off the actual spending levels for the national average (1.03). However, taking a closer look at how this is distributed among the different income-quintiles, it can be seen that the richest 20% of the Mexican population seems to spend more than what would be expected with our 'ICT access packet' (i.e. 64% more; ratio [real spending]/[expected spending to purchase 'ICT access packet] = 1.64). This is not surprising, considering the large variety of expensive high-tech equipment and services available (including 3G and 4G mobile phones and expensive computer systems). Rich Mexicans buy much more ICT than are included in our packet. At the same time, multiplying penetration rates with the respective costs of the components of our packet shows that the average member of Mexico's 2002 poorest quintile can only buy 80% of our 'ICT access packet'. In agreement with what we have anticipated, we can conclude that those people make less intense use of ICT than what we expect with our minimum 'ICT access packet'. Those who have mobile phones do not use it every day for one minute and/or those who have a computer at home can be expected to have obsolete equipment, among other reasons.

The evolution of the digital divide in Mexico between 2002 and 2007 shows us that this tendency has become more pronounced in the poor segments over time (the ratio of [real spending]/[expected spending to purchase 'ICT access packet] in the poorest quintile falls from 0.80 to 0.59, implying that the average member of the poorest quintile can only by 59% of our 'ICT access packet' in Mexico 2007). While more of the poor are connected, the poor spend on average less on digital communication. In other words, while penetration rates have expanded (compare Table 3), it seems that this has, at least partially, been on the expense of the quality of the services purchased by the user in the low-income segment, while high-income segments proceed to higher quality services. As a consequence, the qualitative dimension of the digital divide widens.

Comparing Tables 2 and 3, the data show nicely how income structures contribute to create ICT diffusion patterns. For example, looking at the other quintiles of Mexico between 2002 and 2007 shows why connectivity has almost exclusively increased in the high-income quintile. As shown by Table 3, Internet access in quintile I, II, III and IV has only increased marginally (by 2, 3, 5 and 1 percentage points), while the high-income segment increased from 22% to 44% Internet penetration during this period. This is because Internet access (requiring a computer and connectivity) represents the largest part of ICT spending (50% of our 'ICT access packet', see Table 2) and those segments only have part of the required spending power. Mobile phone, on the contrary, has increased substantially also in the poorer quintiles, which is not surprising, considering that our mobile phone sub-packet has fallen from US$99 to US$57 (see Table 2, making that around 20% of our packet). It is therefore within the possibilities of most income groups (we will present the yearly personal spending per quintile in US$ in Table 4).

A special case is Costa Rica. Table 3 shows that all segments actually do spend more than what we would expect with our 'ICT access packet', and that despite the fact that it is the poorest country of our sample. Costa Rica counts with a public telecommunications provider (GRUPO ICE: soluciones de electricidad e Infocomunicaciones para la inversión en Costa Rica), a state owned monopoly created in 1963. It has survived various attempts of privatization and, as can be verified in Table 2, is providing exceptionally low fixed and mobile tariffs (Internet tariffs have also become among the lowest in the region by 2008; see ITU, 2009). This leads to the paradoxical fact that the poorest quintile of the (low-income) Costa Rican society (who spend 8% more than the cost of our 'ICT access packet') can buy more access than the richest quintile in (relatively wealthy) Uruguay (who only spend 7% more than our packet). Uruguay has a history of inadequate international connectivity and therefore traditionally high costs for Internet services, especially around 2005 (as can be verified in Table 2).

This closes our descriptive analysis. While our data do not give us a perfect description of reality–which is not surprising remembering all the previously analyzed factors that we have decided to leave out of our modeling effort—we have seen how income patterns relate to ICT diffusion patterns and that we can roughly model the digital access divide in this way.

What does our model tell us about future scenarios?

In this section we will apply the previously used logic to create three future scenarios of the domestic digital access divide in the analyzed countries. The two basic alternatives to bridge the income dimension of the digital access divide consist of either reducing technology prices to the level of available income (supply side policy), or increasing the purchasing power of the poor (demand subsidy, for example by public subsidies, international development aid or private philanthropic donations). We can analyze both alternatives with our model by changing the penetration levels to the desired level, and by multiplying these desired levels of connectivity with futuristic prices for our 'ICT access packet'. Scenario 1 focuses exclusively on reducing prices and explores how much we would have to cut the price of our 'ICT access packet' to reach a desired level of penetration. Scenario 2 supposes stable prices and estimates the amount of resources (as % of GDP) that would be needed in order to connect the desired percentage of population. Scenario 3 is more realistic and combines both of these approaches.

