5 What Matters for ICT Diffusion?

Diffusion process will be impeded if the innovation requires new kinds of knowledge on the part of the user, new types of behavior, and the coordinated efforts of a number of organizations. If an invention requires few changes in socio-cultural values and behavior patterns, it is likely to spread more rapidly

Edwin Mansfield (1986)

Abstract

The major targets of the following chapter are twofold. First, adopting a newly developed approach, it traces 'critical mass' effects with regard to ICT diffusion (Mobile Cellular Telephony and Internet) in 17 low-income countries and 29 lower-middle-income countries over the period 2000–2012. To this end, it identifies respective critical penetration rates and a 'technological take-off' interval, which is defined as the period during which ICT diffusion enters an exponential growth phase along an S-shaped trajectory. Along these lines, we demonstrate country-specific socioeconomic and institutional conditions during the 'technological take-off' interval. Second, the chapter provides additional evidence on ICT diffusion determinants in low-income and lower-middle-income countries during the analogous period. It empirically traces the potential effect of selected factors on ICT spread. The analysis covers ten indicators, which are used to explain the level of mobile cellular telephony penetration rates, and nine indicators used to explain the level of Internet usage by individuals. Moreover, we have selected another eight indicators to demonstrate general socioeconomic and infrastructural features of examined countries.

Keywords

Critical mass • Technological take-off • ICT diffusion • ICT determinants

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5.1 Introduction

During the last decade of the twentieth century and the first decade of the twenty-first century, the world has witnessed the unprecedentedly dynamic diffusion of new ICTs across even the most undeveloped countries. The empirical evidence reported in Chap. 4 revealed that many of the analysed countries experienced rapid and dynamic diffusion of ICTs, which resulted in extremely high penetration rates, especially with regard to access to and usage of mobile cellular telephony; other countries failed in this regard and remained stuck in a 'low-level trap' of not being able to actuate the diffusion process. The reasons for this might be traced by running country-specific analyses, which would provide extensive knowledge regarding why some countries succeeded, and others failed, in the complex process of broad ICT deployment. The following Chap. 5 is designed to understand, at least partially, why certain countries succeeded while others failed at ICT adoption and this challenging task requires context-specific thinking and a country-wise approach.

The Chap. 5 is made up of two major parts—Sects. 5.2 and 5.3, that present the results of the empirical analysis. Section 5.2 is aimed to trace the '*technological take-off*' and the '*critical mass*' effects, which allow for concluding on the critical penetration rates that fostered entering the exponential growth phase along the ICT diffusion path; and—explore country-specific social, economic and institutional conditions during the '*technological take-off*' interval. The latter analysis is complemented and enriched by the evidence demonstrated in Sect. 5.3 encompassing panel regression analysis that aims to identify which factors have positively affected—or conversely, impeded the ICT diffusion across analyzed countries. Finally, short Sect. 5.4 contains major conclusions.

5.2 Tracing the '*Technological Take-Off*' and the '*Critical Mass*' Effects

As highlighted in Chap. 4, over the period 2000–2012, most developing countries experienced significant shifts in access to mobile cellular telephony and use of Internet connections. In contrast, except for a few countries,[1] progress in the deployment of fixed-narrowband, fixed-broadband or wireless-broadband networks remained negligible over the analogous period. Thus, our continuing efforts are directed toward evaluating the '*technological take-off*' intervals and the '*critical mass*' effects regarding increases in access to and use of mobile cellular telephony ($MCS_{i,y}$) and Internet networks ($IU_{i,y}$).

[1] For details, see Chap. 4.

5.2.1 The Data

To meet the main targets of Sect. 5.2, we have arbitrary selected a bundle of factors that may help to explain the process of ICT diffusion in developing economies. The defined dataset covers ten indicators, which are used to explain level of mobile cellular telephony penetration rates, and nine to explain individual Internet usage levels. Moreover, we have selected another eight indicators[2] to demonstrate the general socio-economic and infrastructural features of the examined countries. The data were derived from various sources; however, most of the statistics were extracted from the World Telecommunication/ICT Indicators database 2013 (17th Edition) (International Telecommunication Union), World Development Indicators 2013 (World Bank 2014), Human Development Reports 2005–2013 (United Nation Development Program) and Measuring the Information Society reports 2009–2013 (International Telecommunication Union). Additional data were derived from the CIA World Factbook 2014, Freedom House 2013–2014, The Heritage Foundation 2014 and national telecommunication agencies.[3] All indicators used in the analysis are listed and explained in Table 5.1. The forthcoming Sect. 5.2.2 demonstrates the analysis outcomes, where the variables discussed in Table 5.1 are used.

5.2.2 Ready for the '*Technological Take-Off*'?

Section 5.2.2 aims to challenge the identification of the '*critical mass*' and the '*technological take-off*' interval that emerged during the process of gradual ICT diffusion in low-income and lower-middle-income countries over the period 2000–2012.[4] Henceforth, it identifies the '*critical year*', '*critical penetration rate*', the '*technological take-off*' interval that follows right after, along with the bundle of country-specific conditions during the first year of '*technological take-off*' interval. To meet the main aims of this analysis, first, we designate ICT marginal growths ($\Omega_{MCS,i,y}$ and $\Omega_{IU,i,y}$), and the ICT replication coefficients ($\Phi_{MCS,i,y}$ and $\Phi_{IU,i,y}$) for each country separately. Figures 5.1, 5.2, 5.3, and 5.4 outline country-specific patterns of $\Omega_{\mathrm{MCS},i,y}$, $\Omega_{IU,i,y}$, $\Phi_{MCS,i,y}$ and $\Phi_{IU,i,y}$ (for detailed estimations, see

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[2] We intentionally chose not to use any multidimensional ICT indicators, such as the Network Readiness Index (developed by the World Economic Forum) or the ICT Development Index (developed by the International Telecommunication Union). These measures, despite their simplicity and ability to show a country's overall performance in terms of ICT adoption and readiness to adopt and use the technologies, are not very informative for achieving the main goals of our analysis. The methodologies used to calculate the multidimensional indices are often modified, and hence, their values are lack comparability across time and conclusions drawn on that basis are limited and simplified.

[3] In some countries, the gaps in data coverage are significant, and the available statistics are poor with regard to completeness and time series. Henceforth, in the case of missing data, we provide the statistics for the most recent year for which reliable information was available.

[4] As explained in Chap. 4—if possible the period of analysis is extended for selected countries.

Table 5.1 Determinants of mobile cellular telephony and Internet users penetration rate

Determinants of mobile cellular telephony penetration rates	Determinants of Internet users penetration rates
• Mobile-cellular postpaid connection charge (in USD)—initial, one-time charge for a new postpaid subscription (source: ITU 2013) • Mobile-cellular prepaid connection charge (in USD)—initial, one-time charge for a new postpaid subscription (source: ITU 2013) • Number of mobile cellular prepaid connections charge per monthly GNI per capita (source: author's calculations) • Mobile-cellular prepaid—price of a 1-min local call (peak, on-net) (in USD)—the price per minute of call from a mobile cellular telephony to another of the same network[a] (source: ITU 2013) • Number of 1-min local calls (peak, on-net) per monthly GNI per capita (source: author's calculations) • Mobile-cellular prepaid—price of SMS (on-net) (in USD)—the price of sending one Short Message Service (SMS) message from mobile handset (source: ITU 2013) • Number of SMS (on-net) per monthly GNI per capita (source: author's calculations) • Mobile Cellular Sub-Basket—price of a standard basket of mobile usage per month, including 30 outgoing calls and 100 SMS in arbitrary determined ratios, expressed as percentage on monthly GNI per capita[b] (source: Measuring Information Society 2009, 2010, 2011, 2012, 2013) • Fixed telephony penetration rate—fixed telephony subscriptions (per 100 inhab.) (source: ITU 2013) • Type of competition on mobile telecommunication market—monopoly, partial competition or competition (source: ITU 2013)	• Fixed-narrowband subscriptions[c] (per 100 inhab.) (source: ITU 2013) • Fixed-broadband subscriptions[d] (per 100 inhab.) (source: ITU 2013) • Wireless-broadband subscriptions[e] (per 100 inhab.) (source: ITU 2013) • Fixed (wired)-broadband connection charge (in USD)—initial, one-time charge for new fixed-broadband Internet connection[f] (source: ITU 2013) • Fixed (wired)-broadband monthly subscription charge (in USD)—monthly subscription charge for fixed-broadband Internet service (source: ITU 2013) • Number of fixed-broadband monthly subscription charges per monthly GNI per capita (source: author's calculations) • Fixed-Broadband Sub-Basket—price of monthly subscription to an entry-level fixed-broadband plan expressed as percentage of monthly GNI per capita[g] (source: Measuring Information Society 2009, 2010, 2011, 2012, 2013) • Type of competition on Internet telecommunication market—monopoly, partial competition or competition (source: ITU 2013) • Internet Freedom—status (free, partly free or not free) of freedom of Internet and digital media; 0–100 points; encompasses three sub-indices: Obstacles to Access (infrastructural and economic barriers to access, legal and ownership control over internet service providers, and independence of regulatory bodies)—0–25 points; Limits on Content (legal regulations on content, technical filtering and blocking of websites, self-censorship, the diversity of online news media, and the use of ICTs for civic mobilization)—0–35 points; Violations of Users Right (surveillance, privacy, and repercussions for online activity)—0–40 points (source: Freedom House 2011, 2012, 2013)
Determinants of both mobile cellular telephony and Internet users penetration rates	
• Liberalization of Telecommunication market—type of competition on the telecommunication market (full competition/partial competition/monopoly) (various sources) • Gross Domestic Product per capita in PPP—in constant 2011 international US dollars (source: WDI 2013)	

(continued)

Table 5.1 (continued)

Determinants of mobile cellular telephony penetration rates	Determinants of Internet users penetration rates
• Economic Freedom Index—status of economic freedom measured in 4 major areas[h]; scores—0–100 (if 100—the country is fully free) (source: Heritage Foundation 2013) • Democracy (Political Freedom)—status of the political regime: democracy[i] (score: 2); democracy with no alternation (score: 1); non-democracy (score: 0) (source: HDR 2010) • Country Freedom—status (free, partly free or not free) of country freedom with regard to political rights[j] and civil liberties[k] (Freedom House 2014) • School Enrollment, primary—gross enrollment in primary education regardless of age (%) (source: WDI 2013) • Rural/urban population—proportion of country's total population living in rural/urban areas (source: WDI 2013) • Population density—people per square kilometer of land area (source: WDI 2013)	

Source: Author's compilation
[a]Refers to the prepaid tariffs
[b]For detailed description of the methodology used to calculate Mobile Cellular Sub-Basket—see Annex 2 in Measuring Information Society 2011 (ITU 2011)
[c]For details—see Chap. 4
[d]For details—see Chap. 4
[e]For details—see Chap. 4
[f]Refers to the cheapest available tariff
[g]For detailed description of the methodology used to calculate Fixed-Broadband Sub-Basket—see Annex 2 in Measuring Information Society 2011 (ITU 2011)
[h]Rule of Law, Government Size, Regulatory Efficiency and Market Openness
[i]The regime may be considered 'democracy' under the following major conditions: the chief executive must be chosen in free popular elections, the legislature shall be popularly elected, and—in free elections more than one political party shall compete and (Cheibub et al. 2010)
[j]Refers to electoral process, political pluralism and participation, functioning of government
[k]Refers to freedom of expression and belief, associational and organizational rights, rule of law, personal autonomy and individual rights

Appendices F and G), which allows for identifying those countries where the '*technological take-off*' was observed. The first thing to note is that the calculated values of $\Omega_{MCS,i,y}$, $\Omega_{IU,i,y}$, $\Phi_{MCS,i,y}$ and $\Phi_{IU,i,y}$ substantially differ across countries. However, despite essential differences, the majority of the economies included in the empirical sample meet the criteria defined in Eq. (3.39).[5] Thus, both $Y_{Crit,MCS}$ and '*technological take-off*' are observed with respect to $MCS_{i,\ y}$ and $IU_{i,\ y}$. Taking a closer look at the empirical evidence displayed in Fig. 5.1, we conclude that regarding mobile cellular telephony diffusion, the critical years ($Y_{Crit,MCS}$) that were followed by the characteristic '*technological take-off*' are reported for 16 (out of 17 analysed) low-income countries. The only exception, where neither $Y_{Crit,MCS}$ nor '*technological take-off*' was found was Eritrea; the paths that demonstrated $\Omega_{MCS,ERI,y}$ and $\Phi_{MCS,ERI,y}$ in 2012 (the terminal year of the analysis) were still converging toward the intersection point. The in-depth analysis reveals that the

[5] In Chap. 3.

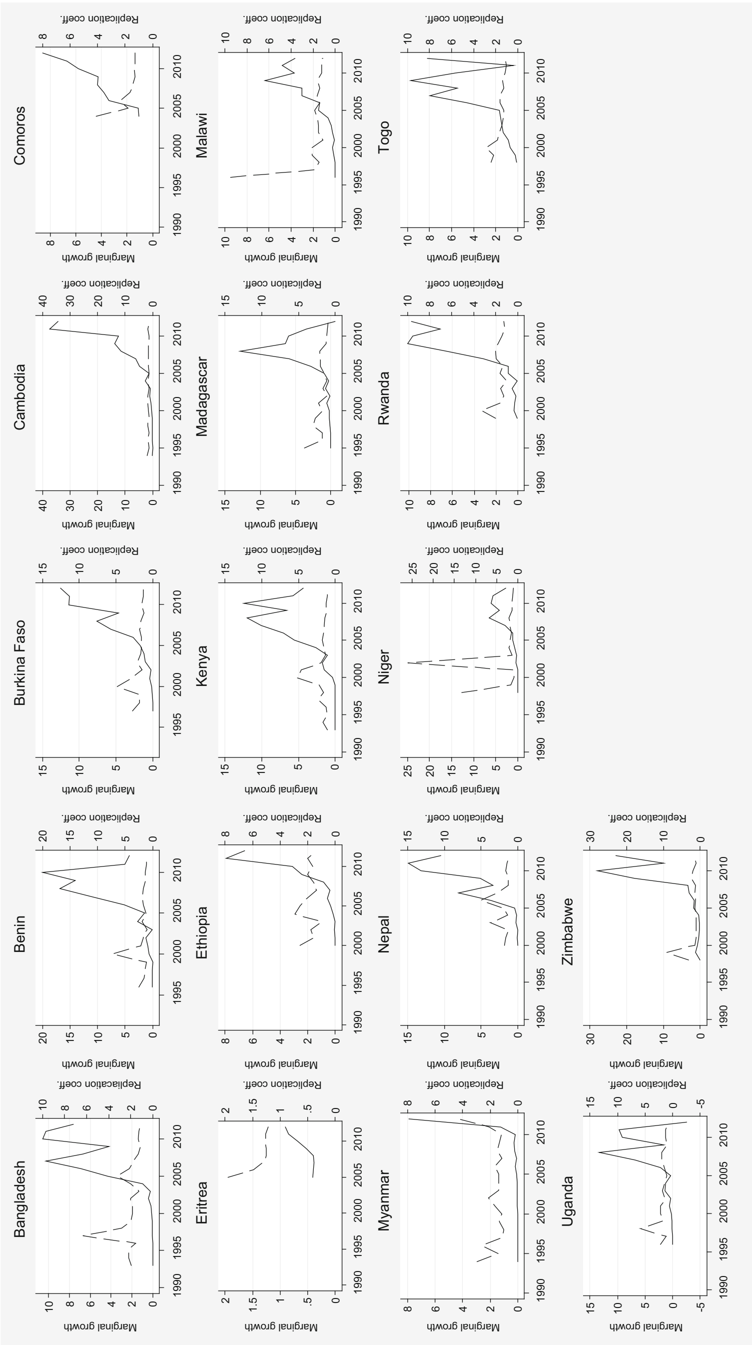

Fig. 5.1 $\boldsymbol{\Omega}_{MCS,i,y}$ and $\boldsymbol{\Phi}_{MCS,i,y}$—Mobile cellular telephony penetration rates. 17 low-income countries. *Source*: Author's elaboration

levels of both $\Omega_{MCS,i,y}$ and $\Phi_{MCS,i,y}$ vary significantly across countries. Over the period 2005–2012,[6] the highest *average* $\Omega_{MCS,i,2004-2012}$ are identified in Cambodia (15.2 per 100 inhab.), whereas the lowest are found in Eritrea (0.5 per 100 inhab.). Consequently, the countries that performed the best in terms of average $\Omega_{MCS,i,y}$ enjoyed the highest dynamics of $MCS_{i,\ y}$ diffusion, which resulted in their achieving highest $MCS_{i,\ y}$ penetration rates in 2012. In contrast, the countries that performed the worst in terms of $\Omega_{MCS,i,y}$, in 2012 were still considerably lagging behind with respect $MCS_{i,\ y}$ penetration rates. Finally, we see that during the 4-year period 2004–2007 that the vast majority of the analysed low-income countries (except Ethiopia and Myanmar) experienced the $Y_{Crit,MCS}$, which, shortly after, was followed by the '*technological take-off*.'[7] The comprehensive study of $\Omega_{IU,i,y}$ and $\Phi_{IU,i,y}$ (see Fig. 5.2), still in the group of low-income economies, documents that the results with respect to $IU_{i,\ y}$ diffusion are far less satisfactory compared with the evidence for $MCS_{i,\ y}$. The $Y_{Crit,IU}$ is registered exclusively in seven countries; in the remaining ten economies,[8] meanwhile, the critical year did not occur,[9] and thus, no '*technological take-off*' was observed. Although in Bangladesh, Cambodia, Kenya, Nepal, Rwanda and Uganda, the '*IU-technological take-off*' potentially emerges, the paths that display the changes in $\Omega_{IU,i,y}$ and $\Phi_{IU,i,y}$ are unstable (for Nepal, Rwanda and Uganda), and only in two countries is the initiation of '*IU-technological take-off*' signalled in 2012 (Bangladesh and Cambodia). Figures 5.3 and 5.4 display the evidence on $Y_{Crit,MCS}$, $Y_{Crit,IU}$, $\Omega_{MCS,i,y}$, $\Phi_{MCS,i,y}$, $\Omega_{IU,i,y}$ and $\Phi_{IU,i,y}$ in lower-middle-income countries during the period 2000–2012. Analysing the empirical results with respect to $MCS_{i,\ y}$, it is evident that irrespective of the strong variations in the $\Omega_{MCS,i,y}$ and $\Phi_{MCS,i,y}$ paths, each of the analysed countries experienced '*MCS-technological take-off*' that was preceded by the country-specific $Y_{Crit,MCS}$ (see Fig. 5.3). More detailed analysis reveals that Bolivia is the country where the $Y_{Crit,MCS}$ registered the earliest, in 1999. During the consecutive period 2000–2005, $Y_{Crit,MCS}$ was identified in the remaining 28 economies.[10] The results of $Y_{Crit,IU}$, $\Omega_{IU,i,y}$ and $\Phi_{IU,i,y}$ in lower-middle-income countries are plotted in Fig. 5.4. The evidence shows that across 26 countries (out of 29 in the scope), the $Y_{Crit,IU}$ occurred and was followed by immediate '*IU-technological take-off*' on the $IU_{i,\ y}$ diffusion pattern. Unfortunately, in Congo, Mauritania and Pakistan, the process of entering the exponential growth phase

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[6] The year 2005 is identified as the first year for the '*technological take-off*' in analyzed countries; see later in this section.

