Technology convergence and digital divides.

A country-level evidence for the period 2000–2010

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1. Digital divide—concept clarification.

The notion of digital divide is fully connected with new information and communication technologies (ICTs). Information and Communication Technologies—ICTs, understood as means of communication, storage and retrieving all kinds of knowledge and information. In recent years a very fast adoption of ICTs in a wide set of countries has been reported.

Digital technologies are broadly considered of great importance for enhancing both social and economic development. However, new technologies have a great ability to spread at a high pace, along with their fast adoption in many countries, growing inequalities may appear. The unequal distribution of ICTs was a point of interest for Schramm [1964], Sussman and Lent [1991], and later—for example—Schiller [1996]. As proven in the works of the cited authors, fast diffusion of new technologies is broadly considered to be accompanied by their uneven distribution.

Growth rates showing the speed of changes in the ICTs' field are astonishing, and the period of (*for example*) ten years can bring crucial changes on the world map. If we take into account i.e. such indicators as the Internet users or mobile cellular subscribers, the annual growth rates achieve an average level of 50–60%[1]. As is widely recognized, a fast implementation of new technologies, however positive in nature, can create huge disparities in inter-country ICTs application (see Table 1). This would suggest that a fast growth in ICTs adoption causes increasing inequalities among countries in the field.

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[1] Own estimates based on data derived from International Telecommunication Union database.

Differences in the level of digitalization bring to mind the notion of "digital divide" also called "digital gap", "technology divide" or "technology gap". In recent literature, there is a multitude of ways to define the digital divide. Different authors conceptualize the digital divide differently and adopt a variety of ways to measure it. The most common definition of the digital gap is the one presented in "Understanding digital divide" [OECD 2001], where the term refers to the

> **gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard to their opportunities to access information and communication technologies and to their use for a wide variety of activities.**

The cited definition, even if very general, reveals the very nature of the problem. Whatever definition we would work out, it always will refer to differences in access to ICTs. It also refers to a kind of separation between those who have and those who are permanently lacking access to ICTs tools. The dichotomy between "haves" and "have-nots" is revealed at the same time. The simple notion of digital divides usually refers solely to technical access, which from an analytical perspective is narrow. However, it is usually perceived as such—taking into account simple access to Internet and/or to other ICTs tools.

Berlot (2003) and other authors point to the significance of such dimensions of digital divide as information technology literacy or effective usage of ICTs. DiMaggio and Hargittai [2001] also stress the importance of ICTs usage patterns, skills enabling to use ICTs in a proper and effective way. Devaraj and Kohli [2003], Zhu and Kraemer [2005] point out the importance of gains that business sector can acquire by employing ICTs—consequently they define digital (technology) gap from a strictly business perspective.

The digital divide however can be analyzed on 3 levels: country, company, household or individual level. Dewan and Riggins [2005] distinguish three different levels of analysis of digital divide. These are: individual (individuals who are excluded from wide access to ICTs), organizational (refers to companies that lag behind in terms of ICTs adoption) or global (when some countries lag behind in terms of ICTs adoption) perspectives.

As specified above, the concept of digital divide refers mostly to the division between societal groups that possess expansible and infinite access to most of recently developed "knowledge products"[2] (see [Adriani and Becchetti, 2003]) and hardware, and those who are excluded from such benefits. While studying the magnitude of past and present digital divides, the applied definition plays crucial role. Results of the study can differ significantly when different notions and measurement methods are implemented. In this paper we shall imply the reductionist definition of digital divides, assuming

[2] Software and databases.

that it refers to a gap between those who have access to ICTs and are able to use it, and those who—regardless of the reasons—do not have such an opportunity.

2. Technology convergence—theoretical outline

As is widely known, the idea of convergence, directly derived from growth theory, is simple and easy to interpret. The process of convergence reports on growing cohesion among selected objects (countries in most cases), in terms of arbitrary assumed variables (indicators), which mainly is assumed to be national income *per capita*. It shows negative correlation between GDP *per capita* growth rates and initial GDP *per capita* level (natural logarithm of GDP). Such a notion of convergence also refers to the catching-up hypothesis (see [Abramowitz, 1986]) which asserts that being backward in the GDP level carries a great potential (possibility) of rapid advance. It implies that in the long run perspective, GDP *per capita* growth rates are inversely related to the initial level of GDP or any other economic indicator (if applied). However the results of convergence process analysis are valuable, they do not explain any causality between variables, or any other factors that could possibly speed up or impede the process. In the following paper, we assume that convergence should be perceived in terms of technology exclusively.

In the paper, we use the idea of unconditional β-convergence, σ-convergence and quantile-convergence. Despite being easy in nature, the estimates of β-convergence have a few recognized limitations. The estimated coefficients report solely on the central tendency of distribution ignoring the behavior of a variable in its non-central locations. In such a case, despite having confirmed—or rejected—the hypothesis of unconditional technology β-convergence, it gives just a simple idea of an average evolution of variable growth behavior over time. To draw more detailed conclusion about technology distribution we run additionally q-convergence (quantile convergence), a methodology based on quantile regression analysis. The q-convergence (see [Castellacci, 2006 and 2011]), a non-parametric method (see [Koenker et Bassett, 1978, 2001, 2005], see also [Hao and Naiman, 2007]), provides more detailed information about the behavior of variable distribution in a set of j quantiles (percentiles)[3]. Since any number of quantiles can be applied in the analysis, it allows modeling arbitrary predetermined position of distribution[4]. Additionally, this methodology tells a lot about variable behavior in certain quantiles of distribution including its left and right tails. Using the q-regression is especially useful when variables' distributions are skewed.

In addition, we will tests for the σ-convergence. The methodology gives a general idea about dynamics of the variability of the particular variables

[3] The numbers of quantile is set arbitrary by the author.
[4] Hao L., Naiman D.Q., *Quantile regression*, SAGE Publications 2007.

distribution. Based on that we learn about the increase/decrease of the dispersion of given variables in the studied time span.