First we have to choose a diffusion level that we can reasonable consider as our "universal service" benchmark. We have to determine at which point the divide can be considered as being bridged. It would be slightly naïve to suppose 100%, as in reality there are always segments of society that fall between the cracks, especially in the developing world. A more realistic approach would be to strive for lifting ICT connectivity levels to the current levels of electricity services, supposing that, at least in Latin America, electricity is generally accepted to be universally available (Mexico: 95.7%; Uruguay: 98.5%; Brazil: 96.6%; Costa Rica: 99.1%). Table 4 shows electricity penetrations per income quintile. The difference between current levels of ICT penetrations and current levels of electricity penetration constitute our digital divide.

Scenario 1 in Table 4 shows the levels of required price cuts to reach the electricity penetration level. Scenario 2 in Table 4 shows the required subsidies (as % of GDP), if we would wish to enable these unconnected income segments to purchase our 'ICT access packet' at the current price level from Table 2. Those figures are shown as national aggregate and per income segment, whereby the poorest quintile has been divided into deciles. Table 4 also shows the personal spending levels in US$ per income segments.

Based on the data of Brazil 2003, for example, prices would have to be cut down to 3% of 2003 prices (to less than US$7 per year) to connect the unconnected of the poorest decile (Scenario 1), or alternatively 6.46% of GDP would have to be spent to subsidize missing connectivity at current prices (Scenario 2). As also shown by Table 4, this would be equal to Brazil's total public spending in health (4.8% of GDP), plus national spending on Research and Development (R&D, 1.0% of GDP), plus public spending on tertiary education (0.8%). In the case of Uruguay 2005, ICT prices would have to be cut down to 6% of the 2005 prices (Scenario 1), because the poor have around US$20 per year to spend on ICT, making that around 40 cents per week in one of Latin America's richest countries. Alternatively (Scenario 2), the required amount of resources to bridge the digital divide (6.23% of GDP) would equal the amount of Uruguay's public spending in health (3.6% of GDP) and education (2.6% of GDP).

When evaluating the results of the model, we have to remember one complementary factors that dynamically influences the evolution of the income dimension of the digital access divide: growing spending levels. Spending levels would increase if households start to spend a larger amount of their spending on communication. However, the time series of Mexico 2002-2008 in Figure 1 seems to suggest that relative portions of spending on communication seem to fluctuate back and forth, but without a clear tendency toward increased proportions[xiii]. Another catalyst of increased spending levels would be economic growth. If the absolute income of households increases, so does spending on communications. Reflecting on this possibility we have to remember that, first, household spending does usually not grow as fast as economic growth would suggest, and second, traditionally only a very small portion of this trickles down to the lowest income segments. The Mexican economy has grown at an average GDP growth rate of 6.46% per year between 2002 and 2007 (CEPAL, 2009). This had some noticeable effects on the communications spending of high-income segments. Table 4 shows that the highest income quintile has increased spending on communication from US$306 in 2002 to US$374 in 2007. This is lower than what economic growth would suggest ($306*[1.0646]^5$ = US$418), but it is still an important increase. However, the trickle down effect of this economic growth to the poorest 20% of Mexican society, has only led to an increase from US$34 in 2002 to US$35 in 2007 of personal spending per year (far from what should be expected considering economic growth:

34*[1.0646]^5 = US$47). Income levels in poor segments grow very slow, which is the main causes for the persistence of worldwide poverty and the reason why 22% of Latin America still lives with less than US$2 per day. As a conclusion of this observation, we can place some (uncertain) hopes on economic growth. On the bright side, we can hope that economic growth (which would partially be also based on ICT-enabled productivity gains) would lift higher income segments to the required levels of spending. On the down side, history has taught us that that spending levels at the so-called "bottom of the pyramid" can be expected to move very slowly beyond the presented levels.

This observation allows us to fine-tune our interpretation of Table 4. Expecting economic growth to lift the richest 60% of Brazilian society up to the required spending levels, "only" 2.84% of GDP (0.68%+0.70%+1.46%) would have to be spent to subsidize the remaining 40% (see Scenario 2 in Table 4). This is more than the country receives annually in Foreign Direct Investments (FDI). Expecting economic growth to lift the richest 60% of Uruguayans up to the required spending levels, "only" 1.15% of GDP (0.59%+0.56%) would have to be spent to subsidize the remaining 40%. This is more than twice as much as Uruguay's public spending on tertiary education.