[7] When the paths that explain the relationship between $\Omega_{MCS,i,y}$ and $\Phi_{MCS,i,y}$ are not stable, the '*technological take-off*' period may be different from that in the two consecutive years after the $Y_{Crit,MCS}$. In the low-income countries, this is the case for Benin, Cambodia, Myanmar and Nepal.

[8] In Comoros, in 2010, the value of $\Omega_{IU,Com,2010}$ exceeds $\Phi_{IU,COM,2010}$; however in 2 consecutive years, $\Omega_{IU,Com,y} < \Phi_{IU,Com,y}$ again; thus, we argue that the '*take-off*' is not reported.

[9] No intersection points between 'lines' displaying changes in $\Omega_{IU,i,y}$ and $\Phi_{IU,i,y}$ are identified.

[10] In 2000, two countries; in 2001 and 2003, six countries in each year; in 2002, three countries; in 2004, eight countries; and in 2005, three countries).

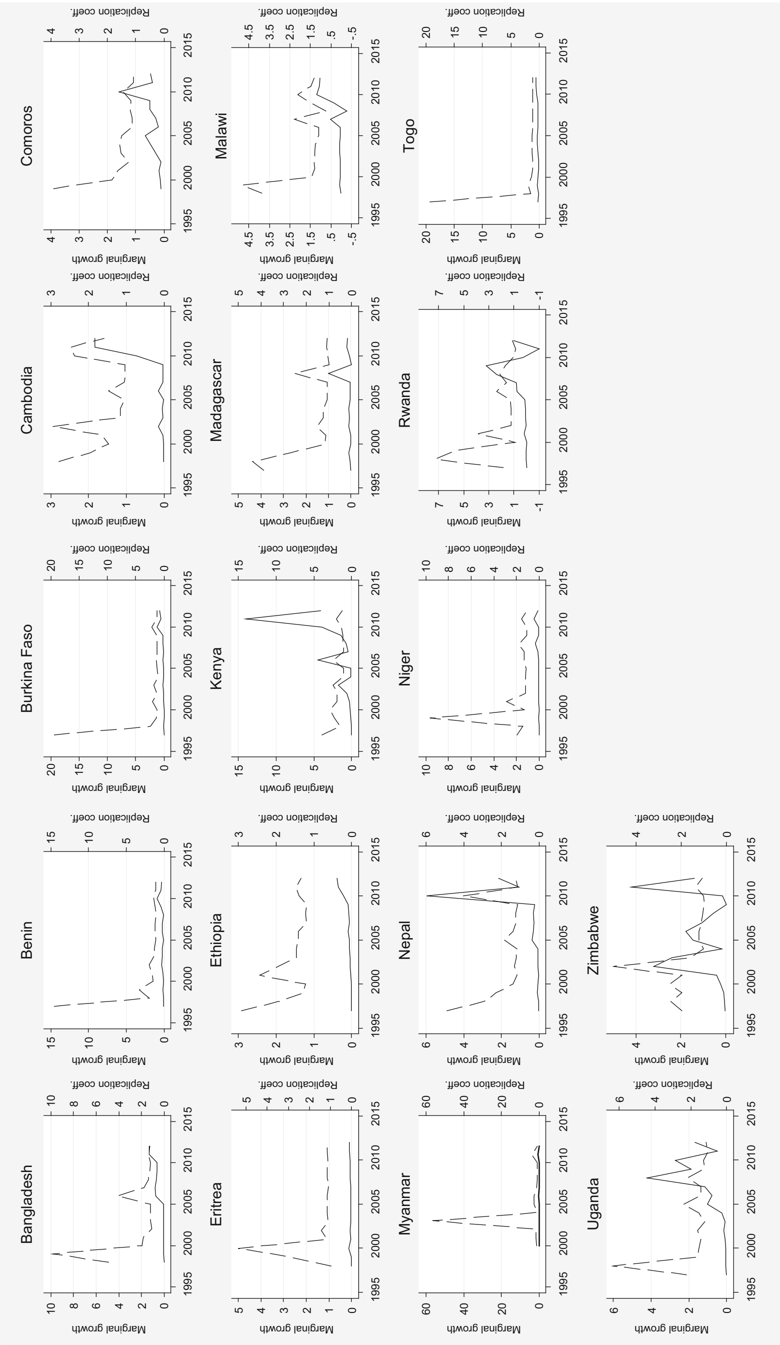

Fig. 5.2 $\boldsymbol{\Omega_{IU,i,y}}$ and $\boldsymbol{\Phi_{IU,i,y}}$—Internet users penetration rates. 17 low-income countries. *Source*: Author's elaboration

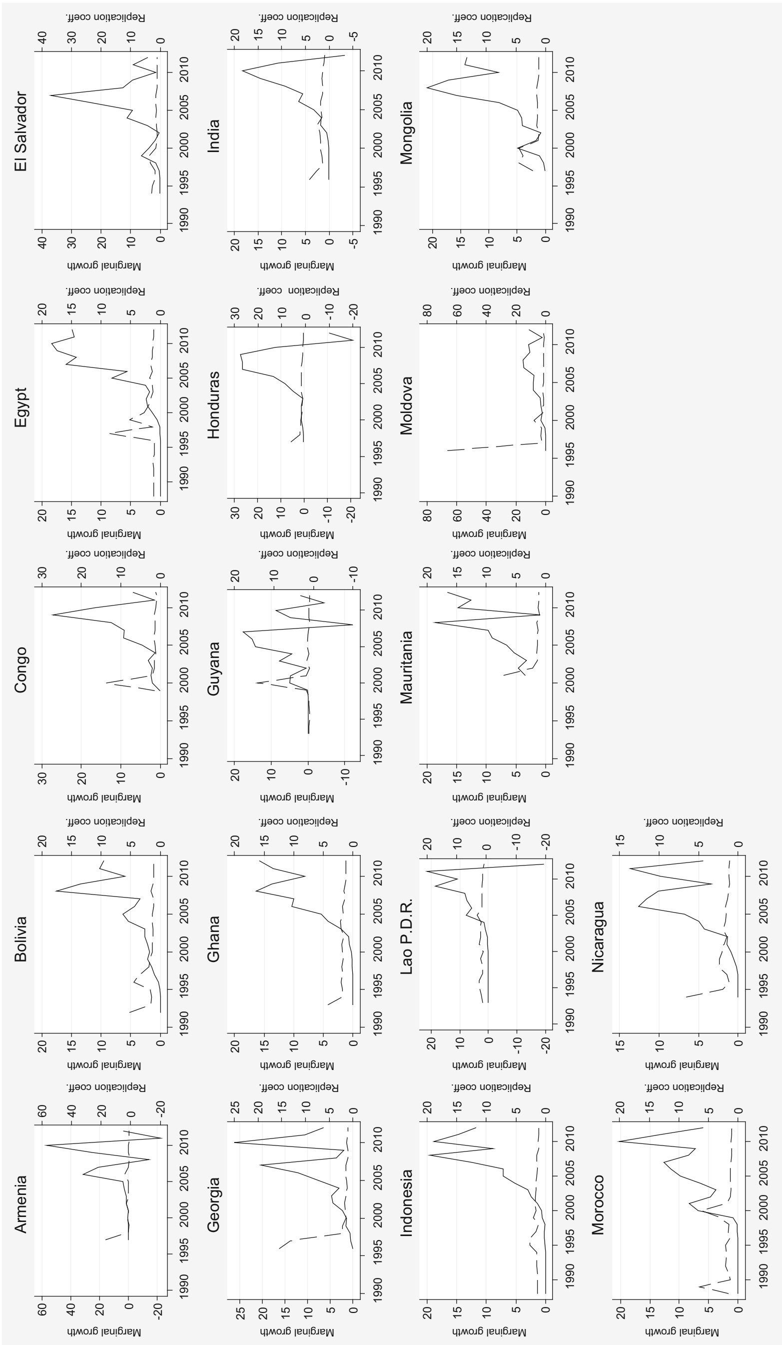

Fig. 5.3 (continued)

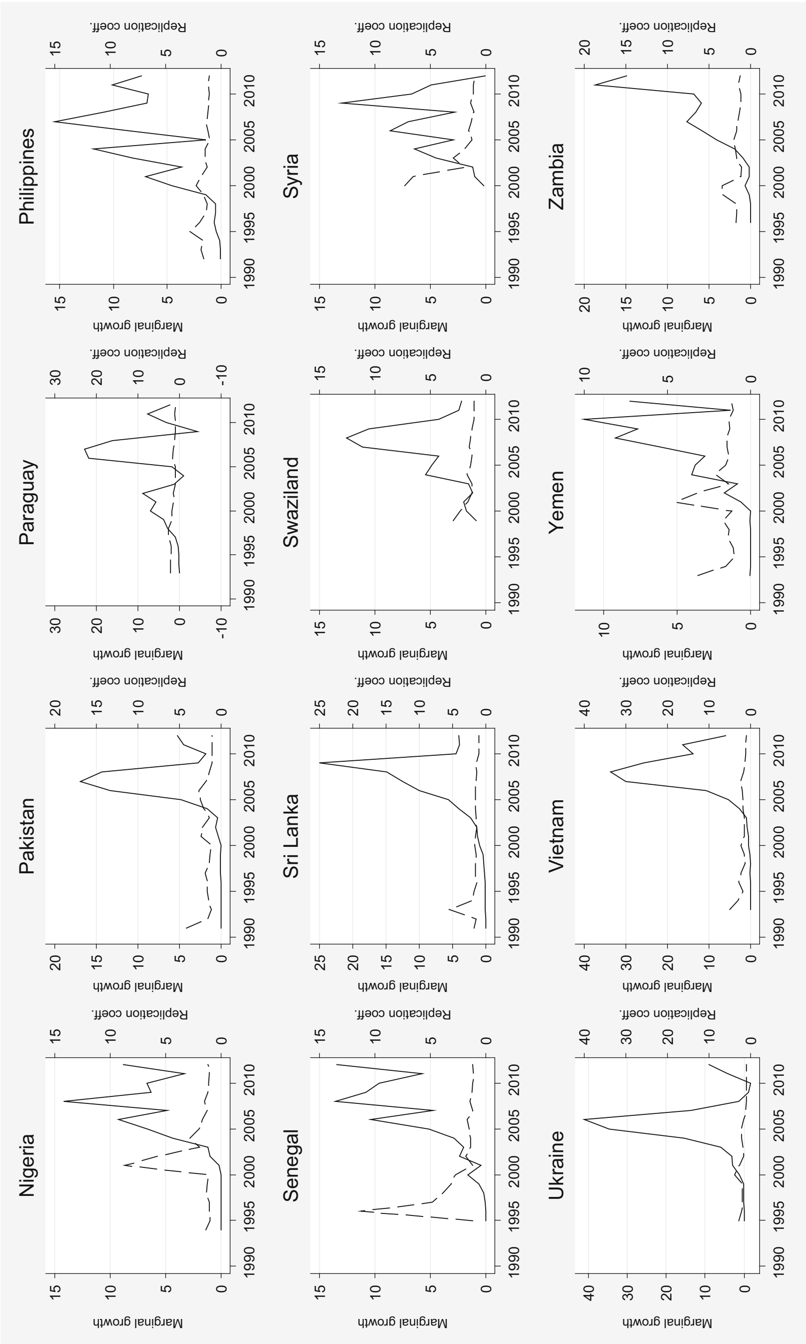

Fig. 5.3 $\Omega_{MCS,i,y}$ and $\Phi_{MCS,i,y}$—Mobile cellular telephony penetration rates. 29 lower-middle-income countries. *Source*: Author's elaboration

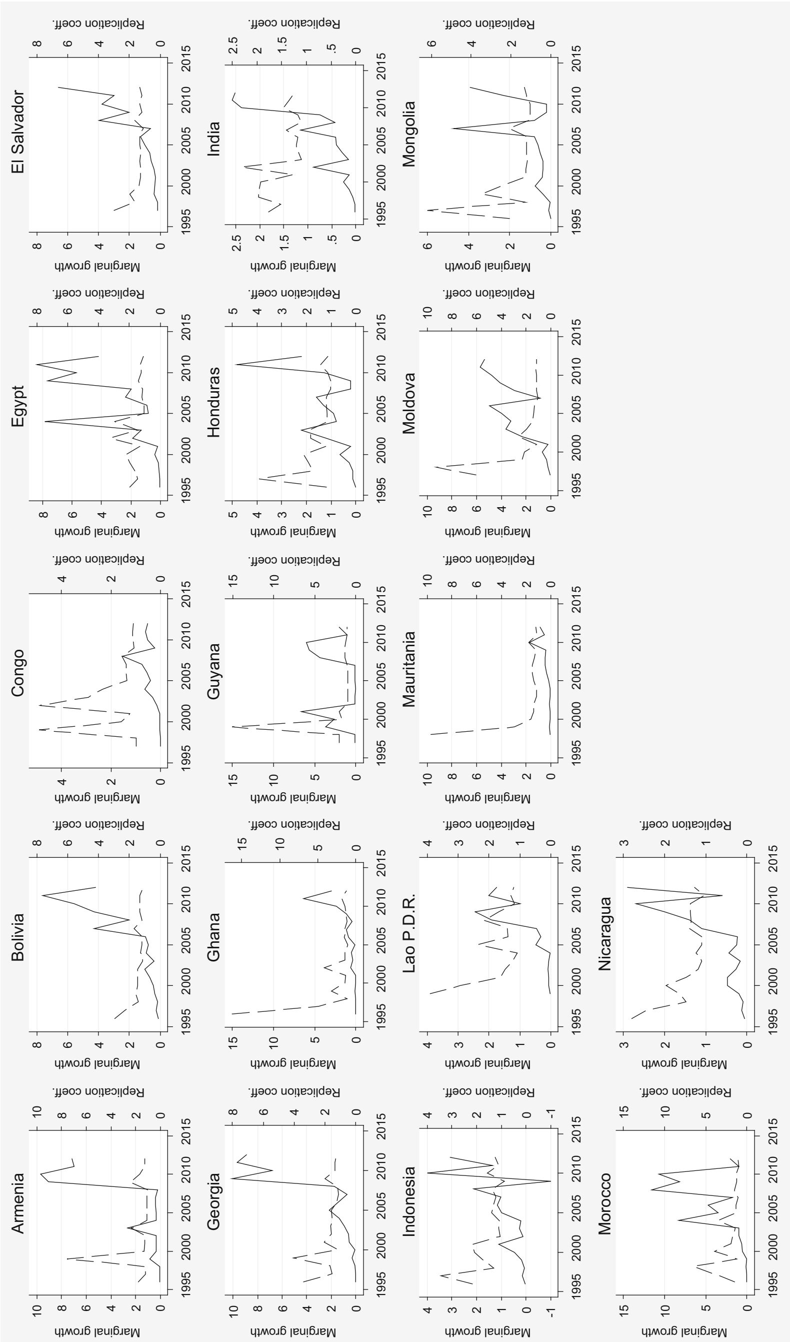

Fig. 5.4 (continued)

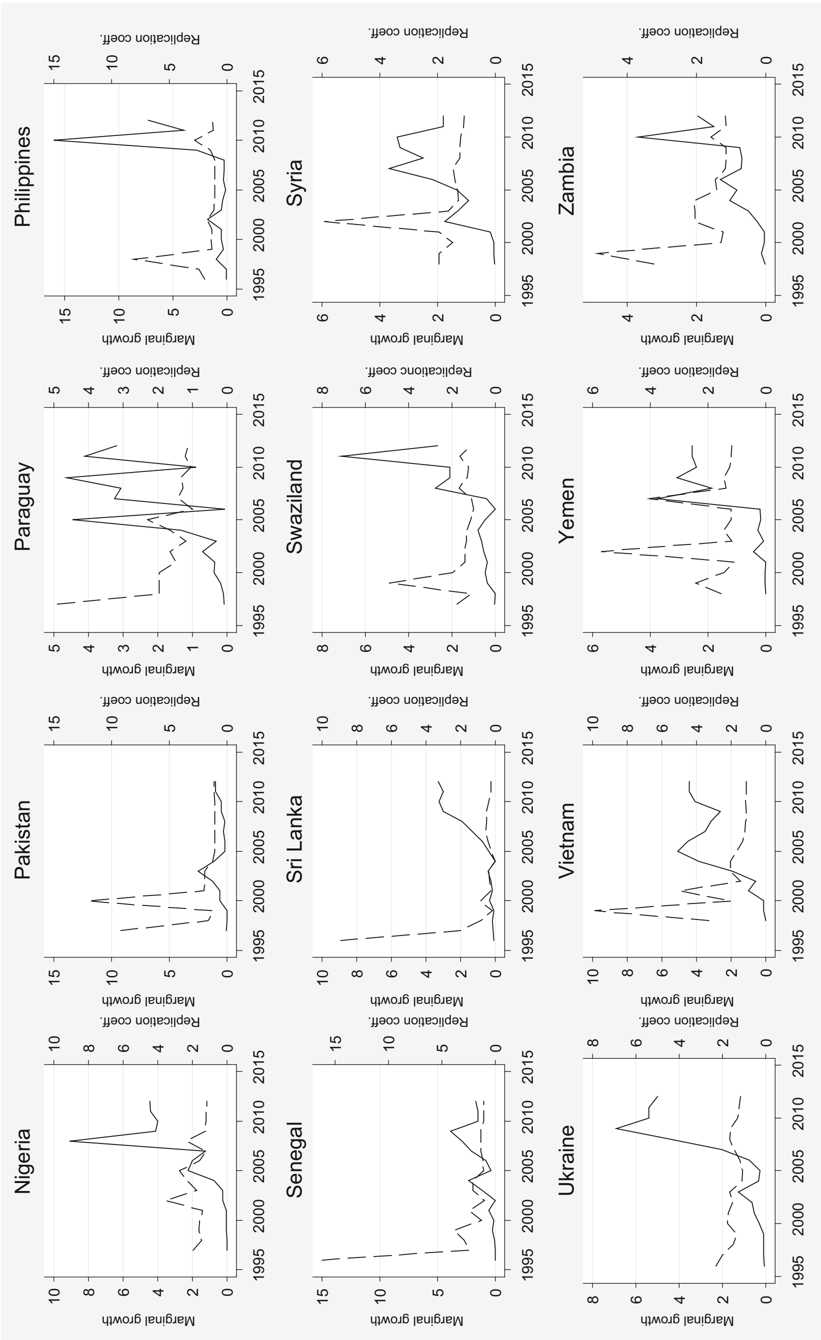

Fig. 5.4 $\Omega_{IU,i,y}$ and $\Phi_{IU,i,y}$—Internet users penetration rates. 29 lower-middle-income countries. *Source*: Author's elaboration

along the $IU_{i,\ y}$ diffusion trajectory was delayed. As a result, in 2012, those countries were still virtually locked in the 'low-level' trap, unable to speed up the ICT diffusion process. From the empirical evidence presented above, a few seminal findings emerge. The analysis of country-wise $\Omega_{ICT,i,y}$ and $\Phi_{ICT,i,y}$ demonstrates that in the early diffusion phase, the ICT replication coefficients are significantly higher compared with ICT marginal growth ($\Omega_{ICT,i,y} < \Phi_{ICT,i,y}$). As diffusion continues, the paths that display the changes in $\Omega_{ICT,i,y}$ and $\Phi_{ICT,i,y}$ gradually converge, so that eventually $\Omega_{ICT,i,y} > \Phi_{ICT,i,y}$. If $\Omega_{ICT,i,y} = \Phi_{ICT,i,y}$ is satisfied, both $Y_{Crit,ICT}$ and the '*technological-take-off*' are reported, which suggests that '*resistance to steady growth*' was overcome (Rostow 1990) and that it fostered exponential growth along the S-shaped diffusion pattern.