Along with the convergence process analysis, there emerges the question of creating groups of "rich" and "poor" countries. In literature the problem is recognized as convergence clubs formation (see [Rostow, 1980; Ben David, 1997; Quah, 1993, 1996]). The notion of "convergence club" refers to an identified group of countries where the catching-up hypothesis was positively verified. Consequently, within the group, the growing cohesion (for example in terms of GDP *per capita*) can be observed. Baumol [1986], in his study, distinguishes three types of convergence clubs. The first one refers to high income industrialized countries which are supposed to converge strongly, the second—to middle income countries when the catching-up hypothesis may or may not be confirmed (in any case, convergence is not supposed to be so strong as in the high income group), and third—to low income countries, where convergence is hardly visible. In literature (see [Quah, 1996]), there is also a distinct classification of convergence clubs. The first one named "*upward convergence*"—refers to the group of relatively backward countries which tend to catch-up with the rich ones; the second one is called "*downward convergence*" and is observed in the group of relatively advanced economies where growth rates (for example GDP *per capita*) are at very low levels—close to 0% *per annum*, or even happen to be negative. Note that with such a distinction, any convergence tendencies within groups do not have to be reported. It rather explains interactions between distinct country groups.

The term of "club convergence", along with the issues just discussed, also refers to the situation when certain economies tend to stay in the same "club" over time, which means that they hardly improve their relative position, i.e. country X was classified as poor in 1970, and after a 30-year period is still classified as such. Such an approach generates the emergence of two theoretical country clusters (groups): poor *("bottom cluster")* and rich ones *("top cluster")*. Clearly it does not mean that certain indicator values for countries within clusters (clubs) do not change. In fact, they do, the changes, however, are not dynamic and strong enough to let a country move from the bottom to the top cluster.

3. Data—preliminary analysis

The data set we employ for the analysis consists of 145 countries, for which we have managed to complete statistical data of 5 different ICTs variables. The time coverage is 2000–2010. The variables show a country's achievements in adoption of most common information technologies tools, and can be treated as proxies of a country's development on the given field. The indicators are: Fixed telephone lines[5] (FTL) per 100 inhabitants, Fixed internet

[5] In the following parts of text, we use abbreviations.

subscriptions (FIS) per 100 inhabitants, Fixed broadband subscriptions (FBS) per 100 inhabitants, Internet users (IU) per 100 inhabitants, Mobile cellular subscriptions (MCS) per 100 inhabitants[6].

A preliminary descriptive data analysis explains basic characteristics of selected variables. The country sample is broad (it covers 145 economies) and allows to detect world general tendencies in information and communication technologies adoption and usage. Following the descriptive statistical analysis (see Table 1 and Graph 1 below), we estimated densities functions for the 5 variables—in 2000 as the start year and in 2010 as the end year, to check for changes in world distributions of ICTs.

Table 1.

Summary descriptive statistic and Gini coefficients. Selected ICTs indicators. Years 2000 and 2010[7], 145 countries

Variable	Mean	Std. Dev.	Min value	Max value	Kurtosis	Gini coeff.
FXTEL2000	23.6	21.9	0.019	86.07	–0.529	0.512
FXTEL2010	22.6	18.7	0.063	82.06	–0.136	0.459
changes in FTL	(–1)	(–3.2)	+0.044	(–4.01)	–	(–0.053)
FXINTER2000	4.71	7.6	0.0037	39.30	5.32	0.718
FXINTER2009	12.0	12.5	0.010	47.35	–0.307	0.557
changes in FIS	+7.29	+4.9	+0.0063	+8.05	–	(–0.161)
FXBROAD~2000	1.3	3.12	0	22.58	16.8	0.830
FXBROAD~2010	11.1	12.2	0	63.83	1.18	0.583
changes in FBS	+9.8	+9.08	0	+41.25	–	(–0.247)
INTUSERS2000	10.03	13.7	0.0059	51.3	1.3	0.662
INTUSERS2010	39.7	27.4	0.72	95	–1.13	0.332
changes in IU	+29.67	+13.7	+0.71	43.7	–	(–0.33)
MOBILES~2000	20.2	24.29	0	81.48	0.009	0.618
MOBILES~2010	96.5	39.3	3.526	206.42	–0.038	0.228
changes in MCS	+76.3	+15.01	0.3526	124.94	–	(–0.39)

Source: own calculations using STATA 11.2 and GRETL Raw data drawn from ITU databases 2011.

The sample consists of 145 world economies. Statistics in Table 1, give a general idea of the level of adoption of given ICTs in selected countries and presents preliminary data descriptive analysis results. Additionally we have estimated the Gini coefficient in 2000 and 2010, to check for changes in distribution inequalities of ICTs variables. The period employed for the analysis is

[6] Detailed definitions of each variable are put in Appendix 1.
[7] For Fixed Internet Subscr. data, the time span is 2000–2009.

widely thought as the one when fast changes in ICTs adoption were taking place worldwide. As seen from statistics values in Table 1, the hypothesis on fast ICTs diffusion definitely can be confirmed. Also, it is clearly visible, that these changes happen at a different pace when different ICTs tools are taken into account. Except for the FTL variable, where we observe hardly any changes in its adoption, in case of the following four indicators (FIS, FBS, IU, MCS) the changes are astonishing. The fixed telephone lines are perceived rather as a kind of traditional means of communication, now being consequently substituted by new ones. That is the reason why we observe minimal changes in mean and standard deviation values. We can conclude that cross--country level of fixed telephones adoption is stable in analyzed period 2000–2010, as well as its distribution (the Gini in 2000 was 0.51; in 2010—0.459). Distinct conclusions are drawn when analyzing FIS, FBS, IU and MCS statistics. In all four cases statistics report on crucial changes, both in absolute levels of ICTs' implementation and in Gini values. It shows how dynamic ICTs are being adopted across countries. In each case we observe high increments in mean values (highest changes in case of MCS, change from 20.02 in the year 2000, to 96.5 in 2010), as well as great increases in Min and Max values for each variable. That proves a fast growth in basic ICTs tools adoption, not only in high-income countries, but also in middle- and low-income ones. In addition, such positive changes show that in the period 2000–2010, a great majority of low and middle-income economies have undergone a kind of "technological revolution", and were adopting basic ICTs tools countrywide. The only exception constitutes the case of FBS, where still in 2010; the Min value is zero for some countries, which means that they cannot benefit from the broadband Internet tool[8]. Apart from great changes in absolute variables' levels, we also observe substantial changes in Gini coefficients. For all indicators, the Gini values were much higher in 2000 than in the year 2010 (see Chart 1).

The greatest decrease in Gini coefficient has been noted for IU: a 33 percentage points decrease, and MCS: a 39 percentage points decrease over the period of 2000–2010. To have an idea about the magnitude of changes in inequalities, see Chart 2 presenting Lorenz curve for MCS variables in 2000, after in 2010—Chart 3.

To learn more about the worldwide distribution of ICTs tools on country level, we estimate distributional graphs for each variable separately. The following 5 charts (Chart 4, 5, 6, 7, 8) show densities function estimates[9]. To show changes in distributions clearly we have prepared two-way charts for each variable.