Table 4: Required price reductions and subsidies for scenarios 1, 2 and 3; personal communication spending; comparison to other national expenditures; weekly minutes in public access center; all as national average and per income quintile

MEXICO 2002		National	Decile 1	Decile 2	Quintile II	Quintile III	Quintile IV	Quintile V
Electricity penetration		95.7%	93.9%	94.7%	96.7%	96.8%	98.4%	98.6%
Scenario 1:	Required price cuts to reach electricity levels (% of current price)		8%	12%	15%	20%	28%	64%
Personal spending per year in US$		$118	$ 34		$54	$78	$119	$306
MEXICO 2007		National	Decile 1	Decile 2	Quintile II	Quintile III	Quintile IV	Quintile V
Scenario 1:	Required price cuts to reach electricity levels (% of current price)		13%	15%	21%	31%	46%	98%
Scenario 2:	Required subsidies to reach electricity levels (% of GDP2007)	1.86%	0.20%	0.18%	0.41%	0.39%	0.40%	0.27%
Personal spending per year in US$		$143	$35		$59	$93	$154	$374
Scenario 3:	Reduced price packet	$145	$118		$134	$145	$162	$190
	Percentage of society that can afford reduced price packet	46.7%	29.8%		44.1%	64.5%	95.2%	everybody
	Remaining required subsidy (% of GDP)	0.42%	0.16%		0.15%	0.10%	0.01%	no subsidy required
Other expenditures as % of GDP Mexico (2002-2005):			Public health: 3%	Public educ: 5.4%	Tertiary educ: 0.9%	Research & Develp: 0.4%	Official develop assist.: 0.0002%	Foreign direct invest. inflow: 2.4%
Weekly minutes in public access center		83	20		34	54	89	

URUGUAY 2005		National	Decile 1	Decile 2	Quintile II	Quintile III	Quintile IV	Quintile V
Electricity penetration		98.5%	96.4%	97.6%	98.5%	99.2%	99.6%	99.7%
Scenario 1:	Required price cuts to reach electricity levels (% of current price)		6%	10%	18%	25%	35%	60%
Scenario 2:	Required subsidies to reach electricity levels (% of GDP2005)	6.23%	0.59%	0.56%	1.31%	1.36%	1.35%	1.06%
Personal spending per year in US$		$155	$29		$79	$122	$193	$355
Scenario 3:	Reduced price packet	$242	$176		$229	$265	$306	$332
	Percentage of society that can afford reduced price packet	32.0%	16.4%		34.5%	45.9%	63.0%	everybody
	Remaining required subsidy (% of GDP)	2.18%	0.57%		0.59%	0.57%	0.45%	no subsidy required
Other expenditures as % of GDP Uruguay (2002-2005):			Public health: 3.6%	Public educ: 2.6%	Tertiary educ: 0.5%	Research & Develp: 0.3%	Official develop assist.: 0.1%	Foreign direct invest. inflow: 4.2%
Weekly minutes in public access center		90	17		46	70	111	

BRAZIL 2003		National	Decile 1	Decile 2	Quintile II	Quintile III	Quintile IV	Quintile V
Electricity penetration		96.6%	87.8%	94.6%	97.2%	98.4%	99.1%	99.8%
Scenario 1:	Required price cuts to reach electricity levels (% of current price)		3%	5%	12%	22%	37%	73%
Scenario 2:	Required subsidies to reach electricity levels (% of GDP2003)	6.46%	0.68%	0.70%	1.46%	1.52%	1.28%	0.81%
Personal spending per year in US$		$96	$9		$32	$69	$117	$254
Scenario 3:	Reduced price packet	$136	$113		$125	$145	$149	$166
	Percentage of society that can afford reduced price packet	32.0%	8.1%		25.7%	47.2%	79.0%	everybody
	Remaining required subsidy (% of GDP)	1.89%	0.61%		0.59%	0.49%	0.20%	no subsidy required
Other expenditures as % of GDP Brazil (2002-2005):			Public health: 4.8%	Public educ: 4.4%	Tertiary educ: 0.8%	Research & Develp: 1.0%	Official develop assist.: (.)%	Foreign direct invest. inflow: 1.9%
Weekly minutes in public access center		56	5		19	40	68	