As countries experience the '*technological-take-off*', the diffusion process speeds up, and ICT marginal growths are higher than ICT replication coefficients ($\Omega_{ICT,i,y} > \Phi_{ICT,i,y}$). Conversely, if during the initial phases of diffusion, the paths that demonstrate the changes in $\Omega_{ICT,i,y}$ and $\Phi_{ICT,i,y}$ tend to diverge rather than converge, and the condition $\Omega_{ICT,i,y} = \Phi_{ICT,i,y}$ is not satisfied; thus, $Y_{Crit,ICT}$ does not occur. Countries where $Y_{Crit,ICT}$ was not identified are those where the process of entering the exponential growth phase was restrained; these economies are locked in a 'low-level' trap are latecomers. The previous is reflected by the distinctly lower ICT penetration rates compared with those observed in the countries that forged ahead in the same area.

The remainder of this section is an attempt to answer the question: Under what conditions do countries break out of technological stagnation into exponential ICT growth?. To stay consistent with this target, we summarized the data on selected social, institutional and economic factors that could potentially have shaped the country's ability to accelerate ICT deployment. The data are collected for the first year of the '*technological take-off*' interval.[11] Tables 5.2 and 5.3 coherently summarize our findings on countries' individual characteristics that potentially may play a role in fostering the '*technological take-off*'. Respective tables also report the identified $Y_{crit,ICT}$ and the '*technological take-off*' intervals in examined countries. Following the conceptual specification provided in Chap. 3, we presume that the '*technological take-off*' interval is specified as the 2-year period that immediately follows $Y_{crit,ICT}$. The prime and striking conclusion that arises from the information included in Tables 5.2 and 5.3 is that the examined countries differ greatly on various dimensions. They vary not only in terms of observed $Y_{crit,ICT}$ and the '*technological take-off*' intervals but predominantly with respect to their socio-economic, institutional and political performances. The data displayed in the second column of Table 5.2 shows cross-country critical years ($Y_{crit,MCS}$), which is a starting point for our further analysis. This demonstrates '*how much was enough*' to enhance a specific chain reaction and boost additional $MCS_{i,\ y}$ deployment. In the low-income countries, observed *crit*$MCS_{i,\ y}$ vary between 4.72 in

[11] If necessary data are not available for the first year of the '*technological take-off*', we use the data from the nearest available year.

Table 5.2 '*MCS-technological take-off*'—country-specific conditions. Period 2000–2012[a]

Country	$Y_{Crit,MCS}$	'MCS-technological-take-off' interval	$critMCS_{i,y}$	Mobile-cellular prepaid connection charge	Mobile-cellular prepaid—price of a 1-min local call	Mobile-cellular prepaid—price of SMS	MCS IPB (% of GNI per capita per month)	Fixed telephony penetration	Tele-communication market competition/ mobile	GDP PPP per capita	Economic freedom index	Investment freedom index[b]	Democracy (political freedom)	Country freedom status
Low-income countries														
Bangladesh	2005	2006–2007	6.29	13.0	0.03	0.01	3.38	0.78	C (2012)	1,757	52.9	30	0	Partly free
Benin	2004	2006–2007 (path unstable)	5.80	9.6	0.31	0.04	32.7	0.91	C	1,590	54.0	30	2	Free
Burkina Faso	2005	2006–2007	4.72	114.7	0.34	0.05	47	0.68	C	1,308	55.8	50	1	Partly free
Cambodia	2004	2006–2007 (path unstable)	6.55	n.a.	0.06 (2005)	0.02	11.10	0.18	C	2,136	56.7	50	1	Not free
Comoros	2006	2007–2008	5.98	38.2 (2006)	0.23 (2006)	0.12 (2006)	25.7	3.09	M	1,533	n.a.	n.a.	2	Partly free
Eritrea	Not reported	Not reported	–	100.1 (2009)	0.11 (2006)	0.06 (2009)	33 (2011)	0.94 (2010)	PC (de facto—M)	1,083 (2010)	36.2 (2012)	0 (2012)	1	Not free
Ethiopia	2009	2010–2011	4.78	14.3 (2009)	0.05	0.02	12.60	1.04	M	1,061	51.2	25	1	Partly free
Kenya	2004	2005–2006	7.31	33.0	0.37	0.06	23.60	1.2 (2007)	C	1,894	57.9	50	2	Partly free
Madagascar	2006	2007–2008	5.56	4.6 (2006)	0.14 (2006)	0.05 (2006)	46.60	0.69	C	1,477	61.1	70	2	Partly free
Malawi	2007	2008–2009	7.66	n.a.	0.19 (2008)	0.07	57.40	0.78	C	794	52.7	50	2	Partly free
Myanmar	2012	Not reported	10.3	n.a.	0.30 (2009)	0.05 (2009)	69.6 (2009)	0.86 (2009)	M	n.a.	38.7 (2012)	0 (2012)	0	Not free
Nepal	2007	2010–2011	12.6	15.5	0.02	0.01	7.80	3.1	PC	1,999	52.7	15	2	Partly free

Niger	2007	2008–2009	6.3	n.a.	0.37	0.05	59	3.06	C (since 2003)	843	52.9	50	2	Partly free
Rwanda	2007	2008–2009	6.4	n.a.	0.18	0.09	37.60	0.16	C	1,189	54.2	40	1	Not free
Togo	2004	2005–2006	6.2	23.7	0.26	0.07	60	1.13 (2006)	C	1,211	47.2	30	1	Not free
Uganda	2006	2007–2008	6.8	5.4 (2006)	0.23 (2006)	0.06 (2006)	36.70	0.53	C	1,160	63.1	50	1	Partly free
Zimbabwe	2005	2006–2007	12.9	3.03	0.20	0.07	53.4 (2009)	2.7 (2007)	C	1,568	33.5	10	1	Not free
Lower-middle-income countries														
Armenia	2004	2005–2006	6.7	17.3	0.08	0.05	3.8	19.7	C	5,297	n.a.	n.a.	2	Partly free
Bolivia	1999	2001–2002	5.1	n.a.	0.11	0.05 (2003)	5.6	6.04	C	4,315	68.0	90	2	Free
Congo (Rep.)	2001	2005–2006 (path unstable)	4.7	2.3 (2006)	n.a.	0.06	n.a.	0.44	C	4,978	n.a.	n.a.	1	Not free
Egypt	2001	2004–2005 (path unstable)	4.2	16.1	0.05 (2003)	0.04	3.4	13.4	C	8,332	55.5	55	1	Not free
El Salvador	2003	2004–2005	19.1	n.a.	0.08	0.09	4.4	14.6	C (2012)	6,693	71.2	70	2	Free
Georgia	2001	2002–2003	6.4	11.4 (2003)	0.13	0.27 (2007)	4.8	13.8	C	3,673	n.a.	n.a.	2	Partly free
Ghana	2004	2005–2006	8.1	8.3	0.19	0.06	12	1.5	C (since 1996)	2,521	56.5	50	2	Free
Guyana	2001	2003–2004 (path unstable)	10.1	23.2	0.19	0.03 (2006)	6.8	12.2	PC (2007)	5,124	50.3	50	1	Free
Honduras	2004	2005–2006	10.5	4.9	0.26	0.05	n.a.	7.1	C (2010)	3,952	55.3	30	2	Partly free
India	2004	2005–2006	4.7	2.2	0.02	0.03	2	4.4	C	3,328	54.2	50	2	Free

(continued)

Table 5.2 (continued)

Country	$Y_{Crit,MCS}$	'MCS-techno-logical-take-off' interval	$critMCS_{i,y}$	Mobile-cellular prepaid connection charge	Mobile-cellular prepaid—price of a 1-min local call	Mobile-cellular prepaid—price of SMS	MCS IPB (% of GNI per capita per month)	Fixed telephony penetration	Tele-communication market competition/mobile	GDP PPP per capita	Economic freedom index	Investment freedom index[b]	Democracy (political freedom)	Country freedom status
Indonesia	2002	2003–2004	5.4	10.3 (2002)	0.03	0.01 (2004)	3.8	3.7	C (2004)	6,035	55.8	50	2	Partly free
Lao P.D.R.	2005	2007–2008 (path unstable)	11.4	5.1 (2006)	0.08 (2006)	0.05 (2006)	6.10	1.6	PC (2005)	3,298	50.3	30	0	Not free
Mauritania	2002	2004–2005 (path unstable)	8.6	7.6 (2003)	0.17	0.03	14.1	1.3	C	2,250	61.8	70	0	Not free
Moldova	2001	2002–2003	5.6	12.5	0.20 (2003)	0.06	8.50	18.1	C	2,666	n.a.	n.a.	2	Partly free
Mongolia	2000–2003 (path unstable)	2003–2006 (path unstable)	6.44 (in 2000)	7.8	0.25	0.02	2.2 (2009)	5.6	PC (since 1999)	4,382	57.7	50	2	Free
Morocco	2000	2001–2006 (path unstable)	8.2	22.1	0.21	0.08 (2002)	11.8	4.1	C	4,710	63.9	70	0	Partly free
Nicaragua	2003	2004–2005	8.8	n.a.	0.48	0.06	16.8	3.9	C	3,644	61.4	50	2	Partly free
Nigeria	2004	2005–2006	6.7	3.8	0.29	0.11	15.6	0.87	C	4,157	48.4	30	2	Partly free
Pakistan	2005	2006–2007	8.1	2.5 (2005)	0.04	0.01	2.60	3.2	C	4,076	57.9	30	2	Not free
Paraguay	2005	2006–2007	32.0	9.8 (2005)	0.13	0.01	4.10	5.5	C	6,180	55.6	50	2	Partly free
Philippines	2000	2001–2004	8.3	3.3	0.15	0.02 (2002)	4.20	4.2	C (2002)	4,275	n.a.	n.a.	2	Free

		(path unstable)											
Senegal	2002	2004–2005 (path unstable)	5.3	5.7	0.28	0.03	12.30	2.2	PC (since 1998)	2,049	58.9	50	2	Free
Sri Lanka	2003	2004–2005	7.1	14.8	0.10	0.02	1.80	5.0	PC (2009)	5,559	62.5	50	2	Partly free
Swaziland	2003	2004–2005	7.8	6.6 (2003)	0.40	0.12	5.60	4.0	M	6,135	61.6	50	0	Not free
Syria	2003	2004–2006 (path unstable)	6.9	13.4 (2004); 31.1 (2005)	0.07	0.14	6.20	15.0	PC (since 2000)	n.a.	40.6	30	0	Not free
Ukraine	2001	2002–2003	4.6	20.0 (2003)	0.40 (2003)	0.06 (2003)	3.80	22.5	C	5,646	n.a.	n.a.	2	Partly free
Viet Nam	2004	2005–2006	5.9	3.1	0.14	0.02	6.40	9.9	C	3,485	48.1	30	0	Not free
Yemen	2004	2005–2008 (path unstable)	7.5	5.07 (2006)	0.03 (2004)	0.04 (2006)	6.70	4.5	C	4,295	53.8	50	1	Partly free
Zambia	2004	2005–2006	4.2	3.4	0.20 (2004)	0.05 (2004)	18.50	0.82	C	2,346	55	50	1	Partly free

Source: Author's elaboration. Note: Data for mobile cellular sub-basket are for 2008 (earlier not available)—reported if otherwise. Data for 'Democracy' are for 2010

[a]If necessary the period of analysis is extended

[b]Investment Freedom Index is a subindex of Economic Freedom Index

Table 5.3 '*IU-technological take-off*'—country-specific conditions. Period 2000–2012[a]

Country	$Y_{Crit,IU}$	'IU-technological-take-off' interval	*crit*$IU_{i,y}$	Internet freedom	Obstacles to access	Limits on content	Violations of users right	$FIS_{i,y}$ in Y_{Crit}	$FBS_{i,y}$ in Y_{Crit}	$WBS_{i,y}$ in Y_{Crit}
Low-income countries										
Bangladesh	2012	*2013–2014 (projected)*	6.3	Partly free	13 (2013)	12 (2013)	24 (2013)	1.5	0.38	0.47
Benin	Not reported	Not reported	–	n.a.	n.a.	n.a.	n.a.	–	–	–
Burkina Faso	Not reported	Not reported	–	n.a.	n.a.	n.a.	n.a.	–	–	–
Cambodia	2012	*2013–2014 (projected)*	4.9	Partly free (2013)	14 (2013)	15 (2013)	18 (2013)	0.41	0.2	6.7
Comoros	Not reported	Not reported	–	n.a.	n.a.	n.a.	n.a.	–	–	–
Eritrea	Not reported	Not reported	–	n.a.	n.a.	n.a.	n.a.	–	–	–
Ethiopia	Not reported	Not reported	–	Not free	22	27	26	–	–	–
Kenya	2009	2010–2011	10.04	Partly free	10	7	12	0.02	0.02	0.01
Madagascar	Not reported	Not reported	–	n.a.	n.a.	n.a.	n.a.	–	–	–
Malawi	Not reported	Not reported	–	Partly free	16 (2013)	11 (2013)	15 (2013)	–	–	–
Myanmar	Not reported	Not reported	–	Not free	22	23	30	–	–	–
Nepal	2010 and 2012	2010–2012 (path unstable)	11.2 (2010)	n.a.	n.a.	n.a.	n.a.	0.47	0.2	n.a.
Niger	Not reported	Not reported	–	n.a.	n.a.	n.a.	n.a.	–	–	–
Rwanda	2008	2008–2012 (path unstable)	4.5	n.a.	n.a.	n.a.	n.a.	0.08	0.1	n.a.

Togo	Not reported	Not reported	–	n.a.	n.a.	n.a.	n.a.	–	–	–
Uganda	2008	2008–2012 (path unstable)	7.9	Partly free (2012)	11	8	15	0.06	0.1	n.a.
Zimbabwe	2003, 2005, 2011	2003–2012 (path unstable)	6.4 (2003)	Partly free (2012)	17	14	23	0.65	0.7	n.a.
Lower-middle-income countries										
Armenia	2009	2009–2012 (path unstable)	15.3	Free (2013)	8 (2013)	9 (2013)	12 (2013)	2.6	1.05	6.5
Bolivia	2007	2009–2010 (path unstable)	10.5	n.a.	n.a.	n.a.	n.a.	2.05	0.35	n.a.
Congo (Rep.)	Not reported	Not reported	–	n.a.	n.a.	n.a.	n.a.	–	–	–
Egypt	2007	2009–2010 (path unstable)	16.03	Partly free (2013)	14	12	33	3.6	0.64	n.a.
El Salvador	2008	2008–2012 (path unstable)	10.08	n.a.	n.a.	n.a.	n.a.	2.04	2	n.a.
Georgia	2008	2009–2010	10.01	Free (2013)	9	10	11	3.04	2.5	n.a.
Ghana	2010	2011–2012	7.8	n.a.	n.a.	n.a.	n.a.	0.21	0.2	6.9
Guyana	2008	2009–2010	18.2	n.a.	n.a.	n.a.	n.a.	2.8	0.65	n.a.
Honduras	2010	2011–2012	11.09	n.a.	n.a.	n.a.	n.a.	0.9	0.01	n.a.
India	2010	2011–2012	7.5	Partly free (2013)	13	9	17	1.5	0.91	0.94
Indonesia	2010	2010–2012 (path unstable)	10.9	Partly free (2013)	11	11	20	0.79	0.94	18.6
Lao P.D.R.	2009 and 2011	2009–2012 (path unstable)	6	n.a.	n.a.	n.a.	n.a.	0.31	0.06	n.a.
Mauritania	Not reported	Not reported	–	n.a.	n.a.	n.a.	n.a.	–	–	–
Moldova	2008	2009–2010	23.4	n.a.	n.a.	n.a.	n.a.	5.6	3.2	0.96

(continued)

Table 5.3 (continued)

Country	$Y_{Crit,IU}$	'IU-technological-take-off' interval	$critIU_{i,y}$	Internet freedom	Obstacles to access	Limits on content	Violations of users right	$FIS_{i,y}$ in Y_{Crit}	$FBS_{i,y}$ in Y_{Crit}	$WBS_{i,y}$ in Y_{Crit}
Mongolia	2007 and 2011	2007–2012 (path unstable)	9	n.a.	n.a.	n.a.	n.a.	0.66	0.28	n.a.
Morocco	2004	2004–2008 (path unstable)	11.6	Partly free (2013)	11 (2013)	7 (2013)	24 (2013)	0.37	0.21	n.a.
Nicaragua	2008	2009–2010	5.3	n.a.	n.a.	n.a.	n.a.	0.75	0.76	n.a.
Nigeria	2006	2008–2009 (path unstable)	5.5	Partly free (2013)	12	9	12	0.08	0.01	n.a.
Pakistan	Not reported	Not reported	–	Not free (2013)	19	18	26	–	–	–
Paraguay	2005 and 2007	2005–2009 (path unstable)	7.9	n.a.	n.a.	n.a.	n.a.	1.01	0.09	n.a.
Philippines	2009	2010–2011	9	Free (2013)	10	5	8	3.9	1.8	1.8
Senegal	2007	2008–2009	7.7	n.a.	n.a.	n.a.	n.a.	0.32	0.38	n.a.
Sri Lanka	2003 and 2005	2003–2009 (path unstable)	1.4	Partly free (2013)	16	18	21	0.43	0.01	n.a.
Swaziland	2008	2008–2011 (path unstable)	6.8	n.a.	n.a.	n.a.	n.a.	1.7	0.06	n.a.
Syria	2005	2006–2007	5.6	Not free (2013)	23	25	35	1.2	0.01	n.a.
Ukraine	2007	2008–2009	6.5	Free (2013)	7	8	12	2.9	1.7	n.a.
Viet Nam	2004	2005–2006	7.6	Not free (2013)	16	26	31	1.9	0.06	n.a.
Yemen	2008	2009–2010	6.9	n.a.	n.a.	n.a.	n.a.	1.4	0.11	n.a.
Zambia	2010	2010–2012 (path unstable)	10	n.a.	n.a.	n.a.	n.a.	0.13	0.07	0.26