[8] The countries identified with "0" value of FBS in 2010 are: the Comoros, Iraq, Ethiopia, Eritrea and Burundi. Data according to ITU database (2012).

[9] In each case we apply Gaussian Kernel densities.

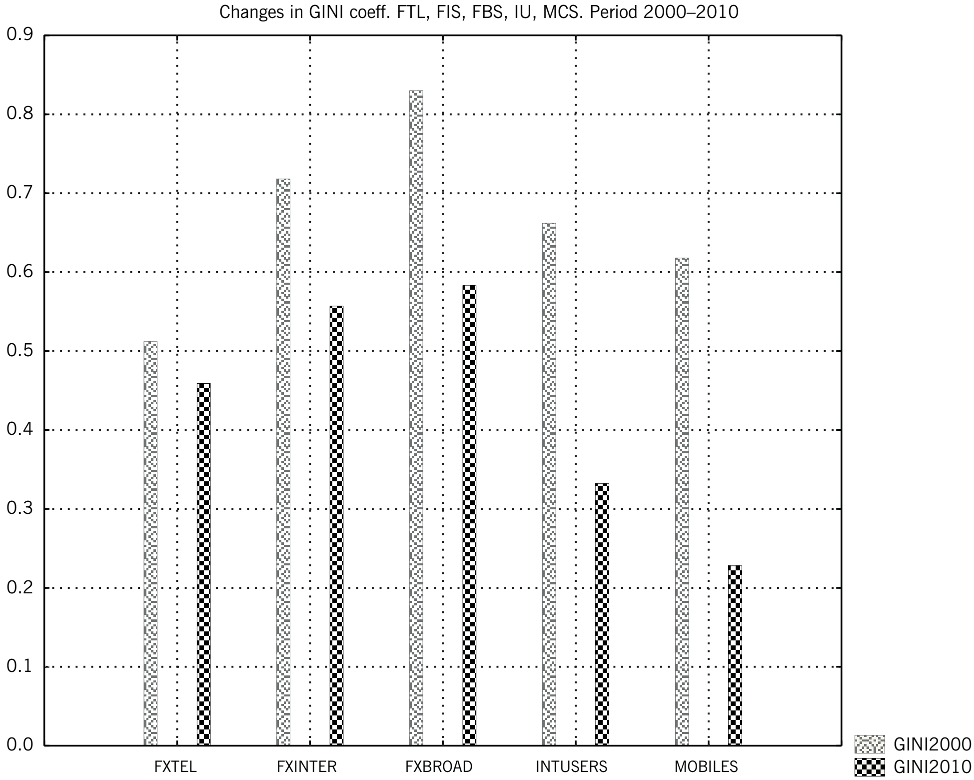

Chart 1.

Changes in Gini coefficients for FTL, FIS, FBS, IU and MCS. Period 2000–2010
Source: own elaboration using STATISTICA 10.0.

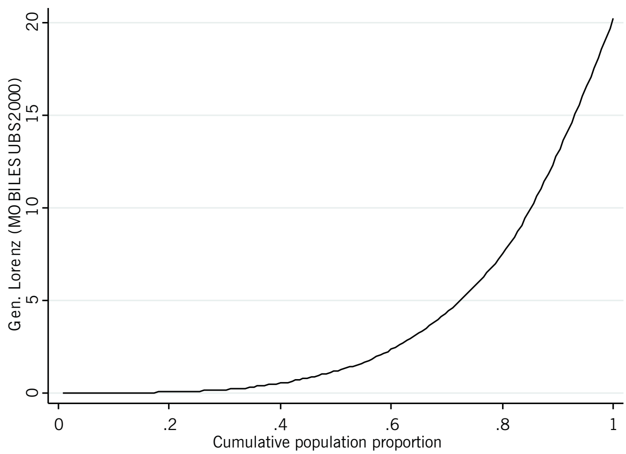

Chart 2.

Lorenz curve for MCS variables in 2000
Source: own elaboration using STATA 11.2.

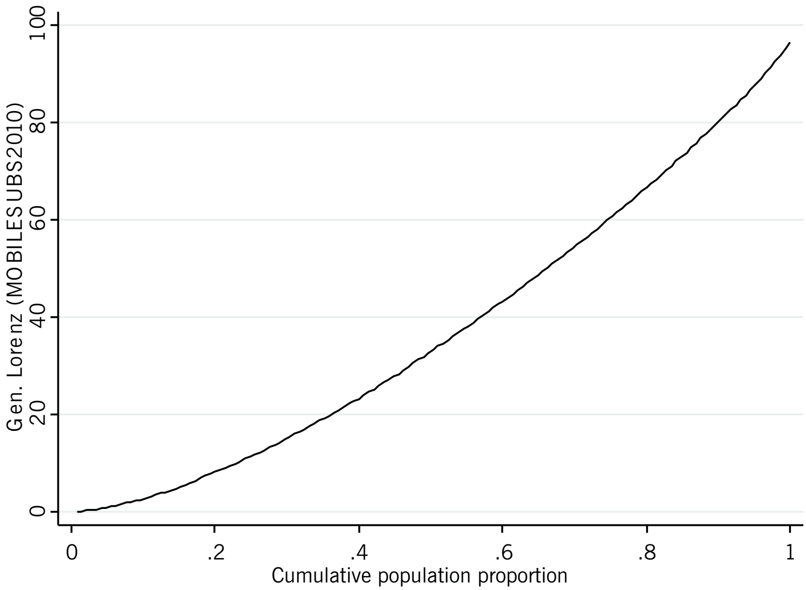

Chart 3.

Lorenz curve for MCS variables in 2010
Source: own elaboration using STATA 11.2.

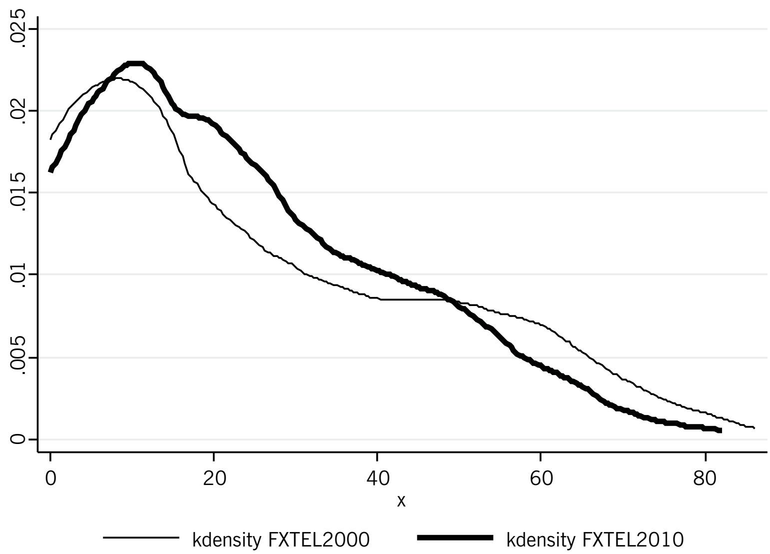

Chart 4.