COSTA RICA 2004		National	Quintile I		Quintile II	Quintile III	Quintile IV	Quintile V
Electricity penetration		99.1%	97.3%		98.8%	99.6%	99.8%	99.9%
Scenario 1:	Required price cuts to reach electricity levels (% of current price)		8%		18%	28%	40%	87%
Scenario 2:	Required subsidies to reach electricity levels (% of GDP2004)	3.74%	0.87%		0.84%	0.80%	0.74%	0.49%
Personal spending per year in US$		$92	$17		$39	$61	$97	$248
Scenario 2008:	2008 price packet	$135	$123		$126	$126	$142	$165
	Percentage of society that can afford 2008 price packet (equal to required price cuts of 2008 price to reach everybody)	32.2%	13.9%		30.6%	48.8%	67.9%	everybody
	Required subsidy to reach electricity levels (% of GDP2008)	0.85%	0.29%		0.25%	0.18%	0.13%	no subsidy required
Other expenditures as % of GDP Costa Rica (2002-2005):			Public health: 5.1%	Public educ: 4.9%	Tertiary educ: n.a.	Research & Develp: 0.4%	Official develop assist.: 0.1%	Foreign direct invest. inflow: 4.3%
Weekly minutes in public access center		53	10		22	35	56	

Source: own elaboration; based on OSILAC, 2009; CEPALSTAT, 2009; UNDP, 2009; respective national household spending reports.

At this point it becomes clear that neither real price reduction of ICT nor demand subsidy can be a solution by itself. The challenge has to be faces with a sophisticated combination of different options. We start with the assumption that the market still has potential to reduce ICT prices, which will enable more people to afford connectivity. As long as this price reduction does not go as far as identified in Scenario 1, we will still require a reduced subsidy. Much in the same line of thought, a recent study by Latin American telecom regulators (Regulatel, 2007) discusses the "market efficiency gap" versus the "access gap." The first concept denotes the difference between the current level of service penetration and the level achievable in a hypothetically well-functioning competitive market under a stable regulatory environment. The "access gap" takes note of those segments of society that continue to be unable to afford access even under best-case market conditions.

So let us become a little futuristic and explore Scenario 3. Let us start with the assumption that eventually it would be possible to create the US$100 laptop (or any other comparable device at that price, such as an evolved multimedia mobile or digital TV device). Let us furthermore suppose that this connectivity would be enough to provide voice services (such as Voice-over-IP) and that through some futuristic 4G wireless connectivity, the device could be moved around as a mobile phone, constantly connecting to the closest base-station to provide Internet service to each individual, while the price of this Internet connectivity would still be shared by all members of the household (a kind of joint family plan for mobile Internet services). This would reduce prices to the plain price of equipment (US$100 per person for three years equipment lifetime, making it US$33 per year) and a household-shared Internet connection (based on current prices), eliminating fixed and mobile phone costs. Let this be our 'reduced price ICT access packet'.

Table 4 shows the result of this Scenario 3. In Mexico 2007, 47% of society could buy such "reduced price access packet", which is a clear improvement from the 12% of society that has access to the Internet in 2007 (compare to Table 3). However, in order to connect the ones that still remain unconnected, still 0.42% of GDP would be required as subsidies. This is equal to the amount Mexico spent on Research and Development (R&D) and half of Mexico's public spending on tertiary education (see Table 4). In Uruguay, Internet connectivity could be increased from 14% (see Table 3) to 32% of society (Scenario 3 Table 4), but the amount required to bridge the digital divide for the remaining unconnected (2.18% of GDP) would be 22 times the total amount of international Official Development Assistance (ODA) the country receives per year (see Table 4).

As already indicated, these scenarios depend on the future development of prices and spending levels. While we do not have more recent statistics on spending, we do have the price figures for 2008 (ITU, 2009). Uruguay and Costa Rica have been able to reduce the price of their 'ICT access packet' from US$ 468 in 2005 to US$275[xiv] in 2008 and from US$ 237 in 2004 to US$135.3 in 2008 respectively (in Uruguay mainly due to reductions in

Internet and mobile prices, and in Costa Rica due to lower mobile prices). The 2008 prices in Uruguay come close to the envisioned prices of our 'reduced price packet' (US$242). If we could now also suppose that Uruguay's economic growth at least benefits the three higher income quintiles so that market forces would eventually enable them to connect, we could conclude that in these cases the required subsidy would be limited to the two lower income quintiles (which reduces subsidies to a little more than 0.57%+0.59% = 1.16% of GDP, see Scenario 3 in Table 4).