Country	Fixed (wired)-broadband connection charge	Fixed (wired)-broadband monthly subscription charge	FBS IPB (% of GNI per capita per month)	Telecommunication market competition (fixed broadband connections/internet services)	GDP PPPper capita	Economic freedom index	Investment freedom index[b]	Democracy (political freedom)	Country freedom status
Low-income countries									
Bangladesh	4.2	4.2	7.3	C/C	2,363.8	53.2	55	0	Partly free
Benin	39.1	48.9	81.5	M/PC	1,686.5	55.7	60	2	Free
Burkina Faso	29.3	43.09	98.2	C/C	1,527.9	60.6	55	1	Partly free
Cambodia	4.9	23.7	34	C/C	2,790.4	57.6	60	1	Not free
Comoros	26.1	48.3	620 (2010)	n.a./M	1,493.2	45.7	15	2	Partly free
Eritrea	68.3	1,596	4,455.4	M/PC	1,179.8	36.2	0	1	Not free
Ethiopia	56.4	22.5	71	M/M	1,218.3	52	25	1	Partly free
Kenya	50.4 (2010)	38.7	57.6	C/C	2,079.9	57.5	45	2	Partly free
Madagascar	45.01	58.7	177.8	M/C (2008)	1,390.8	62.4	55	2	Partly free
Malawi	702.7 (2010)	30.2	169.7	C (2012)/PC (1998)	737.3	56.4	50	2	Partly free
Myanmar	1315.7 (2009)	28.2 (2009)	155 (2009)	PC/M	n.a.	38.7	0	0	Not free
Nepal	7.7	23.2	63.4	C/C	1,999.1	52.7	15	2	Partly free
Niger	39.1	58.2	193 (2011)	n.a./M (2003)	884.0	54.3	55	2	Partly free
Rwanda	175.9 (2009)	91.4	344.3	C/C (2010)	1,189.2	54.2	40	1	Not free
Togo	125.1 (2011)	43.6	101.2	M/C (2010)	1,313.9	48.3	25	1	Not free

(continued)

Table 5.3 (continued)

Country	Fixed (wired)-broadband connection charge	Fixed (wired)-broadband monthly subscription charge	FBS IPB (% of GNI per capita per month)	Telecommunication market competition (fixed broadband connections/internet services)	GDP PPPper capita	Economic freedom index	Investment freedom index[b]	Democracy (political freedom)	Country freedom status
Uganda	145.2 (2009)	131.2	600	C/C (2009)	1,218.9	63.8	50	1	Partly free
Zimbabwe	267.3 (2006)	2,672.9 (2006)	1,059 (2010); 56.3 (2011)	C/C	1,907.7	36.7	10	1	Not free
Lower-middle-income countries									
Armenia	n.a.	33.03	11.3	C/C	6,357.8	n.a.	n.a.	2	Partly free
Bolivia	42.4	34.9	28.9	n.a./C (2001)	5,152.5	53.6	20	2	Free
Congo (Rep.)	250.06 (2012)	400.1 (2012)	n.a.	n.a./C	5,631.3	n.a.	n.a.	1	Not free
Egypt	n.a.	8.11	5.46	C/C	10,272.1	58	50	1	Not free
El Salvador	n.a.	20.3	7.6	C/C	7,450.0	68.5	70	2	Free
Georgia	n.a.	41.9	20.5	C/C	5,654.9	n.a.	n.a.	2	Partly free
Ghana	36.3	29.7	25.3	C/C	3,445.8	59.4	65	2	Free
Guyana	14.7	48.9	41.8	PC/PC (2007)	5,344.4	48.4	40	1	Free
Honduras	n.a.	19.3	14.1 (2010)	C/C (2010)	4,345.2	58.6	60	2	Partly free
India	n.a.	6.01	5.1	C/C	4,883.1	54.5	35	2	Free
Indonesia	8.25	21.4	10.4	C/C (2004)	8,026.7	55.5	35	2	Partly free
Lao P.D.R.	116.2	193.7	315.1	PC/PC (2005)	3,667.5	50.4	30	0	Not free
Mauritania	23.5 (2012)	21.1 (2012)	26.8 (2012)	C/C (2010)	2,828.8	53	40	0	Not free

Moldova	n.a.	13.5	10.9	C/C	3,648.2	n.a.	n.a.	2	Partly free
Mongolia	38.1 (2006)	8.3 (2009)	6.04 (2009)	PC/C (2010)	5,918.9	60.3	60	2	Free
Morocco	n.a.	19.2 (2008)	10.6 (2008)	C/C	5,258.8	56.7	70	0	Partly free
Nicaragua	23.2	34.8	38.2	C/C	3,908.5	69.8	70	2	Partly free
Nigeria	337.4	674.8	890.4	C/C (2001)	4,714.7	55.1	30	2	Partly free
Pakistan	10.7 (2012)	13.3 (2012)	15.5 (2012)	C/C	4,360.3	54.7	35	2	Not free
Paraguay	60.0 (2006)	28.9 (2006)	25.1 (2008)	C/C	6,007.1	53.4	50	2	Partly free
Philippines	24.3	22.1	12.9	n.a./C (2002)	5,613.7	53.6	40	2	Free
Senegal	87.09	40.1	61.3	PC/C (1998)	2,161.7	58.3	50	2	Free
Sri Lanka	3.9 (2004)	23.2 (2008)	16.4 (2008)	PC/PC (2009)	5,343.7	62.5	50	2	Partly free
Swaziland	280.3	1,781.8	873.2	M/PC (1983)	6,526.8	58.4	50	0	Not free
Syria	n.a.	51.7 (2008)	34.9 (2008)	PC/PC	1,799.9	51.2	30	0	Not free
Ukraine	15.4	18.9	9.7	C/C	8,775.8	n.a.	n.a.	2	Partly free
Viet Nam	37.8	3.1	25.7 (2008)	C/C	3,484.8	48.1	30	0	Not free
Yemen	147.8	221.8	277.8	n.a./C (2004)	4,493.9	56.9	50	1	Partly free
Zambia	962.8	58	65	C/C (2011)	2,779.0	58	50	1	Partly free

Source: Author's elaboration. Note: for countries where the '*IU-technological take-off*' was not reported—data are for 2012 (reported if otherwise). The data for 'Democracy' are for 2010. Data for Internet freedom (Obstacles to use, Limits on content and Violations of users rights) are for 2012

[a]If necessary the period of analysis is extended

[b]Investment Freedom Index is a subindex of Economic Freedom Index

Burkina Faso and 12.9 in Zimbabwe; while the average $crit\mathrm{MCS}_{\text{low-income, y}}$ is 7.2[12] per 100 inhab.,[13] demonstrating that these countries inevitably head toward the '*MCS-technological take-off*' once the $\mathrm{MCS}_{i,\,y}$ penetration rates reaches an average of 7.2 per 100 inhab.[14] Our empirical evidence also demonstrates that the average duration of the diffusion initial phase[15]—the length of time required for the '*MCS-technological take-off*' to emerge—in the low-income countries, was approximately 12 years; however, it varied significantly, ranging from 15 years in Bangladesh to 5 years in Comoros. Careful examination of the country-specific structural characteristics that are reported for the first year of the '*MCS-technological take-off*' interval leads to a few important conclusions. First, we consider the elements that may be described as *direct* stimuli for the '*MCS-technological take-off*', which are the following[16]: the price of a 1-min call, the price of sending one SMS, the cost of mobile-cellular prepaid connection, the mobile cellular sub-basket, per capita income and fixed telephony penetration rates, type of competition in the telecommunication market, economic freedom and investment freedom. Elements such as price of a 1-min call, price for sending an SMS, and mobile-cellular prepaid connection charges along with per capita income most directly affect the basic affordability of mobile cellular services. Overall affordability is also demonstrated through the mobile cellular sub-basket, which accounts for the percent of GNI per capita per month that must be spend to buy the standard basket of mobile cellular services; the influence of per capita income is thus demonstrated throughout this channel. The degree of competition (full competition, partial competition or monopoly) in the telecommunication market determines companies' possibilities of operating freely in a country. Economic freedom, as such, constitutes an essential element in shaping a country's economic environment, and investment freedom coherently measures country's market openness for inflows and outflows of goods and services; investment freedom also reflects possible constraints on and restrictions of investment capital flows. Fixed telephony penetration may, to a point, affect the adoption of mobile cellular telephony as a favourable alternative, if the mobile telephony is not freely accessible. The respective prices of 1-min calls varied significantly across countries. The highest prices are reported for Kenya (US$0.37),[17] and the lowest are for Nepal (US$0.02). In the lower-middle-income countries, the price of a 1-min call ranges from US$0.48 in Nicaragua, to US$0.02 in India. The differences in SMS prices are

[12] If the two extreme observations (Zimbabwe and Nepal) are eliminated, the average decreases until $crit\mathrm{MCS}_{i,y} = 6.1$ per 100 inhab.

[13] Author's calculations.

[14] Obviously, the $\mathrm{MCS}_{i,y} = 7.2$ (per 100 inhab.) stands for different absolute numbers of people in each country.

[15] The length of the initial diffusion phase we calculate as the number of years between the year when given ICT was first introduced until the first year of the '*technological take-off*'.

[16] For detailed description of variables—see Sect. 5.2.1.

[17] The prices of one-minute calls and SMS are expressed in United States dollars in PPP terms.

not so striking, although they are still essential across the examined countries in both income groups. Although the analysis of absolute mobile cellular service costs provides elementary information on the potential demand for these services, we argue that it would be far more informative to put mobile cellular service prices into an 'income perspective', which allows for assessing the overall affordability of ICT services. With this aim, we use the cost of the mobile cellular sub-basket expressed as a percentage of GNI per capita per month to draw conclusions on the affordability of mobile cellular services, which mirrors an individual's overall propensity to buy these services in a given country. The extensive analysis of cross-country mobile cellular sub-basket costs supports the supposition that—surprisingly—even *low* affordability does not inhibit the rapid expansion of mobile cellular networks. This is a far-reaching observation that reflects unusual tendencies in low-income countries. In both the low-income and the lower-middle-income groups, the '*MCS-technological take-off*' occurred under highly unfavourable conditions, while the affordability of mobile cellular services was low. According to the evidence summarised in Table 5.2, a few countries reflect extremely low $MCS_{i,\ y}$ affordability[18]: Togo (60 %) or Niger (59 %). The comparison between Niger and e.g. Bangladesh is striking; in Niger, the mobile cellular sub-basket accounts for approximately 59 % of GNI per capita per month, whereas in Bangladesh, the amount is only 3.38 %. Despite the vast differences in the values of mobile cellular sub-baskets, these two countries are primed for exponential growth in $critMCS_{i,\ y} = 6.3\ \%$; they both achieved similar $MCS_{i,\ y}$ penetration rates in the terminal year of our analysis (2012), approximately $MCS_{i,2012} = 60\ \%$. In the lower-middle-income economies, the cross-country disparities in the value of mobile cellular sub-baskets are less striking. The average mobile cellular sub-basket cost was estimated at roughly 7.18 %; the highest costs were reported in Zambia (18.5 %), and the lowest were in India (2.0 %). Although the results, especially in the case of the low-income countries, are at odds with basic intuition, they demonstrate that low affordability does not constitute a significant barrier for mobile cellular services acquisition and does not impede its rapid spread. This evidence also reflects individuals' astonishingly high propensity to acquire mobile cellular telephony even in the most economically backward countries. The cost of mobile-prepaid connection during the '*MCS-technological take-off*' varies extensively across countries, ranging from US$114.7 in Burkina Faso to US$3.03 in Zimbabwe. This evidence coincides with the previous findings and may suggest that the '*MCS-technological take-off*' is possible even if the one-time initial charge for mobile cellular telephony usage is relatively high and could potentially limit the rapid spread of mobile cellular services. Regarding the lower-middle-income countries, the variability in mobile-prepaid connection charges is far lower. The average cost of a mobile-prepaid connection was US$9.32, and there were no substantial differences across countries. As a reminder, the penetration rates for fixed telephony in both income groups remained extremely low over the examined

[18] Note that the first data on mobile cellular sub-basket prices are available in 2008 (ITU 2010).

period; that is, the majority of individuals and firms rarely accessed and used telephone landlines. Because the emergence of the '*MCS-technological take-off*' is a complex phenomenon, we additionally intend to focus on its deep determinants, mostly associated with institutional environments and political regimes (Rodrik et al. 2004).

Table 5.2 also summarizes the information on political regimes, political and economic freedom and types of competition in telecommunication markets across the countries in our scope. The first and very important thing to note is that in 12 (out of 15) low-income countries,[19] the telecommunication markets were fully liberalized during the '*technological take-off*'. The presence of full competition yields increasing telecommunication market efficiency, and provides a solid background for creating benefits for consumers owing to more balanced tariffs and growing geographic coverage. In only two countries, Ethiopia and Comoros, were the telecommunication markets fully monopolized; in another, Nepal, the telecom market was labelled partial competition[20] (World Bank Group 2014). In Ethiopia, in 2010 (the $Y_{crit,MCS}$), the telecommunication market was fully controlled by Ethio-Telecom (provider of fixed, mobile and Internet services), which significantly impeded tariff reductions and any increase in affordable and innovative services. Although the '*MCS-technology take-off*' was observed in Ethiopia in 2010–2011, the overall penetration remained relatively low (in 2012, $MCS_{ETH,2012} = 22.4$ per 100 inhab.). In turn, in Comoros, despite the fully monopolized telecommunication market (the mobile operator is Comoros Telecom/Huri), the relatively high prices of 1-min calls and sending SMSs, and the relatively low affordability; in 2012, the mobile cellular telephony penetration rate reached $MCS_{i,\ y} = 39.5$ per 100 inhab., although according to various sources, the of mobile cellular telephony network coverage was limited to urban areas. Meanwhile, in the lower-middle-income economies, in 22 countries (out of 29 where the '*MCS-technology take-off*' was reported), 'full competition' in the telecommunication markets was observed; 'partial competition' was observed in six countries; and 'full monopoly' was observed in one country (Swaziland). The lack of full competition, however, did not restrict either the '*MCS-technology take-off*' or the rapid expansion of mobile cellular networks. As a reminder, in 2012 (the terminal year of our analysis), the $MCS_{i,\ y}$ penetration rates were unexpectedly high in, e.g., Mongolia (120.7 per 100 inhab.) and Sri Lanka (91.6 per 100 inhab.); the costs of mobile cellular sub-baskets were, respectively, 2.2 % and 1.8 % of GNI per capita per month. The only country where the telecommunication market was *not* liberalized was

[19] In Malawi, although the telecommunication market is labelled 'full competition' (World Bank Group 2014), there are only two telecom operators, Airtel and Telecom Networks Malawi. In Zimbabwe, although from 2000 onward, the telecommunication market was labelled 'full competition', since 2009, it has been labelled 'partial competition'. In 2014 in Zimbabwe, there were three mobile operators, Econet Wireless, Telecell Zimbabwe Ltd., and TelOne.

[20] In Nepal, there are two mobile operators, Ncell and Nepal Telecom. Source: www.africantelecomsnews.com and www.nta.gov.np/en/; accessed: May 2014).

Swaziland. Notably, despite the existence of a fully monopolized telecommunication market,[21] the '*MCS-technology take-off*' took place in 2004–2005, fostering the rapid spread of cellular telephony, so that in 2012, $MCS_{SWZ,2012} = 65.4$ per 100 inhab. Not surprisingly, in Swaziland, because of the absence of liberalised telecommunication services, the prices of both a 1-min call and sending an SMS were comparably high, US$0.40 and US$0.12, respectively, among the highest rates in the lower-middle-income countries. However, despite the relatively high prices for basic mobile cellular services, the cost of acquiring mobile cellular sub-baskets was 5.6 % in 2008; the affordability of mobile cellular services was high in Swaziland. Therefore, high affordability may be recognized as a major driving force of exponential increases in the number of mobile cellular networks users in Swaziland during the period 2003–2012. Regarding the results on political regimes and countries' freedoms, the evidence is rather mixed and reveals little regularity. Using the Freedom House methodology, ten counties were classified as 'partly free', another four were 'not free', and only one country (*sic!*), Benin, attained 'free' status.[22] These results are striking. The remaining four countries labelled 'not free' are those where both political rights and civil liberties were heavily violated. In another ranking of broadly perceived political freedoms, provided in the Human Development Report 2010, seven countries scored[23] '2' and were claimed to be democracies; another seven scored '1' and were claimed to be democracies but with no alternation; and only one country, Bangladesh, scored '0' was labelled nondemocratic. The analogous comparison for the lower-middle-income group reveals that according to Freedom House, eight counties out of the considered were classified as 'not free', and another 13 economies were recognized as 'partly free', and the remaining eight were labelled 'free'. In the classification presented in the Human Development Report 2010, six countries attained a score of '0' and thus were classified as nondemocratic; another five scored '1', and the remaining 18 scored '2' and were considered democracies. Similar to the low-income countries, the lack of democracy and/or heavy violations of political rights and civil liberties did not preclude the emergence of the '*MCS-technology take-off*' and the broad expansion of mobile cellular networks in undemocratic and politically restricted countries. Addressing the results of countries' ratings regarding economic and investment freedoms (see the Heritage Foundation), the cross-country variation is high. Economic freedom is reflected in the freedom to choose to '*work, consume and produce*' (Heritage Foundation 2014) without being constrained '*beyond the extent necessary to protect and maintain the liberty itself*' (Heritage Foundation 2014). However, for the expansion of mobile networks, the level of investment freedom is arguably seminal, as shown in the degree of constrains that are arbitrarily imposed on flows of investment capital. Multiple restrictions on investments generally, depending on state policies and national

[21] The only mobile operator is MTN Swaziland.

[22] The meanings of 'country status' are provided in Sect. 5.2.1.

[23] The meaning of the 'scores' are provided in Sect. 5.2.1.

development strategies, promote or limit the effective investment actions undertaken by domestic and/or foreign companies. Across the low-income countries where the '*MCS-technological take-off*' took place, the average investment freedom index was 39.2, the best-performing country (with the weakest investment restrictions) was Madagascar at 70.0; the worst was Zimbabwe (10.0), where the investment process was highly restricted and state-regulated. The related disparities among the lower-income group are less striking. The average score for the investment freedom index was 49.3, with Bolivia the best performer at 90.0 (*sic!*) and with the worst being Honduras, Lao P.D.R, Nigeria, Pakistan, Syria and Viet Nam (30.0 in each case). The examples of Viet Nam and Swaziland appear to be the most interesting. In Viet Nam, despite the authoritarian regime, the lack of political rights and civil liberties, and the limited investment freedom,[24] the telecommunication market was fully liberalized.[25] For the rapid expansion of mobile cellular networks, the seminal factor was the approval, in 2001 (4 years before the '*MCS-technological take-off*'), of The Vietnam Post and Telecommunication Development Strategy to 2010; this legal document directly states a strong willingness to build, by 2020, a modern ICT infrastructure and, resultantly, an information society in Viet Nam[26] (Tuan 2011). The latter induced the '*MCS-technological take-off*' (in 2005–2006), which in a relatively short period dramatically shifted the mobile cellular penetration rates. The basic analysis of the degree of economic freedom (especially investment freedom) shows that there might be no single correct answer to the question: 'To what extent does economic freedom affect the '*MCS-technological take-off*'?'. The evidence might suggest that even under relatively unfavourable conditions for investment capital flows, the rapid expansion of mobile cellular services is not restricted. In contrast to what might have been expected, the combined evidence on countries' political regimes (democracies or dictatorships), freedom status (regarding violations of political rights and civil liberties) and, especially, investment freedom, has demonstrated that mobile cellular network expansion has relatively little to do with these three elements. The case of Swaziland is even more striking. In 2003 (the $Y_{crit,MCS}$), the country was classified as 'not free' and 'nondemocratic', with a fully monopolized telecommunication market. However, the numerical evidence demonstrates that even under extremely unfavourable conditions, the emergence of the '*MCS-technological take-off*' is still possible. Important to note is that in Swaziland, the cost of a standard mobile cellular sub-basket was relatively low (5.6 %, as mentioned previously), which was below the lower-middle-income group average and may be considered a

[24] Viet Nam has adopted a two-track approach to trade liberalization: By government decision, the country has been opened to foreign investment capital while at the same time providing high protection to multiple sectors (Tuan 2011).