FTL distributions. 2000 and 2010
Source: own estimates applying STATA 11.2.

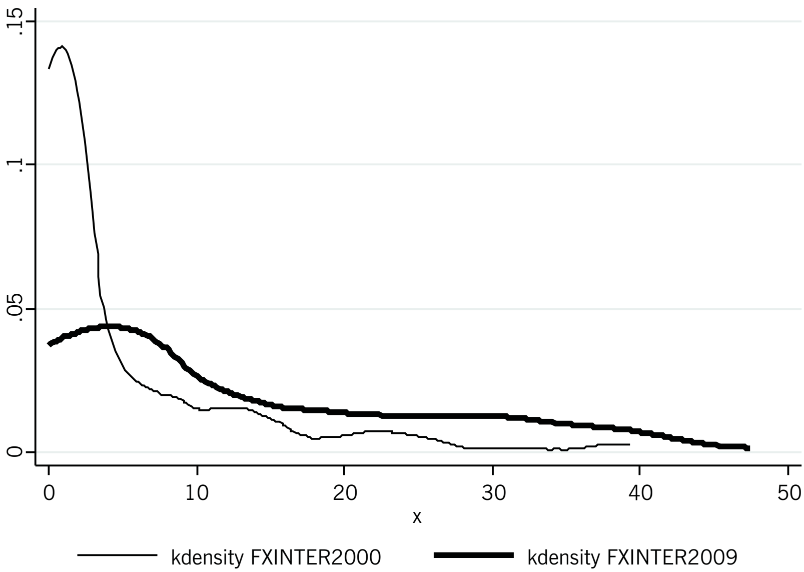

Chart 5.

FIS distributions. 2000 and 2009

Source: own estimates applying STATA 11.2.

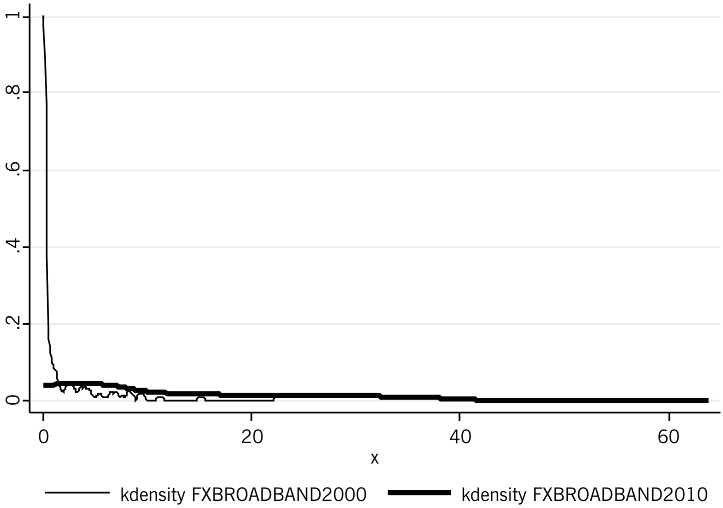

Chart 6.

FBS distributions. 2000 and 2010

Source: own estimates applying STATA 11.2.

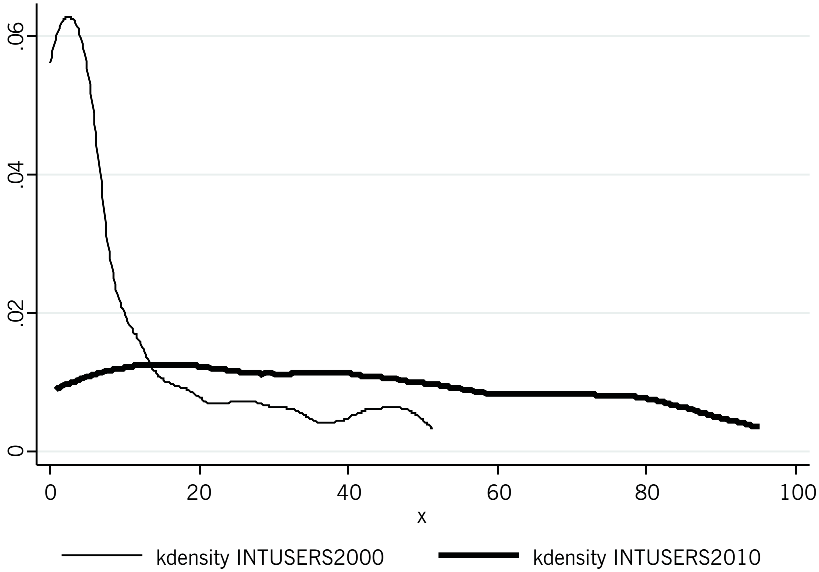

Chart 7.

IU distributions. 2000 and 2010
Source: own estimates applying STATA 11.2.

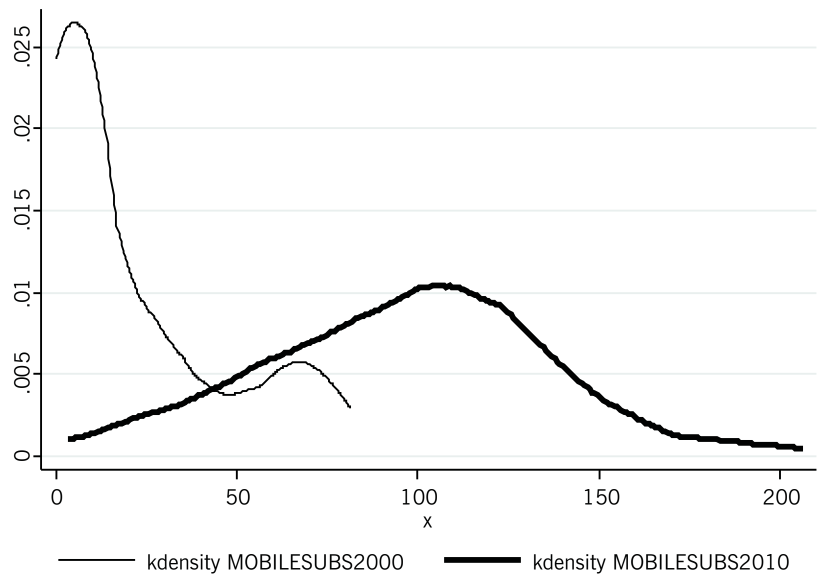

Chart 8.