In the case of the public telecom operator in Costa Rica, prices in 2008 turn out to be even lower than our 'reduced price' Scenario 3 (which would have turned out to be US$184). Due to this impressive price cut in Internet and telephone tariffs, Table 4 does not show a Scenario 3 for Costa Rica, but a Scenario2008 (see Table 4). It takes 2008 prices and 2004 spending levels (unfortunately the last available spending levels). This price reduction lowers required subsidies effectively to 0.85% of GDP, equal to "only" twice the spending in R&D (see Scenario2008 in Table 4). In case that Costa Rica's economic growth had positively affected communication-spending levels between 2004-2008, these required subsidies would accordingly be reduced.

This encouraging outlook, however, cannot be transferred to Mexico and Brazil. In both countries the price of our 'ICT access packet' has risen in recent years, from US$ 307 in 2007 to US$341 in 2008 in Mexico (mainly due to increases in Internet and fixed-line prices), and from US$294 (2003) to US$ 462 in Brazil (due to the same reasons)[xv]. These unfortunate tendencies might be explained with two already observed facts: first, high income segments have more spending power than required to purchase our minimum 'ICT access packet' (see Table 4); and second, market expansion in high income segments is still ongoing and has not even reached saturation for the 'minimum access packet' (see Table 3). Therefore, the natural business strategy for private enterprises consists in creaming off existing spending power in high-income segments. Proof of this is the fact that increases in penetration rates can mainly be attributed to high-income segments (compare Mexico2002 and Mexico2007 in Table 3). Combine this tendency with the already mentioned fact that ongoing economic growth tends to favor the high-income segments, and the result is a clear economic incentive for private enterprises to focus their business model on the spending power of high-income segments. Considering that in all Latin American countries, the richest 20% receive more than 50% of the national income, it becomes beneficial to adjust commercial prices to the constantly increasing spending power in this high-income segment. This also includes the constant introduction of new high-quality ICT (broadband, 4G, etc), which can be expected to constitute a large portion of the revenues of private enterprises. A consequence is increasing, not decreasing ICT prices.

These mixed results show that the heterogeneity in access prices among countries prohibits reaching a general conclusion. However, even in the most favorable cases, the bridge over the digital access divide for the poorest of the region would still be a heavy financial burden.

It is actually quite utopian to think that the region's finance ministers could be convinced to take out even 0.5% of GDP from the general public budget to reduce the digital divide in households. And even if developing countries would have the resources to do so, one would have to ask if this step would be justifiable, or if this money would rather be spend on other urgent issues, such as modernizing hospitals, schools and municipalities, which can of course also be done by introducing ICT in these entities. Such a policy would indirectly benefit citizens, who would remain unconnected at their homes, and as such, would remain victims of the digital divide.

Table 4 also shows that the required funds are currently not available with the international development community in forms of Official Development Assistance (ODA). The required amount of yearly subsidies for the reduced price Scenario 3 in Mexican 2007 only, would be almost twice as much (US$4.3 billon) as the annual net budget of the United Nations (US$2.5 billon in 2009). In other words, even if market forces would drastically reduce ICT prices, the domestic and international financial mechanisms would stop far short from enabling universal service.

Before going on to drawing conclusions, we should once again point to the limitations of our modeling effort. Table 2 shows us that the 'ICT access packet' in Mexico's highest income segment has decreased from US$481 in 2002 to US$388 in 2007 (see Table 2) and Table 4 confirms that spending levels have increased from US$306 to US$374, thanks to economic growth. As a result, in theory, almost every member of the highest income segment in Mexico should have had enough resources to buy our 'ICT access packet' in 2007. Table 3 confirms that Internet penetration has indeed risen in this segment during these five years from 43% to 63% and mobile phone penetration from 27% to 91%. However, still not everybody is connected in 2007, despite the economic capacity to do so. This is proof of the fact that our model is simplified and ignores other important explanatory variables, such as discussed in the second section of this article. As previously shown, the correlation between access and income is high, but not perfectly 1-to-1.

What are the odds for the digitally excluded?