[25] According to ITU data, in 2012 in Viet Nam, there were six active mobile operators, Viettel, Mobifone, Vinaphone, S-Telecom, Hanoi-Telecom, GTEL.

[26] In following years - 2005, 2006, 2008 and 2010, the government of Viet Nam adopted another four documents that enabled a national policy on broad ICT deployment. For details, see Broadband in Vietnam: Forging Its Own Path. Washington, D.C: infoDev/World Bank. 2011.

seminal driver of $MCS_{i,\ y}$ diffusion in Swaziland. It is also not insignificant that in 1995, the United Nation Economic Commission for Africa (ECA) released and adopted the first African Information Society Initiative (AISI), the primary target of which was to promote and assist actions that were designed to build information societies in African countries. In response, in 2000 (4 years before the '*MCS-technology take-off*') in Swaziland, in cooperation with UNDP, UNESCO, ECA[27] and the Swaziland National Association of Journalists, the first national workshop where national ICT policy was discussed was organized (ECA 2003), which resulted in agreement on the future development of national ICT industries and media and telecommunication markets that contributed to the creation of ICT-enabling environments and increased empowerment stemming from the rapidly increasing ICT penetration rates. Eritrea and Myanmar are the only countries where through the final year of the analysis, 2012, the emergence of the '*MCS-technological take-off*' was not reported. Eritrea is a highly centralized authoritarian regime, classified by Freedom House (2014) as 'not free'. Although according to the Human Development Report 2010, the country is recognized as 'democratic with no alternation' (score '1'), from its independence from Ethiopia (1993) until 2011, no free elections were enforced. In 2012 in Eritrea, investment freedom was '0' (*sic!*); thus, the flows of investment capital were completely restricted. In 2010, the cost of a mobile cellular sub-basket accounted for 33 % of GNI per capita per month, which was slightly below the low-income group average. Although according to ITU data (ITU 2013), the telecommunication market was officially partially liberalised, in 2010, only one company, completely controlled by the government—Eritrea Telecommunications Services Corp. (Eritel)—was operating in the telecommunication market. In addition, Eritrea is recognized as one of the most censored countries in the world, where the freedom of expression and of the press is essentially violated. An authoritarian regime, heavy infrastructural underdevelopment, violations of human rights and censorship, and finally, the lack of a national 'e-strategy', all of these completely restricted the widespread deployment of mobile cellular telephony in Eritrea. According to our estimates, in Myanmar, the 'critical year' was found to be 2012. Because 2012 was the terminal year of our analysis, the *strict* identification of the emerging '*MCS-technological take-off*' was precluded. The country's environment is highly unfavourable: it is recognized as nondemocratic, it lacks basic political freedoms and basic investment freedoms were completely eliminated (the investment freedom index was reported '0' in 2012). In addition, the telecommunication market was monopolised. Moreover, the prices of mobile cellular services were extremely high; the cost of a mobile cellular sub-basket was 69.6 % of GNI per capita per month. All of these elements effectively restricted broad usage of mobile cellular networks in Myanmar. The government of Myanmar has adopted the Myanmar ICT Development Master Plan (2011–2015), the major objectives of which are, *inter alia*, the strong enhancement of broader countrywide ICT deployment, with the intent to achieve $MCS_{i,\ y} = 45$ per 100 inhab. by 2015 (ITU 2012). For the country of

[27] Economic Commission for Africa.

Myanmar, the plan brings prospects for the future in achieving gains from higher mobile cellular coverage, accessibility and usage. The picture arising from the $IU_{i,\ y}$ diffusion pattern analysis, is far less promising (see Table 5.3). Regarding the low-income countries, the '*IU-technological take-off*' was indentified in only seven (out of 17). An important observation is that among the countries listed above, Kenya is the only economy in which the '*IU-technological take-off*' interval may be undoubtedly reported for the time interval 2010–2011. In another two countries, Bangladesh and Cambodia, $Y_{crit,IU} = 2012$; as such, for the consecutive period 2013–2014, the '*IU-technological take-off*' is projected. In Nepal, Rwanda, Uganda and Zimbabwe, the $Y_{crit,IU}$ has been designated,[28] but the paths that reflect the changes in $\Omega_{IU,i,y}$ and $\Phi_{IU,i,y}$ are unstable; thus, the identification of a country-specific '*IU-technological take-off*' is marked by uncertainty. The time span when both $Y_{crit,IU}$ and '*IU-technological take-off*' were observed during the 4-year period (2008–2012), and the time required for the '*IU-technological take-off*' to emerge was, on average, 14.3 years.[29] According to our calculations, in the low-income countries, the average $critIU_{i,\ y} = 7.3\ \%$, which may be identified as the critical (threshold) level of Internet penetration rates that enhance the emergence of the '*IU-technological take-off*' leading to exponential growth of $IU_{i,\ y}$ penetration rates. The time span for the '*IU-technological take-off*' interval may be denoted for 2004–2012. The average length of the initial diffusion phase was 14.4 years; in India, it took 20 years for '*IU-technological take-off*' to emerge, whereas in Paraguay, it only took 10 years. Our evidence has also demonstrated that in the respective $Y_{crit,IU}$, the average $IU_{i,\ y}$ penetration rate was approximately 9.52 %; thus, we claim this to be the critical (threshold) Internet penetration rate, $critIU_{lower\text{-}middle,\ y} = 9.52\ \%$, in the lower-middle-income economies. However, the country-specific $critIU_{i,\ y}$ values vary significantly, ranging from $critIU_{LKA,y} = 1.4\ \%$ in Sri Lanka to $critIU_{MLD,y} = 23.4\ \%$ in Moldova. Examining the remaining country's specific conditions under which the '*IU-technological take-off*' occurred, a few conclusions of seminal interest arise. The first important observation is the average penetration rates of both fixed and wireless networks, enabling access to Internet connections. In the low-income group, the backbone infrastructure required to provide both fixed-narrowband and fixed-broadband networks was heavily underdeveloped. In consequence, the average fixed-narrowband penetration rate was $FIS_{aver,\ y} = 0.45$ per 100 inhab. and the fixed-broadband was a meagre $FBS_{aver,\ y} = 0.24$ per 100 inhab.; thus, the accessibility of fixed Internet connections was negligible. Regarding the spread of wireless-broadband infrastructure, the picture is somewhat more promising—average[30] $WBS_{aver,\ y} = 2.4\ \%$. Extremely limited access to fixed

[28] In Zimbabwe, because of rapid changes in $\Omega_{IU,i,y}$ and $\Phi_{IU,i,y}$, there emerged three potential $Y_{crit,IU}$.

[29] Author's calculations.

[30] Note that in the $Y_{crit,IU}$, wireless-broadband networks were reported in only three (out of seven) countries: Bangladesh (0.47 %), Cambodia (6.7 %) and Kenya (0.01 %).

and wireless infrastructure was an important hindrance to unbounded growth in the number of individuals who used the Internet.

The analogous exercise for the lower-middle-income countries finds that the penetration rates of fixed-narrowband and fixed-broadband networks, on average, reached $FIS_{aver,\ y} = 1.62$ per 100 inhab. and $FBS_{aver,\ y} = 0.69$ per 100 inhab., reflecting substantial shortages in access to the landline Internet infrastructure. The average performance in terms of wireless-broadband penetration rates was slightly better, $WBS_{aver,\ y} = 5.13$ per 100 inhab. Important to observe is that across the examined economies, wireless-broadband networks were available exclusively in seven (out of 26). Still, limited access to both fixed and wireless networks did not impede the emergence of the '*IU-technological take-off*', and a great majority of the lower-middle-income economies managed to enter the exponential growth phase along the $IU_{i,\ y}$ diffusion trajectory. Surprisingly, in the low-income countries, the reported prices of fixed-broadband connection and fixed-broadband monthly subscriptions were extremely high, which induced the indecently low affordability of Internet network access. The average fixed-broadband subscription charge was US$93.6 (if Zimbabwe, at US$64.7, is excluded); the average fixed-broadband monthly subscription charge was US$52.1 (again excluding Zimbabwe[31]). The lowest-cost fixed-broadband monthly subscription was reported in Bangladesh, US$4.2, and the highest was in Uganda,[32] US$131.2. The high costs of accessing Internet networks were mirrored by the critically low affordability. The cost of acquiring a standard fixed-broadband sub-basket was 166.1 %[33] of GNI per capita per month. Moreover, the observed cross-country disparities in Internet access affordability are enormous. For example, in Bangladesh, the price of a standard fixed-broadband sub-basket in 2012 was 7.3 % of GNI per capita per month; in Uganda it was 600 %, and in Rwanda, it was 344.3 %. Regarding the lower-middle-income group, the numerical evidence on the costs of a fixed-broadband connection and a fixed-broadband monthly subscription is even more striking. The average fixed-broadband connection charge[34] was reported to be US$131.5 (US$79.5 excluding Zambia[35]), and the average fixed-broadband monthly subscription charge[36] was US$133 (US$67.03 excluding Swaziland[37]). Shifting focus to the affordability of Internet network access, it is shown that although the cross-country

[31] According to ITU statistics, in 2006 in Zimbabwe, a fixed-broadband monthly subscription cost approximately US$2,673 (*sic!*).

[32] Excluding Zimbabwe from this comparison.

[33] Excluding Zimbabwe, where the price of a standard fixed-broadband sub-basket was 1,059 % (in 2010) of GNI per capita per month.

[34] The price of a fixed-broadband connection ranged from US$3.9 in Sri Lanka to US$337.4 in Nigeria.

[35] In Zambia, in 2010, the fixed-broadband connection charge was US$962.8.

[36] The price of a fixed-broadband monthly subscription ranged from US$3.1 in Viet Nam to US$674.8 in Nigeria.

[37] In Swaziland, in 2008, the fixed-broadband monthly subscription charge was US$1,781.8.

variability is tremendous, the average price of a fixed-broadband sub-basket was approximately 26 % of GNI per capita per month (24 % excluding Nigeria and Swaziland). This rate reflects the essentially higher affordability of accessing Internet connections and services compared with the low-income economies and is possibly the reason that the '*IU-technological take-off*' occurred in a great majority of the lower-middle-income countries while the great part of the low-income economies remained stuck in the low-level trap, unable to take off.

Demonstrably, in the vast majority of both the low-income and the lower-middle-income countries (in the 'critical years'), the telecommunication market (for fixed broadband connections and Internet services) was fully liberalized and free competition was introduced, allowing for the presence of multiple operators. In only four countries was the telecommunication market labelled 'partial competition' in both areas; meanwhile, only in Swaziland was there a telecommunication monopoly (in fixed broadband connections). This evidence sharply contrasts with the fact that according to the data provided by the Freedom House (House 2013),[38] none of the examined low-income countries was classified as 'free' (*sic!*) in terms of political rights and civil liberties; three countries were 'not free' and the remaining four were 'partly free'. Moving to the lower-middle-income group, the evidence shows that in the 'critical years', five countries were classified as 'not free', another 13—'partly free', and the remaining eight were labelled 'free' (for the specifications, see Table 5.3). Still, despite the significant lack of broadly defined freedoms, in a great number of the analysed economies, the emergence of '*IU-technological take-off*' was not restricted. This coincides with the conclusion derived from the analysis regarding the '*MCS-technological take-off*' (see the preceding paragraphs). Significant restrictions on political freedoms and civil liberties are mirrored in the limited digital media and Internet freedoms in the analysed countries. According to the Freedom House Freedom on the Net index, (see the reports Freedom on the Net 2011, 2012 and 2013), five[39] out of seven countries in our scope were classified as 'partly free'; that is, none was identified as free. The Freedom on the Net index comprehensively measures the level of Internet and ICT freedom (Freedom House 2013) in three major areas: Obstacles to use (refers to infrastructural and economic barriers to unbounded Internet and digital media access, legal control of Internet service providers and the independence of the relevant regulatory bodies); limits on content (refers to legal regulations on content, filtering or blocking websites, censorship, and the diversity of online media); and Violations of rights (refers to surveillance and repercussions for online activity, e.g., imprisonment or cyber attacks). Although in Bangladesh, Cambodia, Kenya, Uganda and Zimbabwe, the Internet network and other digital media access and use are nominally free from any governmental restrictions, there are still

[38] Officially, the data on Internet freedom are available beginning in 2009. However, for most low-income and lower-middle-income countries, data are available exclusively for 2013 and are reported as such.

[39] No data were available for either Nepal or Rwanda in 2010 and 2008, respectively.

violations in this area. The most prominent hindrance to unlimited access to and use of the Internet was still poorly developed backbone infrastructures (especially in rural regions), power shortages, low bandwidth for Internet connections and high pricing. Online media and Internet net were officially unfettered; however, in some cases (e.g., Bangladesh, Uganda and Cambodia), filtering and censorship were observed (Freedom House 2013). Internet users' rights were violated, especially in Bangladesh and Cambodia; a number of attacks on government websites were documented, mainly owing to their technical weaknesses and vulnerability. Additionally, the analogue evidence for lower-middle-income economies reveals that the degree of Internet freedoms regarding the obstacles to use and limits on content, is very close to that found among the low-income group. As reported by Freedom House (Freedom House 2013), an important obstacle to broader Internet us is poorly developed infrastructures, underserved rural areas, and the relatively high costs of acquiring Internet services (see, e.g., Georgia, Yemen and Lao P.D.R.). In 2012, in many countries, Internet users' rights, especially in terms of broad censorship and/or filtering content in digital media, were significantly violated. The worst-performing countries in this regard were Syria (35),[40] Viet Nam (31), Egypt (33) and Morocco[41] (24). Moreover, in 2012, Syria and Viet Nam faced extremely high obstacles to use and limits of contents arbitrary imposed by legal authorities. Finally, we consider the data that explain the degree of economic and investment freedoms in both income groups. Overall examination of the cross-country statistics shows that on average, these results do not differ significantly from those reported for the '*MCS-technological take-off*' study (to compare, see Table 5.2). In a small number of economies, we observe increasing values for various economic freedom measures. Slight improvements can be found in, e.g., Bangladesh, where investment freedom was at 55 in 2012 (as opposed to 30 in 2006), and Cambodia, where investment freedom increased from 50 (in 2006) to 60 (in 2012). Among the lower-middle-income economies, the sharpest changes were observed in Bolivia, where investment freedom decreased from 90 (in 2001) to 20 (in 2009).

Section 5.2 was intended to trace the country-specific '*technological take-off*' interval and the '*critical mass*' effects that are closely associated with ICT diffusion patterns. With this aim, we have indentified: '*critical years*', '*critical penetration rate of ICT*' and the country-specific conditions during the '*technological take-off*' intervals. In the analysis outcomes regarding the mobile cellular telephony adoption, the important observation is that the '*critical penetration rates*' vary slightly between the low-income and lower-middle-income countries, accounting for 7.05 per 100 inhab. in the low-income group and 8.22 per 100 inhab. in the lower-middle-income group. The duration of the initial (early) phase of diffusion is roughly 12 years in both income groups. Deeper investigation into the issue reveals that both within and between income groups, the country-specific features vary widely and, countries share very few common conditions. These findings suggest

[40] Forty is the worst score.

[41] Data are for 2013 (earlier not available).

that there are no commonly recognized country conditions that predetermine leaving the early diffusion phase and the emergence of the '*MCS-technological take-off*'. In the low-income countries, an even more striking observation is that they experienced the '*MCS-technological take-off*' in extremely unfavourable environments. However, it is important to note that in a great majority of countries, the telecommunication markets were fully liberalised, which unquestionably facilitated the rapid expansion of mobile cellular service in even the most backward economies. Regarding Internet usage, the analysis of the 'critical conditions' yields similar conclusions to those in the previous case. Although the '*IU-technological take-off*' was identified in only 7 low-income and 26 lower-middle-income countries, the countries' individual conditions appeared to be highly unfavourable for any increases in Internet usage; there were high costs for fixed-broadband network access, low per capita incomes, and poor infrastructural development.

Bearing in mind that the analysis presented in Sect. 5.2.2 is unconventional and its results may be questionable, we have intended to complement and broaden the latter by providing additional empirical evidence, which can contribute to better understanding of the issues discussed, and shed more light on the considered relationships. To this aim, using the regressing analysis, the next Sect. 5.3 extends and enriches the evidence presented above, unveiling which factors have fostered—or conversely impeded—the $MCS_{i,y}$ and $IU_{i,y}$ diffusion across examined countries. Section 5.3.1 presents the data used, Sect. 5.3.2 displays the preliminary graphical evidence demonstrating the relationships between $MCS_{i,y}$ and $IU_{i,y}$ and their potential determinants, while Sect. 5.3.3 explains and discusses the regression results.

5.3 ICT Diffusion Determinants. A '*Traditional*' Approach

The following section provides additional evidence on $MCS_{i,\ y}$ and $IU_{i,\ y}$ diffusion determinants across low-income and lower-middle-income countries during the period of 1997–2012. Hence, the primary objective is to trace these variables empirically, which affected the most increases of $MCS_{i,\ y}$ and $IU_{i,\ y}$ penetration rates. To this target, we arbitrary select a bundle of various factors and investigate whether their impact on $MCS_{i,\ y}$ and $IU_{i,\ y}$ growth has been positive and strong, or conversely—negligible.