MCS distributions. 2000 and 2010
Source: own estimates applying STATA 11.2.

For FTL, we can hardly observe any changes in distribution. The densities functions look very similar both for the year 2000 and 2010. Similar conclusions were already drawn from descriptive statistics, as well as we observed only slight decrease in Gini coefficient. Opposing to that, Charts 5, 6 and 7 show substantial changes in variables (FIS, FBS and IU) distributions. The density function plots, for the year 2000, show one-peak distribution accompanied by long right tail. It shows highly uneven distribution of ICTs tools in 2000 among countries, but also proves the existence of numerous groups of countries where the ICTs adoption was at an extremely low level. At the same time, the distribution of ICTs among middle- and high-income countries was highly uneven (see long left tail). In 2000, in terms of ICTs adoption, the group of low-income countries was rather homogenous, while the group of middle- and high-income economies was much more diversified. Over the period of 2000–2010, the situation changed significantly. Looking again at the same charts (see Chart 5, 6, 7), but for densities functions in 2010, we note that line shapes differ substantially drawing a different picture of the problem. The densities lines show highly advanced stratification processes of ICTs distribution among countries. Such changes are a consequence of dynamic process of ICTs implementation across countries, and the disappearance of high left peak proofs that in the countries ICTs adoption level has increased. The group of countries experiencing a high level of ICTs deprivation in the year 2000, could enjoy using new technologies at an acceptable level as early as 2010. The ICTs diffusion process, despite having an unquestionable positive impact, has also led to a great diversification of countries in terms of ICTs adoption. The sharp division on the world map has disappeared, but in exchange, countries (as a group) are much more diversified in terms of ICTs implementation.

The last chart (Chart 8) refers to world distribution of mobile cellular subscribers in the countries included in the sample. In the year 2000, we can observe a clear polarization—see twin-peak density function, on the world map. Each peak stands for a relatively homogenous group of economies with a similar level of MCS, while the differences between the two groups are high. A high left peak of distribution stands for low income (and probably low-middle-income) countries with a relatively poor adoption of mobiles in their societies. The right peak of distribution stands for a group of relatively rich countries which enjoy a higher level of mobiles usage. The polarization disappeared in the year 2010, when we observed a sole, centered peak. Such changes show a great increase in the usage of mobile phones, especially in low- and medium-income countries.

4. Do countries converge in the field of technology?

As presumed in section 2, we intend to verify the hypothesis of inter-country technology convergence in the time span of 2000–2010. To learn more about convergence tendencies—or a lack of them—we run a 3-step analysis.

First, we check for traditional beta-convergence (1-step), then we estimate quantile—convergence (2-step) and finally sigma-convergence (3-step). Following the idea, in each step, five separate regressions will be estimated. We assume that the dependent variables are the growth rates of the selected ICTs indicators in the period 2000–2010, while as explanatory variables are used the initial levels (in the year 2000) of the respective indicators. Therefore, we limit the analysis to one regressor. The data and time coverage is analogous to section 2.

a. The β-convergence testing—1-step.

As assumed, each regression shall have just one regressor—the initial level[10] of a given variable in a given country. We estimate 5 different equations, for each indicator separately. The models 1(a), 2(a), 3(a), 4(a) and 5(a) are identifiable as following:

$$Y_j(FTL_{2000-2010}) = \alpha + \beta_j(ln\_FTL_{2000}) + \varepsilon_j \quad (1a)$$

$$Y_j(FIS_{2000-2010}) = \alpha + \beta_j(ln\_FIS_{2000}) + \varepsilon_j \quad (2a)$$

$$Y_j(IU_{2000-2010}) = \alpha + \beta_j(ln\_IU_{2000}) + \varepsilon_j \quad (3a)$$

$$Y_j(\mathrm{FBS}_{2002-2010}) = \alpha + \beta_j(ln\_FBS_{2002}) + \varepsilon_j{}^{11} \quad (4a)$$

$$Y_j(\mathrm{MCS}_{2000-2010}) = \alpha + \beta_j(ln\_MCS_{2000}) + \varepsilon_j \quad (5a)$$

Where, Y_j denotes the average annual growth rate of a given technology indicator in j-country. The β-coefficient reported in a set of regression is crucial to verify the hypothesis on existence the convergence among the set of countries. If the β-coefficients result to be negative and statistically significant, it suggests that countries tend to converge. Complete analysis results are presented in Table 2 (see below).

Table 2.

β-convergence estimation results. ICTs variables, time coverage 2000–2010

Variable	_cons	β-coeff.	R-squared
FTL	6.33	–1.96[12] (–10.57)[13]	0.438
FIS	15.89	–2.99 (–7.96)	0.307

[10] In the year 2000.
[11] Estimates for 108 countries.
[12] 0.05 significance level.
[13] *t*-statistics in parenthesis.

Variable	_cons	β-coeff.	R-squared
IU	28.43	–5.43 (–22.24)	0.775
FBS	33.28	–7.55 (–20.62)	0.80
MCS	41.29	–8.14 (–46.86)	0.93

Source: own estimations using STATA 11.2.

In the equations (1a), (2a), (3a), (4a) and (5a), the estimated parameters result to be negative and statistically significant[14] in each case. The negative β parameter, let us to confirm the hypothesis on existence of unconditional technology convergence among the 145 countries applied for the study. In the case of FTL, the coefficient results to be the lowest, however still negative. The regression (1a) refers to the fixed telephone lines it is rather not surprising that its adoption does not play a crucial role in the economy. In 63 countries out of the 145, growth rates presenting changes in per inhabitant fixed lines are negative. This proves a substitution of traditional means of communication by modern ones. In this case, we would conclude on substitution of fixed line by mobile phones.

In regressions (2a), (3a), (4a) and (5a) the β-coefficients are still negative and relatively high. It reports on dynamic unconditional technology convergence process in the analyzed countries. The best score we obtained was the one of MCS indicator. The coefficient at (–8.14) together with the very high negative correlation coefficient (–0.96)[15] show that process of mobiles phones implementation is very dynamic. A similar conclusion can be drawn from Chart 8 (see previous section). In terms of per inhabitant, an average usage of mobile phones has grown enormously, both in low- and high-income economies.