The underlying question of this paper was as simple as it is direct: How much would it cost and how far would ICT prices need to be reduced to bridge the domestic digital divide in the Latin American context? The answer has been modeled on basis of household spending statistics and adjustable ICT penetration rates and access prices. The results turn out to pose an extremely challenging task, constrained by the reality of Latin American income levels. Any realistic bridge over the digital divide will need to be constructed as a combination of various solutions, including price reduction and sophistically distributed subsidies in close public-private cooperation, and hopefully alleviated by substantial (ICT-enabled) economic growth that trickles down to the poorest segments. We will discuss some examples of the available alternatives in this concluding section.

Given the fast and unforeseeable technological progress of ICT, it does not seem advisable to limit price reduction strategies to a specific technological solution. New technology is being developed at this moment and this innate uncertainty has to be taken as an opportunity, not a threat. It is definitely easier to change technology than it is to change the present reality of income levels. The development of cheap (or free) source software, as well as of cheap hardware equipment makes part of this approach. The US$ 100 laptop set off a debate that moves into the right direction. Another area with great potential is the introduction of digital TV. Converter "set-up boxes" can upgrade analogue television sets with digital interactivity and have been manufactured for less than US$40. However, the eventual provisions of e-government, e-health and e-business services through a converted analogue TV set still remain to be seen. Besides equipment and software, traffic prices also need to be reduced. The use of unlicensed radio frequency spectrum, in combination with cheap broadband wireless technology, such as the popular Wi-Fi, is part of this challenge.

Regarding public subsidies, our model has clearly shown that income levels of the developing world are simply too low to strive for "universal service" in the short-term. Household connectivity is a viable option for the high-income segments, but low-income segments will have to be satisfied with a voice- and short-message based mobile telephony. While mobile phones are an important first step, they do not convert the poor into full-fledged members a true Information Society. In order to provide e-government and other e-services to the poor, the provision of "universal access" seems much more realistic than the ambitious goal of "universal service". The economic model behind this strategy is an old one. It is the same that gave birth to Thomas Jefferson's ideal of giving access to books to all people by sharing their fixed price through the establishment of public libraries. Fitness clubs and the public transportation system follow the same line of reasoning. The benefit lies in sharing the fixed cost, while covering the variable cost. Even more than 125 years after the commercialization of the automobile, not everybody in the developing world posses a car. But most people have nevertheless access to automated mobility, thanks to decades of massive public and private investments in public transportation. Special machines have been built for collective access to transportation—such as busses, metros, auto rickshaws, "guaguas" and "tuk-tuks"—and micro entrepreneurs provide transportation services and offer to share their motorcycles, often resulting in breathtaking acrobatic acts. The logic of collectively sharing the access price to technology becomes obvious when looking at the reality of transportation systems in developing countries even 125 years after the "mobility-revolution". Of course, this still leaves a qualitative dimension of the "mobility divide" (some have more mobility than others, and the well-off have better cars and even go by helicopter), but the "minimum access divide" to mobility has been bridged.

The same reasoning is behind the massive sprouting of the so-called "*info-centros*", or public ICT access centers. More than 140,000 of these public access points have been identified throughout Latin America in 2006 already (Maeso and Hilbert, 2006). The only viable solution for an important part of the region's society might be to buy some minutes in a public Internet access point. Table 4 shows that the poorest 20% of the analyzed Latin American societies have between US$ 0.18 – 0.67 per week to spend on ICT (Mexico2007: US$ 0.67 per week; Uruguay2005: US$ 0.55; Brazil2003: US$ 0.18; Costa Rica2004: US$ 0.33), while 40% of society has less than US$ 1.50 per week. Supposing an average cost of US$2 per hour for Internet access at a commercial Internet café[xvi], the poorest 20% of Costa Rica2004 could buy some 10 minutes of access per week. Generally speaking, Table 4 shows that the poorest half can afford around half an hour of Internet access at a public access place at a price of US$2 per hour. This is not a lot, but could enable them to take care of an urgent transaction with the government or make a reservation at a far away hospital, for example. One additional benefit of public access places is the frequent updating of equipment and service (usually broadband connectivity is available and the equipment is being maintained by the owner), while there is always help around to assist the user to overcome skill limitations.