Estimating the relationships between ICTs diffusion and its factors is a challenging task, not only because countries in the scope of the analysis are highly heterogeneous but also because the examined relationships are complex and are influenced by multiple factors, which are often difficult to identify or quantify. Econometric modeling, by convention, is 'traditionally' used to report on the relationships between variables. However, it is important to mention that a country's individual features heavily pre-determine the nature of the investigated relationships, which are poorly captured through econometric models and statistics. Hence, to a point, the relationship between the process of ICTs diffusion and its determinants remains empirically intractable, and this should be borne in mind while reading this section. Although voluminous empirical literature has been published that attempts to provide adequate explanations for cross-country differences in new technology adoption, the evidence is mixed, lacks robustness, and yields different conclusions. The seminal contribution to identifying technology diffusion determinants was made by Comin and Hobijn (2004). They present a long-term analysis of technology adoption determinants across countries over the period 1788–2001, and they find that the most prominent determinants of the present adoption of technologies are factors such as human capita, government type, openness to international trade, and the degree of adoption of predecessor technologies (Comin and Hobijn 2004). These results are consistent with the evidence presented in another paper by Comin and Hobiijn (2006). This study (Comin and Hobiijn 2006), covering 19 different technologies across 21 countries over the period 1870–1998, demonstrates that democracy, quality of human capita and trade openness contribute significantly to technology diffusion. In another study (Comin and Hobijn 2009) that covered 23 countries over the last two centuries, they explore the similarities in the diffusion of 20 technologies. Their main finding is that quality of institutions and political lobbying play important roles in the growth of adoption of newly emerging technologies. The evidence presented in the study by Norris (2000) covering 179 countries and relied on multivariate regression, demonstrates that for Internet penetration neither literacy rate, level of education nor democratization showed a significant and positive influence. Internet diffusion, however, was strongly attributed to GDP per capita and R&D expenditures. Caselli and Coleman (2001) adopt random and fixed-effects regressions for the extensive study of Internet diffusion determinants, covering 89 countries between 1970 and 1990. Their major findings confirm the positive role of investment per worker, property right protection, and a small share of the agriculture sector in GDP in fostering Internet penetration. Kiiski and Pohjola (2002) demonstrate the evidence for cross-country determinants of Internet diffusion. They present evidence for OECD and non-OECD countries over the period 1995–2000. Using the Gompertz model, they find that neither the level of competition in the telecommunication market nor investments in education and mean years of schooling are statistically insignificant in explaining the differences in Internet penetration rates in OECD countries. However, the proxy for level of education became significant in the sample of developing countries. Factors that were significant in both OECD and non-OECD countries were GDP per capita and the costs of accessing Internet networks. These results contrast with the earlier findings provided by Hargittai (1999), who used OLS estimates and reported that across 18 OECD countries (1995–1998), both GDP per capita and regulation of telecommunication markets significantly affected Internet penetration rates. He also found that level of education and state policies positively affected Internet usage, whereas the price of access to the Internet showed negligible significance. Baliamoune-Lutz (2003), analysing developing countries, finds that Internet and mobile cellular penetration rates are positively affected by per capita incomes and government trade policies, whereas—contrary to expectations—freedom proxies and level of education were found to be statistically insignificant in explaining cross-country

ICT diffusion. Dasgupta et al. (2005), in their study of 44 economies over the period 1990–1997, found that among the factors that positively affected Internet penetration were per capita income, degree of urbanization, level of education and quality of institutions. Crenshaw and Robison (2006), concentrating exclusively on 80 developing countries during the period 1995–2000, underline the seminal impact of urbanization in enhancing network effects on Internet use. They also note the important role of government in ensuring property rights, which may induce an increase in Internet hosts and Internet penetration rates. In 2010, Chinn and Fairlie (2010) examined ICTs' (computer and Internet penetration rates) determinants in a panel of 161 countries over the period 1999–2001. They found that both the computer and Internet penetration rates were significantly attributed to income per capita, illiteracy rate, mean years of schooling, degree of urbanization, telecommunication market regulations and electricity consumption. Trade openness and prices on telecommunication markets were reported as insignificant for computer usage. Andrés et al. (2010), examining the Internet diffusion determinants across 214 countries (they divide the sample into two subsamples: low-income and high-income economies) during 1990–2004 and unveil the strong role of network effects in Internet diffusion that are very robust and were noted in both low-income and high-income economies. Bakay et al. (2011), examining the ICT diffusion factors in Latin American countries, affirm the seminal roles of per capita income, literacy and urbanization. They also find that social networks are essential in fostering ICT diffusion among individuals. In 1999, Ahn and Lee (1999), using observations for 64 countries, modelled the demand for mobile cellular telephony. Their major findings were that per capita income and fixed telephony penetration positively affected the increase in mobile cellular subscriptions, whereas pricing revealed little relevance. Madden et al. (2004), in their study of 56 countries during 1995–2000, show that network effects have great explanatory power in the increase in mobile cellular subscriptions, while Madden and Coble-Neal (2004) demonstrate similar results with respect to mobile cellular telephony determinants. These results, however, contradict the findings of Garbacz and Thomson (2007), who in a study of developing countries (time span 1996–2003) report high price elasticity of mobile telephony and note that pricing may be the seminal factor that spawns mobile cellular telephony diffusion. The results of Garbacz and Thomson (2007) coincide with those provided by Barrantes and Galperin (2008), who, based on their evidence for Latin American countries, argue that affordability is the main driver of or barrier to broad mobile cellular dissemination. Factors that determine the process of the spread of mobile cellular telephony were extensively studied by Rouvinen (2006). Using the Gompertz model and a broad array of economic and non-economic factors, he examined 200 developing and developed countries in the 1990s. He found that in developing countries, the total population variable was positively and statistically significantly associated with the increase in mobile telephony users, mainly owing to emerging network effects. Other variables that entered the regression with positive signs were degree of urbanization, development of fixed infrastructure, and trade openness. The overwhelming conclusion from Rouvinen's (2006) study is that in developing countries, the role of social and infrastructural factors are far more important compared with developed economies. Billon et al. (2009), in a study that covered 142 countries in total, reported that in low-income economies, the key determinants of ICT (mobile cellular telephony and Internet usage) diffusion were market regulations, competition in the telecommunication market, and relatively low prices. They also suggested that more urbanization may foster the spread of ICTs in less developed countries. More evidence regarding ICT diffusion's determinants may be found in, e.g., studies by Islam and Meade (1997), Michalakelis et al. (2008), Singh (2008), Jakopin and Klein (2011), Yates et al. (2011), Gupta and Jain (2012), Lee et al. (2011) and Liu et al. (2012).

5.3.1 The Data

To meet the main goals of this empirical analysis, we use a sample including 17 low-income and 29 lower-middle-income countries, which are examined for the period between 1997[42] and 2012. Depending on the data availability, 17 explanatory variables have been isolated, which are applied to provide complex and insightful explanation of the $MCS_{i, y}$ and $IU_{i, y}$ growth in the analyzed countries. Hence, the explanatory variables are as following[43]: Price of a 1-min call ($Call_{i, y}$), Price of one SMS ($SMS_{i, y}$), Fixed telephony penetration rate ($FTL_{i, y}$), Mobile Cellular Sub-Basket ($MCSIPB_{i, y}$), Number of 1-min calls per GNI per capita per month ($CallsMonth_{i, y}$), Number of SMSs per GNI per capita per month ($SMSMonth_{i, y}$), Number of mobile-cellular prepaid connection charges per GNI per capita per month ($MCSChargeMonth_{i, y}$), Fixed Internet Subscriptions ($FIS_{i, y}$), Fixed-Broadband Subscriptions ($FBS_{i, y}$), Wireless-Broadband Subscriptions ($WBS_{i, y}$), Fixed (wired)-broadband monthly subscription charge ($FBSCharge_{i, y}$), Fixed-Broadband Sub-Basket ($FBSIPB_{i, y}$), Number of fixed-broadband subscription charges per GNI per capita per month ($FBSChargeMonth_{i, y}$), Gross Domestic Product per capita ($GDPPPPpc_{i, y}$), School Enrollment ($School_{i, y}$), Population density ($PopDens_{i, y}$) and Urban population ($Urban_{i, y}$). The main data sets used in this study are the World Development Indicators 2013 and the World Telecommunication/ICT Indicators database 2013 (17th Edition). Additional information has been extracted from global reports—Measuring the Information Society 2010, 2011, 2012 and 2013, developed by the International Telecommunication Union. We presume that mobile cellular telephony penetration rates might be predominantly affected not only by per capita income but also by costs of adoption and the usage of mobile services, e.g., the cost of a 1-min call. Both per capita income and costs of usage, should strongly affect affordability for the adoption of mobile cellular telephony. We have also chosen the fixed telephony penetration rates as the determinant of the usage of mobile cellular services. We argue that poor

[42] In this case, to ensure the maximal reliability of estimates we have arbitrary extended the period of analysis so that it covers 1997–2012.

[43] Full description of the variables used in the analysis is presented in Sect. 5.2.1.

diffusion of fixed telephony should strongly enhance the acquisition of mobile telephony as a good alternative for the previous. As explained in Chap. 4, economically backward countries suffer significantly from lack of broad access to fixed telephony. In such cases, mobile services are an attractive, and often the sole, alternative for the traditional telephony. Additionally, we claim that primary school enrollment might be a factor determining the usage of cellular telephony as access to education, determining the level of a country's human capital, assures basic skills to use and benefit from this type of ICT. Finally, we argue that due to the effects of emerging networks, mobile cellular telephony spread should be favored in densely populated and highly urbanized areas, hence we argue that population density and the degree of urbanization might enhance the broader adoption of mobile cellular telephony. With respect to the penetration rates of Internet users, it is argued here that the level of usage of Internet connections is predominantly gauged by access to necessary infrastructure. Hence, we test the relationships between $IU_{i,\ y}$ against fixed Internet subscription rates, fixed-broadband subscription rates and wireless-broadband subscription rates. Similarly, as in the case of mobile cellular telephony, the usage of Internet by individuals hypothetically shall be fostered by the growth of per capita income and the decreasing costs of the usage of Internet connections. The reasoning lying behind recognizing school enrollment, population density and the degree of urbanization as potential determinants of Internet usage is similar to the case of mobile cellular telephony.

5.3.2 Graphical Evidence

Figures 5.5 and 5.7 graphically explain the relationship between the level of adoption of mobile cellular telephony ($MCS_{i,\ y}$) and Internet usage ($IU_{i,\ y}$) *versus* their selected determinants, in low-income economies over the period 1997–2012; while Figs. 5.6 and 5.8 present analogous relationships in the group of lower-middle-income countries. Visual inspection of the empirical findings reveals that certain regularities can be identified with regard to the examined relationships. Not surprising, all the evidence that is considered with respect to mobile cellular telephony determinants, both in low-income and lower-middle-income economies, reveals that the $MCS_{i,\ y}$ penetration rates are inversely correlated with the variables explaining the costs of acquiring and using mobile cellular services, which are: mobile cellular sub-basket, the price of a 1-min call,[44] price of SMSs,[45] and mobile-cellular prepaid[46] connection charges. The negative impact of the costs associated with the adoption and usage of mobile cellular telephony on respective penetration rates, seems to be relatively stronger in the group of low-income countries. During

[44] Peak and on-net.

[45] Peak and on-net.

[46] For analytical purposes, the prepaid tariffs have been chosen, because among low-income users they are usually the only available method of payment for mobile services.

the analyzed period 1997–2012, significant reduction in the prices of 1-min calls and/or of sending SMSs, as well as drops in mobile-cellular prepaid connection charges, fostered growth in the affordability of mobile services, which in turn boosted the use of mobile cellular telephony, even in the most economically backward countries. Interestingly, in three low-income and 14 (*sic!*) lower-middle-income countries, the value of a Mobile-Cellular Sub-Basket *increased* during the period 2008–2012.[47] Surprisingly, the unfavorable trends did not impede the spread of mobile telephony in some countries, despite that fact that mobile cellular services became *less* affordable. It is important to mention that regardless of the substantial increases of $MCSIPB_{i,\ y}$ in a few countries, still the prices of calls ($Call_{i,\ y}$) and SMSs ($SMS_{i,\ y}$) were gradually falling. Hence, the downward trends in the prices of basic mobile cellular telephony services was revealed to be a powerful stimulus for the rapid expansion of mobile cellular telephony across low-income and lower-middle-income countries. Referring back to Figs. 5.5 and 5.6, conversely to what was initially hypothesized, the variable showing the degree of development of fixed telephony ($FTL_{i,\ y}$) is positively correlated with $MCS_{i,\ y}$ penetration rates. Such results are valid both for low-income and lower-middle-income economies, which generally contradicts our preliminary expectations. However, detailed research of country-wise fixed telephony penetration rates demonstrates that during the period 1997–2012, the development of fixed telephony networks was extremely poor, especially in the group of low-income countries,[48] and any positive changes with this respect are negligible.[49] Henceforth, we claim that this result is inconclusive, and the variable $FTL_{i,\ y}$ has little explanatory power with respect to $MCS_{i.y}$ changes. The other two explanatory variables—per capita income ($GDPPPPpc_{i,\ y}$) and primary school enrollment ($School_{i,\ y}$)—seem to positively impact changes in mobile cellular penetration rates. The established relationships $GDPPPPpc_{i,\ y}$*versus* $MCS_{i,\ y}$, and $School_{i,\ y}$*versus* $MCS_{i,\ y}$, might suggest that growth of per capita income, along with the growth of human capital (approximated by primary school enrollment) translate into greater deployment of mobile cellular telephony, in both income groups. The impact of per capita income on mobile cellular telephony deployment seems to be unquestionable, mainly in terms of affordability. Meanwhile, it is interesting to observe how various countries that differ greatly with regard to $GDPPPPpc_{i,\ y}$, perform equally well in terms of $MCS_{i,\ y}$ penetration rates. The results displaying the connections between primary school enrollment and access to mobile cellular telephony reveal a positive relationship. It is clear that education matters, and shifts in human capital may profoundly reshape the way people act. In our case, providing basic education may be identified as an important driver of the increasing usage of mobile cellular telephony, even though significant

[47] The data on the value of Mobile-Cellular Sub-Basket are available only since 2008.

[48] In low-income countries, the average $FTL_{i,y}$ in 1997 and 2012 was respectively 0.52 and 1.43 (per 100 inhab.).

[49] For a detailed discussion of the relationship between the state of development of fixed telephony versus mobile telephony expansion—see Chap. 4.

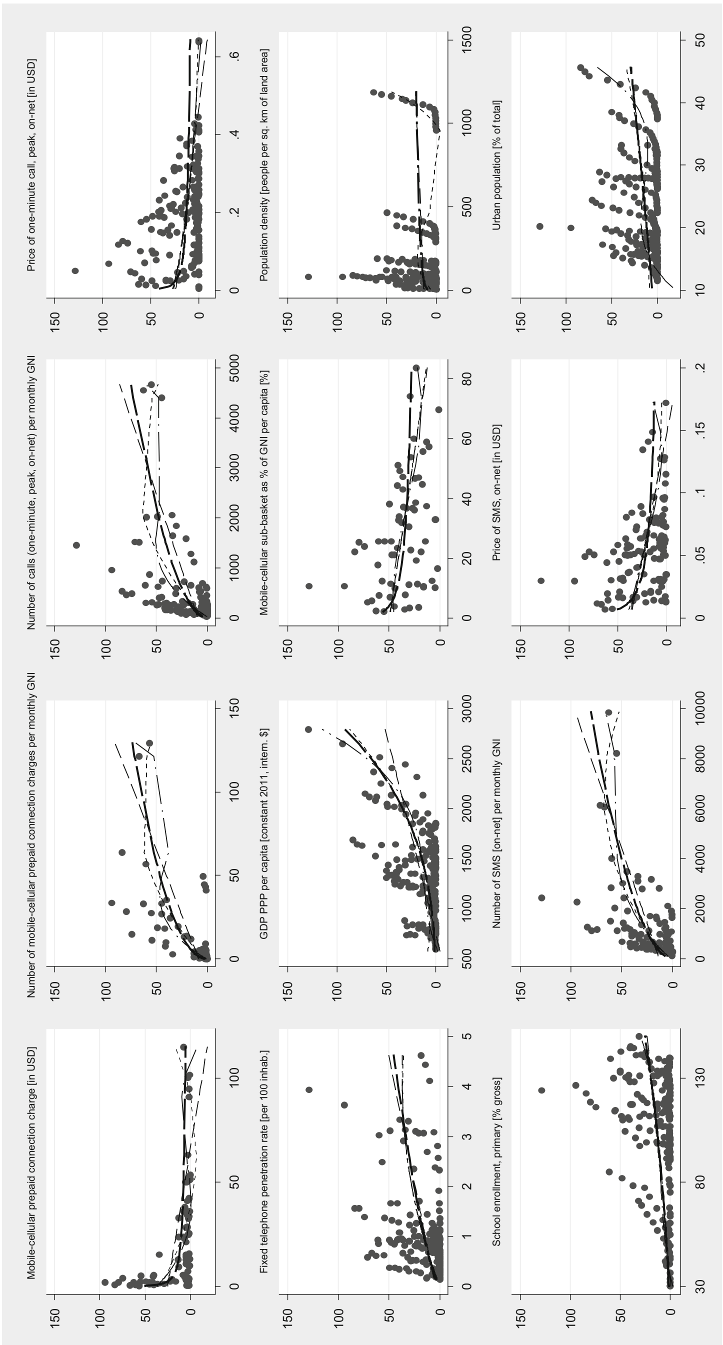

Fig. 5.5 Mobile cellular telephony penetration rates and its selected determinants. 16 low-income countries. 1997–2012. Note: Outlier (Zimbabwe)—excluded. On vertical axis—$MCS_{i,y}$ penetration rates (per 100 inhab.). *Dash line*—linear prediction; *very short dash*—quadratic prediction; *long dash dot line*—cubic prediction; *long dash*—power prediction

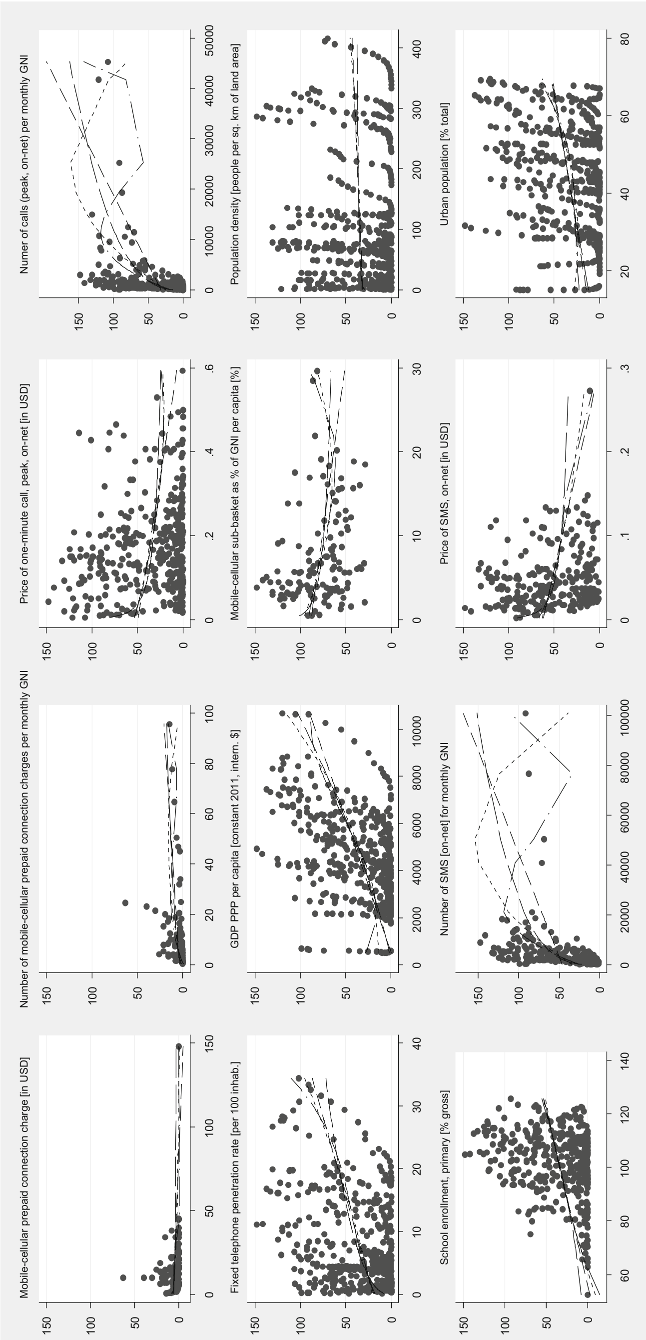

Fig. 5.6 Mobile cellular telephony penetration rates and its selected determinants. 29 lower-middle-income countries. 1997–2012. Note: On vertical axis—$MCS_{i,y}$ penetration rates (per 100 inhab.). *Dash line*—linear prediction; *very short dash*—quadratic prediction; *long dash dot line*—cubic prediction; *long dash*—power prediction