It is no surprise that countries that had a relatively low level of ICTs adoption in the year 2000, tended to grow at an enormously high pace in the period of 2000–2010. Thanks to that effect they have an opportunity to get closer to economies already advanced in ICTs usage. The results also report on catching-up effect in terms of new information and communication technologies application and usage in the 145 economies. However, the effect is positive and can influence enormously the socio-economic development path in low- and middle-income countries, it shall be underlined that these economies do not create new technologies. They just adopt them at a relatively low cost. ICTs implementation also enhances higher investments in basic human skills enabling to use these technologies effectively. The so-called "digital literacy" or "digital readiness" is a prerequisite to get gains from ICTs usage.

[14] For each equation the p-value < 0.05.
[15] Own calculations using STATA 11.2.

b. The q-convergence testing—step 2.

In the following subsection, we run a set of quantile regressions for each of the ICTs indicators. Applying the non-parametric method will help us find out more on the variables' behavior in non-central locations of the respective distributions. We use a set of mathematical formulas to estimate technology convergence—if reported—on arbitrary assumed quantiles.

$$Y_{ji}(FTL_{2000\text{–}2010}) = \alpha + \beta_{ji}(ln\_FTL_{2000}) + \varepsilon_j \tag{1b}$$

$$Y_{ji}(FIS_{2000\text{–}2010}) = \alpha + \beta_{ji}(ln\_FIS_{2000}) + \varepsilon_j \tag{2b}$$

$$Y_{ji}(IU_{2000\text{–}2010}) = \alpha + \beta_{ji}(ln\_IU_{2000}) + \varepsilon_j \tag{3b}$$

$$Y_{ji}(FBS_{2002\text{–}2010}) = \alpha + \beta_{ji}(ln\_FBS_{2002}) + \varepsilon_j{}^{16} \tag{4b}$$

$$Y_{ji}(MCS_{2000\text{–}2010}) = \alpha + \beta_{ji}(ln\_MCS_{2000}) + \varepsilon_j \tag{5b}$$

The i stands for an i^{th} quantile of the growth distribution of the indicator. The author arbitrarily assumes the estimations of 20^{th}, 40^{th}, 60^{th} and 80^{th} quantile of the respective ICTs indicators distribution. As in previous cases, the regressions consist of one predictor variable. The results of the quantile regressions are presented in Table 3 (see below).

Table 3.

Fixed Telephone Lines, Fixed Internet Subscribers, Fixed Broadband Subscribers[17], Internet Users, Mobile Cellular Subscribers. The *q*-convergence estimates. 145 countries. Years 2000—2010

	q-convergence (the (coefficients)			
Indicator	20^{th} quantile[18]	40^{th} quantile	60^{th} quantile	80^{th} quantile
FTL	–1.28 (–5.10)[19]	–1.73 (–8.79)	–2.06 (–10.18)	–2.52 (–18.37)
FIS	–1.85 (–3.82)	–2.25 (–7.04)	–3.47 (–17.30)	–5.20 (–16.56)
IU	–4.24 (–13.73)	–5.22 (–30.05)	–6.29 (–38.79)	–6.95 (–38.52)
FBS[20]	–5.73 (–1.34)	–6.98 (–24.49)	–8.07 (–26.56)	–9.36 (26.75)
MCS	–7.71 (–41.37)	–8.38 (–50.06)	–8.63 (–57.61)	–9.03 (–47.71)

Source: own estimations using STATA 11.2.

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[16] Estimates for 108 countries.
[17] For the MCS the regressions are run for 99 economies in the period of 2002–2010.
[18] The estimates for the sequent quantiles are always run in the whole country sample.
[19] The t-statistics are put in parenthesis.
[20] Estimates for 108 countries.

The quantile regression analysis completes the unconditional beta-convergence, and shades more light on the dynamic of inter-country technology convergence. In Table 3, q-regression coefficients are reported on the 20^{th}, 40^{th}, 60^{th} and 80^{th} quantiles for each ICTs variable separately. In each case, the regression coefficients are the lowest in the first (20^{th}) quantile, and are increasing in the following 3 quantiles, reaching the highest level in the 4^{th}. For FTL, FIS, FBS, IU and MCS, the coefficients turn out to be higher in the 4^{th} quantile than in case of the inclusion if the whole distribution. That is because the 4^{th} quantile's estimate does not include long right tail of the variables' distributions.

The overall results show clearly that in countries with a relative low initial level of ICTs adoption, the elasticity of ICTs implementation is also relatively lower. That suggests poorer ability of underdeveloped countries to acquire and use new ICTs tools. This is probably due to a relatively low cost of mobiles' adoption and a great ability to use it with no special human skills requirements.

c. The σ-convergence testing—3-step

Thirdly, we turn attention to the sigma-convergence testing, which reports on an increase or decrease in the coefficients of variation of certain ICTs variables. Such an approach shows the general tendency in growing or diminishing diversification within an analyzed group of countries in terms of dispersion of given variables' distribution.

Here below, we present results of sigma-convergence estimates (see Table 4 below).

Table 4.

Sigma-convergence coefficients estimates for FTL, FIS, FBS, IU and MCS. Years 2000 and 2010

Variable	Coeff. of variation in 2000	Coeff. of variation in 2010	% change in variation coefficients levels in the period 2000–2010.
FTL	93.0	82.93	(–10.92%)
FIS	162.91	103.85	(–36.25%)
IU	229.80	110.42	(–51.95%)
FBS	137.08	69.04	(–49.63%)
MCS	120.16	40.74	(–66.09%)

Source: own calculations using STATISTICA 11.2, based on data from ITU 2012.

As expected, also sigma-convergence tests show enormous changes in variation coefficients for selected ICTs indicators. The greatest decrease in coefficients of variation is observed in case of Internet users (decrease of almost 52%) and—again—mobile phones subscribers (decrease of 66%). Provided such results we can again strongly confirm that in the period of 2000–

–2010, a fast and dynamic process of ICTs diffusion across countries took place.