While shared access seems to be a viable solution to "bridge" the divide, the financial sustainability of the applied business models is a mayor concern (e.g. Celedon and Razeto, 2009). The results of the analysis presented here show a reality in which it does not seem likely that the poor will gain sufficient purchasing power to attain personalized access in the short term. The logical conclusion is to prepare for a long period in which public access is the only viable access solution to assure quality and up-to-date access for these income segments. An apparatus would be comparable to the institutional structure of today's public transportation system, which might of course consist of public and private components (similar to public transportation). Notwithstanding, any sustainable solution of such institution requires a reliable stream of resources. Currently, few financial mechanisms are in place to support such an institutional structure of public access to information.

Throughout Latin America, public Universal Access Funds have started to support those shared access initiatives. Most Latin American countries maintain such Universal Access Funds, which are alimented by an earmarked tax on the telecommunications industry (and are therefore highly polemic, given their interventionist nature). These funds have their historical roots in the days of public pay phones and usually charge telecom operators around 1% (up to 5%) of their revenues, in order to finance connectivity in underserved populations. Until 2006, these funds have collected US$2.7 billion throughout Latin America (Regulatel, 2007). The Brazilian FUST (Fundo de Universalização dos Serviços de Telecomunicação), has collected a yearly average of US$ 354 million between 2001 and 2006. This constitutes 3.4% (or $^{1}/_{30}$) of the subsidies that would be required to provide individual universal service in the case of our 'reduced price access packet' (see Table 4). In other words, if prices could be reduced to the aspired level of our reduced price scenario and if the fund would be modernized to actually subsidize public ICT access initiatives, then the Brazilian Universal Access Fund could provide one shared connectivity packet per 30 unconnected inhabitants. This does not lead to "universal service", but to "universal access" and 30 people per station is not overly crowded for a public access cyber café. This scenario enables to end our analysis on a "glass-half-full" outlook. It seems that the innovative combination of public and private efforts to reduce prices, together with public and private efforts to provide shared access provide at least one viable path to follow.

It is important to point out that not all countries around the world have such funds, and many of the existing funds face fierce opposition from groups that defend free-market mechanisms. Others have suggested exploring the possibility to extend this model to the international level and hold the globally connected responsible to connect the global poor. This fits the global nature of digital networks and it would also enable to expand the logic of digital solidarity from telecom, to hardware and software services. As already mentioned, most ICT are tradable goods. In the established Universal Access Funds, however, only the non-tradable telecom services are subject to contributions. National authorities only tax non-tradable national telecommunications service companies, and do not place a tax on imported hardware or software products. This does not only result in indirect subsidies from telecom companies to hardware and software companies[xvii], but is also difficult to justify ideologically, because "ICT access" requires hardware and software just as much as telecom services.

During the 2003-3005 World Summit on the Information Society, Heads of States and governments have proposed the creation of a public-private "Digital Solidarity Fund", "as an innovative financial mechanism of a voluntary nature" (WSIS, 2005). The initial idea of some participants was to establish global contribution system, similar to the national Universal Access Funds in Latin America, which will then be alimented by the global ICT industry. A contribution of 1% of the revenues of the world's ten largest non-telecom ICT enterprises[xviii] (Fortune, 2008) would have provided US$ 4.6 billion to provide connectivity to the world's poor in 2008. Used for public access or for R&D to develop cheap equipment suitable for the poor, such a constant source of yearly resources would surely have a significant and sustainable impact. Notwithstanding the potential of the idea, the voluntary nature of the Digital Solidarity Fund has raised less than US$10 million during the entire period of its first five years of existence (until 2009), with a substantial part of the donations coming from developing country governments in a good-will effort to show their sympathy for the idea. This reality shows the "glass-half-empty" side of the current challenge: the low degree of commitment to the overcome of the digital abyss. Many more innovative and creative ideas—and their practical implementation—will have to be explored to find sustainable solutions for the digital excluded.

Let us relativize these findings with a final word of caution on the limitations of the presented approach. It has to be remembered that the presented numbers will inevitably change over time as new household spending surveys become available. What will not change as easily, however, is the general logic of combining the structural characteristic of the highly skewed income distribution in low-income countries with tradable ICT equipment, whose prices are internationally defined. While the numbers have to be checked in the future, it can be expected that the digital divide will persist over the coming years. Besides new statistical input, the current model can and should also be refined (which will happen at the cost of increasing complexity). Two of the most straightforward improvements would include estimations on future spending levels (considering estimations for economic growth and its trickle down effect to different income levels) and the inclusion of explanatory variables beyond income distribution (education levels seems especially promising).