delays between the cause (growth in education) and effect (growth in $MCS_{i,\ y}$) may emerge. The evidence also suggests that the positive impact of education on mobile cellular telephony deployment is comparably strong in both the low-income and lower-middle-income economies. However, it is important to note that with regard to the relationship between education and use of mobile cellular telephony, the potentially stronger effects may be reported in the group of low-income countries, as during the period 1997–2012 these countries progressed the most in primary school enrollment. With regard to the variable, population density, the results obtained slightly contradict the predictions. We have hypothesized that across more densely populated regions the propensity of mobile cellar telephony to spread would be relatively higher, mostly due to emerging network effects. Unfortunately, the graphical evidence does not seem to support this hypothesis, and population density shows little relevance with regard to diffusion of mobile cellular telephony. Conversely, the variable denoting the degree of urbanization is positively correlated with $MCS_{i,\ y}$, both in low-income and lower-middle-income countries. According to the evidence, the impact of a growing urban population on changes in access to mobile cellular telephony seems to be relatively stronger in the low-income group. This is probably because, between 1997 and 2012 in low-income countries, the growth in urbanization has been more notable (see, e.g., Cambodia, Kenya, Malawi or Rwanda) compared to lower-middle-income economies. With the exception of Viet Nam or Yemen, such prominent shifts have not been observed in lower-middle-income countries, where the degree of urbanization showed little variation during analyzed period. Figures 5.7 and 5.8 reflect the relationships between the use of Internet connections against its selected determinants, in low-income and lower-middle-income countries over the period 1997–2012. Factors considered which hypothetically may affect the use of Internet connections across analyzed countries, are partially analogous to those discussed with respect to mobile cellular telephony and are as follows: per capita income, primary school enrollment, population density and degree of urbanization. As the quantitative results do not vary significantly from those displayed for the low-income group, hence the qualitative conclusions would be analogous, and thus, are not discussed here. However, apart from the factors just mentioned, another six potential determinants of Internet penetration rates have been specified. These are: fixed (narrowband) Internet subscriptions (per 100 inhab.), fixed broadband subscriptions (per 100 inhab.), wireless-broadband subscriptions (per 100 inhab.), fixed broadband subscriptions charges, number of fixed broadband subscription charges per GNI per capita per month, and fixed broadband sub-basket. Graphical analysis of the evidence displayed in Figs. 5.7 and 5.8 demonstrates that fixed-broadband sub-basket ($FBSIPB_{i,\ y}$) and fixed-broadband monthly subscription charges ($FBSCharge_{i,\ y}$) are inversely related to the Internet penetration rates. The conclusion is valid both for the group of low-income and lower-middle-income economies. Nevertheless, more detailed visual inspection of the respective charts where $FBSIPB_{i,\ y}$ and

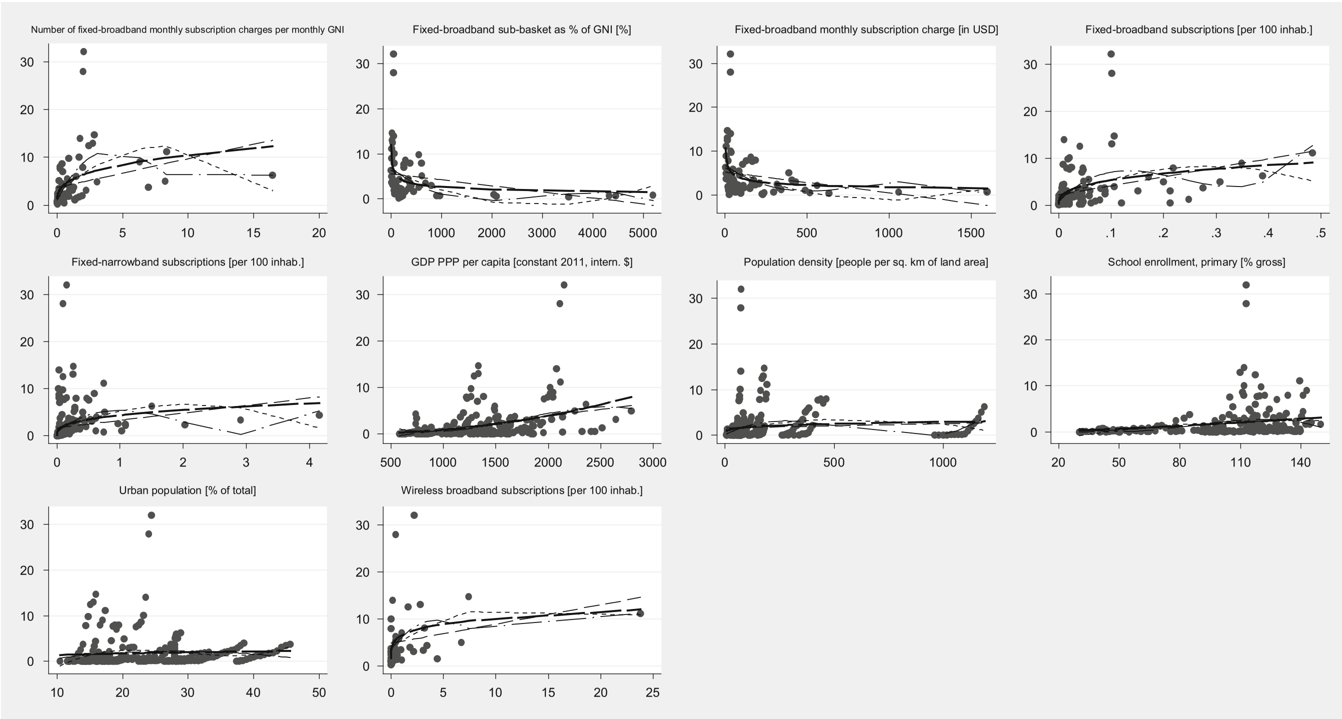

Fig. 5.7 Internet users penetration rates and its selected determinants. 16 low-income countries. 1997–2012. Note: Outlier (Zimbabwe)—excluded. On vertical axis—$IU_{i,y}$ penetration rates (% of individuals). *Dash line*—linear prediction; *very short dash*—quadratic prediction; *long dash dot line*—cubic prediction; *long dash*—power prediction

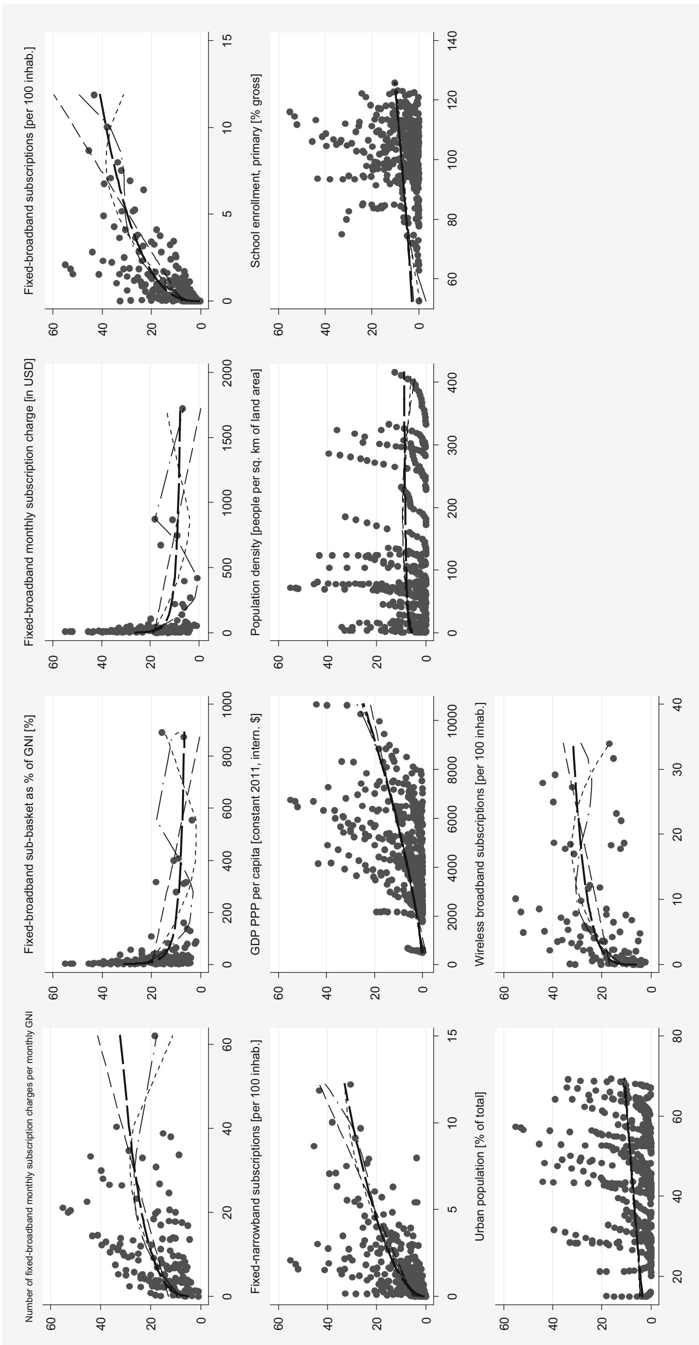

Fig. 5.8 Internet users penetration rates and its selected determinants. 1997–2012. Note: On vertical axis—$IU_{i,y}$ penetration rates (% of individuals). *Dash line*—linear prediction; *very short dash*—quadratic prediction; *long dash dot line*—cubic prediction; *long dash*—power prediction

$FBSCharge_{i,\ y}$ are plotted against $IU_{i,\ y}$, shows that the curves approximating the respective relationships are mostly flat. The latter suggests that the striking differences in $FBSIPB_{i,\ y}$ and $FBSCharge_{i,\ y}$, are poorly reflected by the differences in Internet penetration rates, which vary moderately across countries. The evidence suggests that, conversely to what was witnessed with regard to mobile cellular telephony, the impact of dramatically falling prices of access to an Internet network had a relatively weak impact on its broad deployment and usage. In most low-income countries (except Zimbabwe and Eritrea), during the period 2008–2012,[50] the cost of Fixed-broadband connection charges was rapidly decreasing; however, in only few countries has this price decrease generated significant increases in $IU_{i,\ y}$. In Kenya, the $FBSCharge_{i,\ y}$ dropped from US$158.8 in 2008 to US$35.3 in 2012, which enhanced growth of $IU_{i,\ y}$ from 8.6 % in 2008 to 32.1 % in 2012; in Uganda the analogous values were, respectively $FBSCharge_{UGA,2008} = US\$328.5$, $FBSCharge_{UGA,2012} = US\$14.1$, $IU_{UGA,2008} = 1.7\ \%$ and $IU_{UGA,2012} = 14.7\ \%$. Conversely to what might have been expected, e.g., in Ethiopia drops in fixed-broadband connection charges from US$635 (in 2008) to US$22.5 (in 2012), or Malawi—from US$1,057.4 (in 2008) to US$30.2 (in 2012), the price decreased hardly impacted the shifts in access to and use of the Internet among individuals.[51] This suggests that in low-income countries the $IU_{i,\ y}$ variable revealed little sensitivity to essential decreases of costs of access to the Internet; while there might have been other factors that impeded the growth of individuals using Internet connections.[52] Closer analysis of the statistics on $FBSIPB_{i,\ y}$ seems to support the previously explained results, namely, that decreased charges for fixed-broadband connection have negligible impact on the growth of Internet penetration rates.

The variable $FBSIPB_{i,\ y}$ gives the representation of the price of a standard basket of fixed-broadband monthly usage and is expressed as a percentage of an average GNI per capita per month; hence, it sheds light on the affordability of fixed-broadband use. According to data collected in the Measuring the Information Society reports (ITU 2010, 2013), in the vast majority of low-income countries during the period 2008–2012, the reported values of $FBSIPB_{i,\ y}$ significantly exceed 100 %, which suggests that people in low-income countries can barely afford to buy a standard fixed-broadband basket. In only a few countries—Bangladesh, Cambodia, Nepal and Uganda—between 2008 and 2012, drops in $FBSIPB_{i,\ y}$ were enough,[53] to fairly increase the affordability of buying a standard fixed-broadband basket. Analysis of the analogous evidence for the group of lower-middle-income countries leads to similar conclusions as for the low-income group. Still, despite notable decreases in the prices of fixed-broadband connection charges and increasing affordability of the standard fixed-broadband basket, the use

[50] The data on Fixed-broadband connection charged are available only for the period 2008–2012.

[51] In Ethiopia in 2012 the $IU_{ETH,2012} = 1.5\ \%$; in Malawi—$IU_{MWI,2012} = 4.3\ \%$.

[52] For broader discussion—see Sect. 5.2.2.

[53] In 2012, the $FBSIPB_{i,y}$ in Bangladesh, Cambodia, Nepal and Uganda were respectively 7.3 %, 34 %, 17.8 % and 32.9 %.

of Internet connections by individuals remains relatively low. For example, in Sri Lanka in 2012 the $FBSIPB_{LKA,2012} = 2.1$ %, while the $IU_{LKA,2012} = 18.2$ %; while Senegal performed comparably well in terms of Internet penetration rates ($IU_{SEN,2010} = 19.2$ %), however at a significantly lower affordability—$FBSIPB_{SEN,2012} = 42.8$ %. Examples of this type abound in the group of lower-middle-income economies, hence the evidence explaining the relationships between $IU_{i,\ y}$ versus $FBSIPB_{i,\ y}$ and $FBSCharge_{i,\ y}$ is rather mixed and shows little robustness; thus, this evidence might suggest that the prices of access to, and use of, the Internet have a relatively weak impact on $IU_{i,\ y}$ growth, compared to the influence of prices of mobile cellular services on $MCS_{i,\ y}$ shifts. Finally, we exhibit the evidence regarding the relationships between $IU_{i,\ y}$ against the access indicators, namely: Fixed (narrowband) Internet subscriptions (per 100 inhab.), Fixed Broadband subscriptions (per 100 inhab.), and Wireless-broadband subscriptions (per 100 inhab.). For both graphical and numerical results, see Figs. 5.7 and 5.8. It is expected that gradually increasing access to infrastructure, which in this study is approximated by the number of subscriptions of fixed or wireless networks, should inevitably foster growth in the number of individuals using the Internet. Considering the group of lower-middle-income countries, the empirical results generally confirm our supposition that improvements in backbone infrastructure positively influence the Internet penetration rates. Plotting $IU_{i,\ y}$*versus* $FIS_{i,\ y}$, $FBS_{i,\ y}$ and $WBS_{i,\ y}$ (see Fig. 5.8), it is discovered that rapid advances in the number of subscription to either fixed or wireless-networks brings considerable shifts in the broad use of the Internet connections. The results displayed in the correlation matrices in Appendix H reveal growing reliance on fixed-broadband technologies, compared to fixed-narrowband, across the countries covered in this analysis, and, at least up till now, wireless-broadband connections. The analogous evidence for low-income countries, gives few prospects for the future (see Fig. 5.7). It is important to note that, over the period 1997–2012, the average $FIS_{i,\ y}$ and $FBS_{i,\ y}$ remained at extremely low levels (in 2012, the respective averages[54] were 0.59 and 0.13), with the exception of Malawi, which significantly exceeded group average scores with respect to fixed-narrowband penetration rates. Analyzing plotted Internet penetration rates against wireless-broadband subscriptions per 100 inhabitants (see Fig. 5.7), evidence that is slightly more promising is emerging. Since 2009 onward, in a few low-income countries gradual expansion of wireless-broadband technologies is reported, which is mirrored by the growing number of individuals using the Internet.

The evidence provided earlier in this section yields to be confirmed by the statistical analysis which results are demonstrated in the consecutive Sect. 5.3.3.

[54] Author's calculations.

5.3.3 Panel Regression Results

The forthcoming Sect. 5.3.3 is fully subjected to present complementary evidence on the relationships between $MCS_{i,\ y}$ and $IU_{i,\ y}$ *versus* selected determinants. We do so by building two separate panels—for low-income and lower-middle-income countries—and re-examining the hypothesized relationships. Similarly, in the preceding sections, we separately consider low-income and lower-middle-income countries, which are analyzed between 1997 and 2012. The mobile cellular telephony ($MCS_{i,\ y}$) and Internet user ($IU_{i,\ y}$) penetration rates are denoted as response variables, while as predictors we consider all of the variables specified in Sect. 5.3.2, except the mobile-cellular prepaid connection charge. By doing so, we aim to draw inferences about the intensity of the influence of selected factors on $MCS_{i,\ y}$ and $IU_{i,\ y}$ in countries in our scope of study. Relying on the fixed effects regression,[55] which allows for heterogeneity across countries, we estimate the Eq. (5.1):

$$ICT_{i,y} = \alpha + \beta\left(x'_{i,y}\right) + u_{i,y}, \tag{5.1}$$

where $\boldsymbol{\alpha}$ is the scalar, $\boldsymbol{ICT_{i,y}}$ denotes alternatively $MCS_{i,\ y}$ or $IU_{i,\ y}$; $\boldsymbol{\beta}$ is the $\boldsymbol{L} \times 1$ and $\boldsymbol{x}'_{i,y}$ stands for the $\boldsymbol{iy}$th observation on $\boldsymbol{L}$ explanatory variables (Baltagi 2008). The subscripts $\boldsymbol{i} = \{1, \ \ldots\ldots \boldsymbol{N}\}$ stand for country and $\boldsymbol{y} = \{1, \ \ldots\ldots \boldsymbol{T}\}$ for the time period. In Eq. (5.1), the $\boldsymbol{u_{i,y}} = \boldsymbol{\mu_i} + \boldsymbol{\nu_{i,y}}$, while the $\boldsymbol{\mu_i}$ accounts for the unobservable and time-invariant country-specific effect, which is not captured in the model, and $\boldsymbol{\nu_{i,y}}$ is the remainder disturbance (the observation-specific errors) (Greene 2003). To control for the possibly of emerging heteroskedasticity or within-panel serial correlations, robust standard errors are specified and reported (Arellano 1987; Hoechle 2007). In addition, to investigate the potential importance of the earlier technology adoption level in explaining current ICTs deployment, using one-step Arellano-Bond difference GMM estimator (Arellano and Bond 1991) we estimate the dynamic panel regression model, specified in Eq. (5.2):

$$\boldsymbol{ICT_{i,y}} = \left(\boldsymbol{ICT_{i,y-1}}\right) + \boldsymbol{\beta}\left(\boldsymbol{x'_{i,y}}\right) + \boldsymbol{u_{i,y}}, \tag{5.2}$$

where $\boldsymbol{ICT_{i,y-1}}$ shows the lagged[56] value of $MCS_{i,\ y}$ or $IU_{i,\ y}$, the ξ stands for $\boldsymbol{ICT_{i,y-1}}$ coefficient, and the remaining notations are as in Eq. (5.1). For the

[55] To select between the *fixed* or *random* effects regression, the authors have tested both to choose the most appropriate specification. Relying on the Hausman specification test (Hausman 1978; Maddala and Lahiri 1992), for the vast majority of estimates models, the *fixed* effects specification was reported as more appropriate to examine the relationship between covariates. In only few cases, was the *random* effects regression suggested as the superior specification compared to the *fixed* effects model.