To sum up, in the fourth section we have tested for convergence process in 145 economies in the time span of 2000–2010. For the convergence analysis, we have chosen three methods: β-convergence, σ-convergence and *q*-convergence. As proxies of ICTs adoption level we have selected 5 indicators: fixed telephone lines, fixed Internet subscribers, Internet users, fixed broadband subscribers and mobile cellular subscribers. Given statistics draw a clear picture of overall basic ICTs tools usage in each of 145 countries. General results from convergence testing—regardless of methodology—are similar and prove a strong and fast inter-country technology convergence. This is mainly due to fast ICTs adoption, especially in low- and middle-income countries. However, the process of cross-country ICTs adoption is positive and generates great possibilities for ICTs users, it shall be underlined, that in a great number of countries the average use of basic ICTs is still relatively low. In addition, it should be noted that fast technology convergence does not imply directly that the technology gaps will disappear. This is a long-term process and requires huge financial resources and great improvements in basic human skills, so that the ICTs adoption would be effective and gains generating.

The gap still stays, which can be easily concluded from most recent ICTs cross-country adoption statistics. We need to remember that ICTs implementation and usage is also growing rapidly in high and medium income economies. The process is not static—quite the contrary—is it characterized as highly dynamic in each country and from a global perspective.

5. And what about technology club convergence?

As stated in the first section, the objectives of the paper are twofold. Firstly, we checked for catching-up (determined by technology convergence) effects in the group of selected 145 countries (which has been confirmed), and secondly, we aimed to identify the convergence clubs formation within the same group of economies. Following the Schumpeterian[21] model of convergence clubs, we assume that countries differ significantly from one another. These differences cover *inter alia*: *per capita* income level, GDP *per capita* growth dynamics, basic human skills, absorptive capacity of human capital, ability to absorb and adapt innovations and new technologies. We also make an assumption that low- and middle-income countries (relatively backward economies) have poor absorptive capacity which enables them to jump from the "poor club" into the "rich club". The overall country ability to adapt and use new technologies is a prerequisite to change the club.

[21] Kang S.J. [2002].

To group countries, we employ a country's dynamics based classification approach, which stands for classifying countries according to the magnitude of progress they made in the period of 2000–2010. To shed more light on the idea of country clustering, we present a theoretic scheme of clubs (see Chart 9 below). Cluster I (club I) includes countries which are mostly highly developed in terms of ICTs adoption (in year (1) and (2) these countries enjoyed the highest level of development); Cluster II (club II)—countries that in the examined time span managed to change their relative position from low to high developed countries; Cluster III (club III)—countries relatively backward in terms of ICTs adoption, countries which did not manage to jump into the "rich club"; Cluster IV (club IV)—a group of countries that worsened their relative position in the assumed time span.

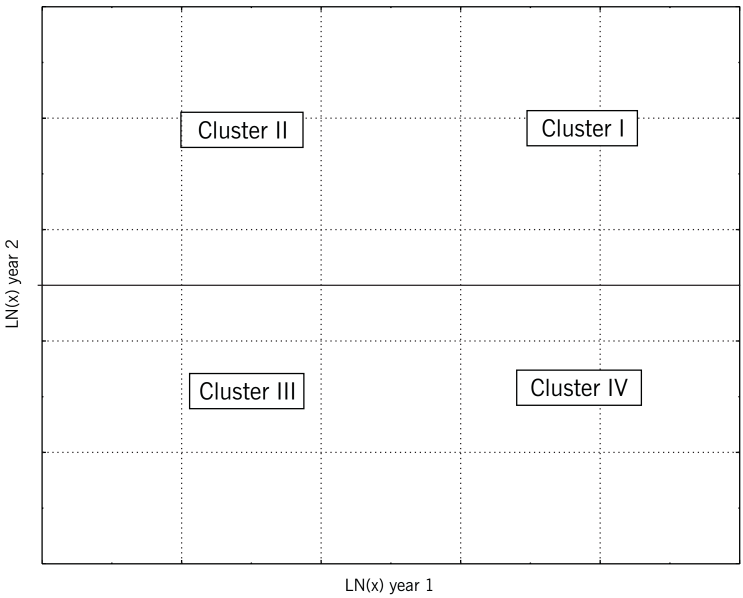

Chart 9.

Convergence clubs (clusters)—theoretical framework

Source: own elaboration.

To check for the club convergence, we plot 5 ICTs variables separately (see Charts 10, 11, 12, 13 and 14). In each we divide coordinate system into 4 parts, pointing 4 clusters (see Chart 10. for details). We draw the vertical line at value "0" on the axis LN(x)year1, to make a clear division between Cluster III and IV. The zero value at the LN(x)year1 axis indicates the value of an indicator for a country in 2000 at about 1 (units). In this case, the initial value "1" for a given indicator—in the year 2000, a threshold is assumed for an initial classification of poor and rich countries. We have named the following clubs as: Cluster I—advanced countries, Cluster II—fast followers, Cluster III—lagging behind countries, Cluster IV—marginalized countries.

First, we check for club convergence in the case of fixed telephone lines (see Chart 10).

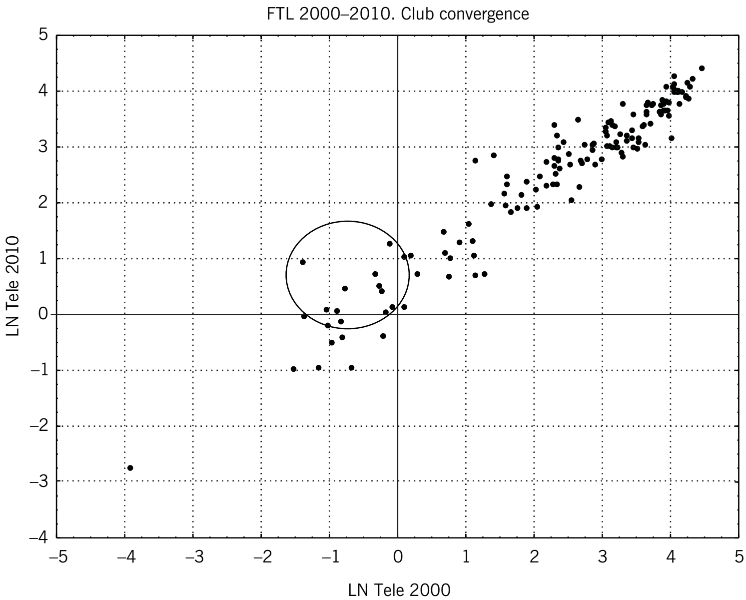

Chart 10.

Convergence club for FTL. 2000–2010

Source: own elaboration using STATA 11.2.

Most of the 145 countries belong to Cluster I—highly developed economies in terms of fixed telephones adoption. Only 8 economies (see Table 5.) managed to jump from the poor into the rich club (see Cluster II), by moving from the third quarter of the coordinate system into the second one. Very few countries still stay in Cluster III, which means that they are still lagging behind in terms of FTL.