Summing up, by putting numbers and quantities to the omnipresent rhetoric about the digital divide, this paper has shown that, once again, long-standing structural characteristics of the developing world could be about to deepen the vicious circle between inequality and technology diffusion. The numbers have shown that the challenge of breaking this circle is a formidable one. The presented model allows for a quantification of the challenge and the identification of normative goals to break it. The development of such normative models is an important first step, but not sufficient. The exploration of practical policy tools requires complementary further research in the light of the presented findings. This research will have to be realistic and convincing enough to motivate national and international public and private sectors to take up those concepts and implement sustainable solutions that enable the world's unconnected to become full-fledged members of a truly global Information Society.

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Notes

[i] "Ignoranti, quem portum petat, nullus suus ventus est".

[ii] Discriminant analysis goes back to Fisher (1936) and can basically be understood as a multiple regression where the criterion variable is nominal rather interval or ratio (in our case: access or not) and the aim is to search for a combination of variables that maximally discriminates between those groups (e.g. Williams and Monge, 2001).

[iii] This variable is supposed to test if people in single or double households tend to connect more to the Internet to avoid social isolation.

[iv] 1st group (primary): agriculture/ hunting/ forestry/ fishing/ mining/ quarrying/ construction; 2nd group (secondary): manufacturing/ electricity/ gas/ water; 3rd group (services1): wholesale/ retail/ repair/ household/ community/ hotel/ restaurants; 4th group (services2): Financial/ real estate/ business/ public administration/ defense/ education/ health/ social work/ extraterritorial organizations.

[v] This variable is supposed to test for the degree of previous technological adoption and a general interest in ICT.

[vi] This variable is supposed to test for eventual language or cultural barriers.

[vii] Tolerance in the order of variables enlistment in text: .634; .617; .904; .759; .871; .662; .878; .722; .951; .999. Similar values result in the subsequent tests of Brazil 2005 and 2002 and Uruguay 2005 and 2007.

[viii] The canonical correlation is the correlation between the new canonical variables formed by applying the weights from the discriminant function to the 10 predictors, and the grouping variable of either having or not having household Internet access.

[ix] The term personal computer is used to refer to all kind of household computers, including laptops, notebooks and Mac.

[x] For example, in Mexico 2002, only two minutes and 45 seconds daily dial-up Internet for one person cost as much as unlimited 256kbps broadband shared with the average size of household members.

[xi] Industry and government collaboration, such as “mi primer PC” in Chile, offer financing plans for PCs for around USD 500. Normal industry prices are slightly above this number.

[xii] Given that no spending figures exist for Mexico 2007 (but given that this is the last year for which we count with the harmonized household penetration levels), the Mexico 2008 spending levels have been applied to model Mexico 2007. This is justifiable because Graph 1 confirms that spending levels in Mexico stay pretty constant.

[xiii] National household spending levels on communication as % of total household spending in Mexico: 2002: 3.01%; 2004: 2.89%; 2005: 3.20%; 2006: 3.08; 2008: 3.15%.

[xiv] Uruguay’s 2008 ‘ICT access packet’ is the sum of [US$77.4fixed]+[US$39.6mobile]+[US$100.7Internet]+[57.5PC].

[xv] Mexico's 2008 'ICT access packet' is the sum of [US$137.1fixed]+[US$39.6mobile]+[US$116.8Internet]+[47.4PC]; and Brazil's [US$146.0fixed]+[US$99.0mobile]+[US$172.1Internet]+[45.0PC].

[xvi] Prices for commercial cyber-cafes in 2008/9 range between US$1 per hour (Brazil and Uruguay) up to US$3 per hour in Mexico.

[xvii] By forcing telecom operators to expand their networks to underserved areas, new markets are consequently opened for hardware and software producer in the developing world. Telecom operators have to chip in to make this step possible, while hardware and software producers are under no regulation to provide cost-effective solutions to marginalized populations. Additionally, if public access centers are financed by the universal service funds, these centers need to buy hardware and software equipment, which in some cases is financed with the resources that are collected from the telecom operators through the fund.

[xviii] In 2008 this included: Hewlett-Packard, IBM, Dell, Microsoft, Intel, Cisco Systems, Apple, Oracle, Xerox and Google.