[56] As demonstrated in Chap. 4, the yearly dynamic of $MCS_{i,y}$ and $IU_{i,y}$ diffusion is extremely high and, thus, it is important to explain its diffusion in consecutive periods; we argue that the most justifiable would be 1-year lagged values of $MCS_{i,y}$ and $IU_{i,y}$.

model specified in Eq. (5.2), as in the previous (see Eq. (5.1)), we assume the $\boldsymbol{u}_{i,y} = \boldsymbol{\mu}_i + \boldsymbol{\nu}_{i,y}$, if $\boldsymbol{\mu}_i \sim \boldsymbol{IID}\left(0, \boldsymbol{\sigma}_{\mu}^2\right)$ and $\boldsymbol{\nu}_{i,y} \sim \boldsymbol{IID}\left(0, \boldsymbol{\sigma}_{\nu}^2\right)$ (Baltagi 2008). Analogously to the fixed effects regression, we estimate Eq. (5.2) using robust standard errors to obtain the errors consistent with panel-specific autocorrelations and heteroskedasticity. As the Sargan test of over identifying restrictions is not available after robust estimations, we calculate the Arellano-Bond test for second-order autocorrelation in the first-differenced errors (Arellano-Bond 1991). To control for possibly emerging multicollinearity among variables, we calculate bivariate correlation coefficients along with Variance Inflation Factors[57] between respective variables. The calculated correlation coefficients are summarized in respective tables in Appendix H. In addition, as the distributions of selected variables across the examined samples are heavily-tailed, to avoid strong violation of the regression analysis results, all extreme observation have been detected and excluded from the main data set.

The results of the panel regression analysis are displayed in respective tables summarized in Appendix I. Considering the low-income group, the results of random effects regressions estimations reporting on the $MCS_{i,\,y}$ determinants (see Tables I.1 and I.3), show that the final results differ with regard to various specifications. The only explanatory variable which reveals persistence in explaining the mobile cellular telephony penetration rates is population density ($PopDens_{i,\,y}$). In consecutive specifications (1), (2), (4), (5) and (11) in Table I.1, the variable $PopDens_{i,\,y}$ enters the regressions with the expected positive sign and is statistically significant at the 5 % level of significance. The β coefficients explaining the impact of growth of population density on $MCS_{i,\,y}$ increase vary from $\beta_{PopDens} = 10.5$ in regression (2) to $\beta_{PopDens} = 17.98$ in regression (11). The rationale behind these results is rather simple. In densely populated areas, the access to mobile cellular telephony is much easier mainly due to a better developed backbone infrastructure, as well as easier contacts between users and non-users of new technology (the 'word of mouth' effect), the network effects emerge, and hence the technology spread is highly facilitated. By contrast, in low-income countries, in poorly populated and often geographically isolated regions, the access to mobile cellular infrastructure is still restricted and contacts between people are rarer, which may impede diffusion of $MCS_{i,\,y}$. With respect to lower-middle-income countries, the impact of population density on mobile cellular telephony diffusion is equally strong and positive. In each estimated regression, the coefficients explaining the strength of $PopDens_{i,\,y}$ impact on $MCS_{i,\,y}$ are high (varying from 7.16 in specification (2) to 19.17 in specification (12)) and statistically significant. The rest of the estimated coefficients in the consecutive

[57] The Variation Inflation Factor (VIF) is the reciprocal of the Tolerance $(1 - R_i^2)$, and determines how much of the variance of estimated regression coefficients are being *inflated* due to emerging collinearity between examined variables. Usually, we should be concerned about the multicollinearity once the VIF exceeds 10 (Mansfield and Helms 1982; O'Brien 2007; Dormann et al. 2013).

specifications suggest that this finding is robust and has a controlling effect for other variables. It also shows that in this lower-middle-income income group the positive networks effects are revealed, which fosters the dynamic spread of mobile cellular telephony among society members. Analyzing the impact of population density on mobile cellular telephony diffusion, however, it is important to note that a vast majority of examined countries carry one important characteristic. In the great majority of low-income and lower-middle-income countries, high fertility rates are reported, which translates into high natural growth rates, and finally contributes significantly to increases in population density. Thus, it shall be borne in mind that because both $PopDens_{i,\ y}$ and $MCS_{i,\ y}$ demonstrate relatively high annual growth rates across the analyzed countries during the period 1997–2012, it might have heavily determined the panel regression outcomes. Another factor that demonstrates a positive influence on increasing the number of mobile cellular telephony users, both in low-income and lower-middle-income countries, is per capita income ($GDPPPPpc_{i,\ y}$). In only two instances—(1) and (3) for the low-income group, the variable $GDPPPpc_{i,\ y}$ is reported as statistically insignificant. In the remaining models, the impact of per capita income on $MCS_{i,\ y}$ penetration rates is found as intensive and positive, statistically significant and unaffected by inclusion or exclusion of various variables in the regressions. These findings suggest that economic growth may strongly shift the usage of mobile cellular telephony by individuals, mainly due to the increasing affordability of buying mobile services. Interestingly, the potential effect of economic growth on $MCS_{i,\ y}$ is relatively smaller compared to the intensity of impact of population density (sic!). In the group of low-income economies, the estimated impact of level of education and fixed telephony penetration rates is relatively unrobust and generally reported as statistically insignificant. Conversely, in lower-middle-income countries, both the $School_{i,\ y}$ and $FTL_{i,\ y}$ variables reveal positive associations with the increasing number of mobile cellular services users. However, earlier investigations and evidence show that these results might be misleading—see the discussion in preceding section (Sect. 5.2.2). According to our estimates, unexpectedly, the degree of urbanization ($Urban_{i,\ y}$) shows little relevance with the increasing number of mobile cellular telephony users. In both income-groups, the estimated coefficients are statistically insignificant, with the only exception being when the $Urban_{i,\ y}$ is the only explanatory variable included in the model. Further evidence, however suggests, that the results produced in models (12)'s[58] lack robustness and reveal strong justification for including other variables in the regression. Essential for understanding these 'strange' results is keeping in mind that in the countries examined in this study, a vast majority of people live in rural areas, while the degree of urbanization remains extremely low (for 2012, see, e.g., Cambodia—20 %, Ethiopia—17 % or Malawi—15 %), which arguably is not unimportant for the results. Conversely to what might be hypothesized, the two consecutive variables—$Call_{i,\ y}$ and $SMS_{i,\ y}$, which denote the basic costs of using

[58] Separately for low-income and lower-middle-income economies.

mobile cellular services, are identified as statistically insignificant in most of the specifications. Moreover, in model (1) for the low-income group, the variable $Call_{i,\ y}$ enters the regression with a 'wrong' positive sign. The same is reported in specification (2) in Table I.1—the same income group, with regard to the $SMS_{i,\ y}$ variable. These results seem surprising, however, Figs. 5.5 and 5.6, clearly demonstrate that in various countries, similar $MCS_{i,\ y}$ penetration rates are achieved at substantially different prices of 1-min calls and SMSs, and this is likely to have strongly affected the regression estimates. Turning to the analysis of the explored relationships presented in Table I.3 an important issue arises. The estimated coefficient for the respective variables $CallsMonth_{i,\ y}$, $SMSMonth_{i,\ y}$ and $MCSChargeMonth_{i,\ y}$ show that increasing affordability positively affects the growing number of mobile cellular telephony users in both country-income groups. The positive effects of the decreasing costs of mobile cellular services on the number of mobile telephony users is then explicitly, although indirectly, demonstrated through the growing availability of mobile cellular services to individuals. Therefore, removing a key factor such as 'low-affordability' enhances the spread of $MCS_{i,\ y}$, and accounts for a 'joint effect' of economic growth and drops of prices of mobile cellular telephony services. The empirical results summarized in Tables I.2 and I.4 (see Appendix I), illustrate the dynamic panel regression estimates with regard to $MCS_{i,\ y}$ in low-income and lower-middle-income countries. Including the lagged value of the $MCS_{i,\ y}$ variable in each of the models fundamentally reshapes the results. Nevertheless, when the $MCS_{i,\ y-1}$ is entered solely, or jointly, with other control variables, it remains positive and statistically significant. Moreover, most of regressors, except $GDPPPpc_{i,\ y}$ and $FTL_{i,\ y}$ in the selected specifications, lose their explanatory power; while the influence of 'epidemic mechanism' (Gray 1973; Sarkar 1998; Kumar and Krishnan 2002; Gomulka 2006) in the spread of $MCS_{i,\ y}$ is dominant over other determinants. Such evidence leads to a seminal conclusion on the existence of strong network effects with respect to the process of mobile cellular telephony diffusion. It might be claimed that once the critical conditions (see Sect. 5.2.2) are achieved, the process of diffusion is self-sustaining and predominantly conditioned by intensity and frequency of interpersonal contacts.[59] The results presented in Tables I.5 and I.7 (see Appendix I), help to explore the impact of selected factors of Internet usage in low-income and lower-middle-income countries over the period 1997–2012. First, we investigate the importance of the determinants of Internet penetration rates in both income groups. An important observation is that in low-income economies, specifications (1)–(3) (Table I.5) with multiple explanatory variables, although relatively high R^2 (within), report that the degree of urbanization ($Urban_{i,\ y}$) exclusively produced positive and statistically significant effect on the growth of Internet users penetration rates. In models (2) and (3), the inverse, and statistically significant, impact of fixed-broadband connection charges ($FBSCharge_{i,\ y}$) on

[59] For broader discussion—see Chaps. 3 (theoretical aspects of diffusion mechanism) and 4 (empirical evidence on ICTs diffusion).

$MCS_{i,\ y}$ is shown. The fixed-broadband connection charge, which presents the basic cost of acquiring Internet, is a seminal factor that may significantly encourage, or contrariwise, hinder, the possibility of paying for access and usage of the Internet by individuals. Importantly, the previous results coincide with the evidence presented in Table I.5, which confirms the importance of fixed-broadband connection charges on broad access to, and use of, an Internet network. It is worth noting that, despite that in the regressions (1) and (3), the $GDPPPpc_{i,\ y}$ is observed as statistically insignificant, the positive impact of economic growth on $IU_{i,\ y}$ is, however, indirectly captured by $FBSIPB_{i,\ y}$ and $FBSChargeMonth_{i,\ y,}$ variables that explain the affordability of accessing the Internet network (see evidence in Table I.7). The impact of the remainder of the control variables on $IU_{i,\ y}$ changes, is found to be statistically insignificant.[60] Because the estimated models demonstrate little evidence on $IU_{i,\ y}$ seminal determinants in low-income economies, these results may be perceived as slightly disappointing. Yet, it is important to keep in mind that during the period 1997–2012, the average $IU_{i,\ y}$ in the low-income group persisted, with the exception of few prominent examples of Kenya, Uganda and Zimbabwe, at an extremely low level, which partially explains the lack of the robustness of the evidence in this regard. Concerning the lower-middle-income countries, we observe a marked positive effect of improving access to wireless-broadband networks on the share of individuals using the Internet. In each case (see respective models (1), (2), (3) and (8) in Table I.5), the coefficient going with the $WBS_{i,\ y}$ variable, is positive and statistically significant. These findings yield a straightforward conclusion regarding the increasing importance of wireless-broadband infrastructure in enabling broad usage of the Internet in lower-middle-income countries. Interestingly, this importance is reported neither for fixed-narrowband-, nor for fixed-broadband networks. Similarly, as in the case of low-income countries, the variable $FBSCharge_{i,\ y}$ turns out to be inversely correlated with $IU_{i,\ y}$ and statistically significant, suggesting that due to increasing competition and decreases in the price of access to fixed-broadband infrastructure, shifts in the number of individuals using the Internet network are observed. Moreover, as suggested by the evidence in Table I.5, the strong and positive effect of economic growth on $IU_{i,\ y}$ is demonstrated through the growing affordability of buying and using fixed-broadband networks by individuals. Because an important constraint such as 'low-affordability' is being gradually eradicated, there emerges an enormous potential of further expansion of Internet infrastructure, resulting in striking growths of Internet penetration rates. Contrary to what was reported for the low-income group, in lower-middle-income countries the population density arises as an important factor, positively contributing to the increasing number of individuals who use the Internet. The emphasized $IU_{i,\ y}$ determinant—population

[60] The consecutive models (4)–(11) with only one explanatory variable introduced demonstrate each of explanatory variables as statistically significant; but in some cases the overall fit of the model to the empirical data is poor (e.g. see regression (8) and (9)). For this reason, it is questionable to consider these results as valid and conclusive—see evidence from models (1), (2) and (3).

density, may play a role in enhancing the use of Internet connections because in more densely populated areas the access to fixed-, or wireless-networks is highly facilitated due to better developed backbone infrastructure, compared to remote and isolated regions. Hence, the population density may emerge as a country-specific feature conductive to $IU_{i,\ y}$ growth. Finally, the evidence summarized in Tables I.6 and I.8 in Appendix I, mirrors the results of the dynamic panel regression estimates of $IU_{i,\ y}$ determinants in low-, and lower-middle-income group. It provides support in favor of the supposition that, as in the case of $MCS_{i,\ y}$ determinants analysis, inserting the lagged value of $IU_{i,\ y}$ into the regression, reshapes the outcomes. The main finding is that regardless of the model and the regressors included, the coefficient for $IU_{i,\ y-1}$ (ζ) is always positive and statistically significant. This exercise yields a sharp conclusion that the current level of $IU_{i,\ y}$ penetration rates are highly pre-conditioned by the number of Internet users in the preceding period, which confirms the hypothesis that an existing strong network affects the underlying mechanism of technology diffusion. Interestingly, according to the dynamic panel regression estimates for lower-middle-income countries, the $WBS_{i,\ y}$ is reported as significant in each case and hence may be considered as valid explanatory factor of $IU_{i,\ y,}$ changing in scope over time and across countries. In turn, the variable standing for population density ($PopDens_{i,\ y}$) has 'lost' its explanatory power, which shows that population density does not play an essential role in enhancing $IU_{i,\ y}$ growth, as was previously suggested by the estimates reported from the respective fixed effects regressions. Additionally, contrary to what might have been expected, the degree of urbanization remains insignificant. The rationale behind this is that in the examined countries, a vast majority of people still live in rural regions that persistently suffer from underdevelopment of the backbone infrastructure that enables Internet connections. This finding is also supported by the fact that in the majority of backward countries, the urban-rural divide with regard to Internet penetration rates is substantial and persistent. According to the data provided in the report Measuring the Information Society 2011 (ITU 2011), in developing countries fundamental differences still exist between urban and rural areas in access to and use of Internet networks. The Internet penetration rates differ remarkably between urban and rural areas; people living in rural regions are still heavily deprived of the opportunity of using the Internet.

In the final part of Chap. 5, we have investigated the factors, which might potentially influence mobile cellular telephony and Internet penetration rates in low-income and lower-middle-income countries during the period 1997–2012. First we have estimated the fixed effects regressions to test which variables might be considered as important determinants of $MCS_{i,\ y}$ and $IU_{i,\ y}$ diffusion. Our estimates suggest that in the examined countries (in both income groups), $MCS_{i,\ y}$ was positively attributed to GDP per capita, level of education ($School_{i,\ y}$) and population density, and although these results are not fully robust, they reveal little sensitivity to the inclusion or exclusion of other control variables in the model. We may also conclude that the overall affordability explains changes in $MCS_{i,\ y}$ growth in both income-groups relatively well. The population density variable has been shown to be statistically significant, and these effects are robust. Somewhat unexpectedly, the price of a 1-min call, and of SMSs, in most instances did not demonstrate any statistical significance to explain the variability in cross-country $MCS_{i,\ y}$. Our estimates of $IU_{i,\ y}$ diffusion determinants show that, in low-income countries, GDP per capita and the price of fixed-broadband connection revealed statistical significance and may be considered factors positively influencing a growing number of Internet users. In the group of lower-middle-income countries, the variables GDP per capita, the prices of fixed-broadband connection and wireless broadband penetration rates are reported as having positive impact on increasing Internet penetration rates. However, if the fixed effects models, both for $MCS_{i,\ y}$ and $IU_{i,\ y}$, are refined by including the lagged values of response variables, the overall picture changes dramatically. Relying on the dynamic panel regressions, we have revealed the existence of strong network effects with regard to mobile cellular telephony and Internet user growth. The coefficients going with the lagged values of $MCS_{i,\ y}$ and $IU_{i,\ y}$ are positive and statistically significant regardless of the specification and are insensitive to the inclusion/exclusion of various control variables. Hence, it is justified to claim that the network effects are fully robust and reveal great explanatory power in cross-country ICTs diffusion.

5.4 Summary

The main targets of Chap. 5 were twofold. First, adopting the newly developed methodological approach, it aimed to trace the 'critical mass' effects. Henceforth, we have identified the '*critical year*', '*critical penetration rate*', and the '*technological take-off*' and explored country's individual conditions during the specific '*technological take-off*' interval. Regarding the mobile cellular telephony the important observation is that the '*critical penetration rates*' barely vary between the low-income and lower-middle-income countries—7.05 (per 100 inhab.) in low-income and 8.22 in lower-middle-income group. The country-wise analysis revealed that in both within and between income groups, the country-specific features vary widely and countries share *very few* common conditions that pre-determine leaving the early diffusion phase and the emergence of the '*MCS-technological take-off*'. Regarding Internet network diffusion, the analysis of the 'critical conditions' yields similar conclusions to those in the previous case. However, importantly to note that the overall Internet penetration rates in many of the examined countries in 2012 were still very low, which indicates that access to Internet connections was still a 'luxury' good and could not be unboundedly afforded in a vast majority of economically backward countries. The latter implies that the analysis results regarding $IU_{i,y}$ and detecting country-specific conditions during the '*IU-technological take-off*' are—to a point—violated, and thus shall be interpreted carefully. Second, we targeted to trace those factors which have had positive impact of ICTs diffusion across analyzed countries. Regarding $MCS_{i,y}$ diffusion we have found that GDP per capita, level of education and population density impact positively the latter. Contrary, factors like price of a 1-min call and of SMSs are reported as statistically insignificant. Across analyzed countries, the

$IU_{i,y}$ was mostly enhanced by GDP per capita, changes in price of fixed-broadband connection and (in lower-middle-income group) by growing access to wireless broadband solutions. In addition, the analysis has demonstrated that both in case of $MCS_{i,y}$ and $IU_{i,y}$ ICT diffusion is predominantly conditioned and enhanced by the 'word of mouth', which give rise to the emergence of strong network effects. Finally, a few important issues should be mentioned with regard to the evidence provided earlier in this chapter. Due to short data time series in the case of some variables and limited data availability, this may heavily violate analysis outcomes and conclusions. This is a serious limitation, which may cause lack of robustness of our results. Moreover, the analysis predominantly explains statistical relationships between variables. Hence, the question arises: Are the explanatory variables causes of, or simply correlates of, $MCS_{i,\ y}$ and $IU_{i,\ y}$? Considering the type of selected explanatory variables, it might be justified to argue that these are factors driving profound changes in access to and use of basic ICTs, although these relationships may not be straightforward, and severe time lags may emerge between the cause and the outcome.

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