The second plot (Chart 11), shows club convergence for FIS indicator. In the case of 42 economies (the list of economies is specified in Table 5., see below) belong to Cluster II—these are fast following countries that in the period of 2000–201 managed to change their position in the world ranking. However, still many countries stayed in the lagging behind group. It proves that in these countries the process of fixed Internet adoption was not dynamic enough to be classified as a member of Cluster II. The average per 100 inhabitants fixed Internet implementation in countries from Cluster III, although slightly higher than in the year 2000, in 2010 was still at a very low level—below 1[22] in each country.

[22] 1 per 100 inhabitants.

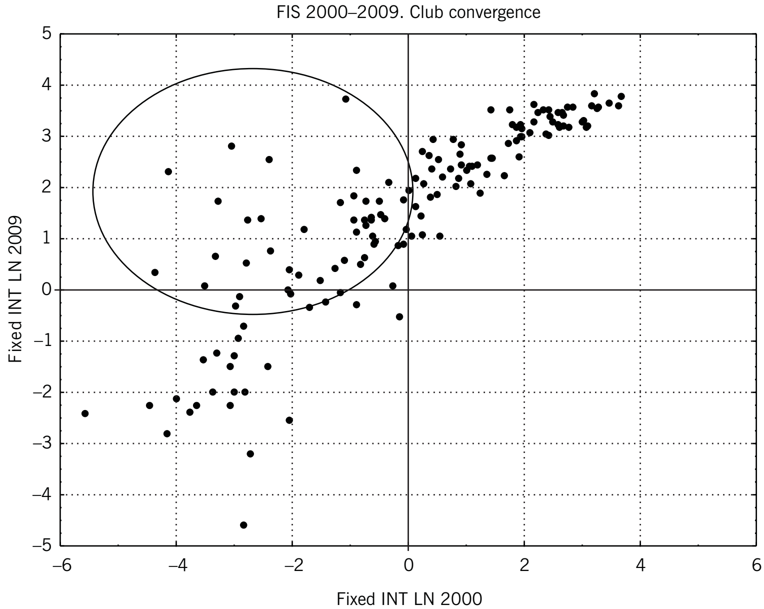

Chart 11.

Convergence club for FIS. 2000–2009
Source: own elaboration using STATA 11.2.

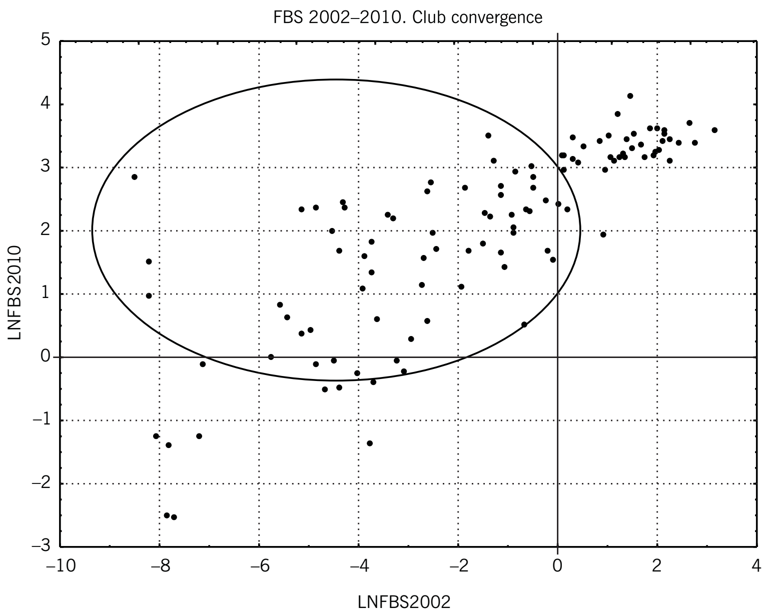

Chart 12.

Convergence club for FBS. 2002–2010
Source: own elaboration using STATA 11.2.

Quite a similar situation is shown in Chart 12, presenting club formation when fixed broadband (FBS) subscribers are taken into account. In Cluster II we find 57 countries (fast followers) which is the best score out of the 5 cases analyzed. It should be underlined that all 57 economies, in the year 2002 were classified as poor in terms of FBS. In the year 2002 the average per 100 inhabitants fixed broadband adoption level was considerably below 1 per 100 inhabitants. By contrast, in 2010, each of the countries enjoyed a significantly higher level of FBS adoption. Still, the group of countries (Cluster II) is highly diversified. Although there are many countries where the FBS adoption level stands at about 30–40 units per 100 inhabitants[23], in many economies the analogous values are just above zero. Hopefully, in the case of FBS, Cluster III is poorly populated and no country is classified as a marginalized economy.

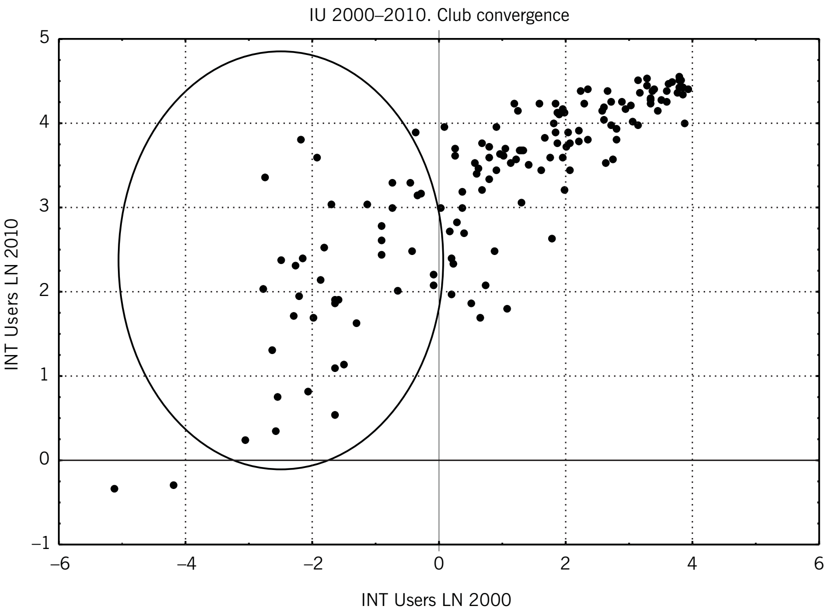

Chart 13.

Club convergence for IU. 2000–2010

Source: own elaboration using STATA 11.2.

When analyzing the Internet user (IU) indicator, we have found out a highly positive situation. Many countries are classified as rich (Cluster I), and in the period of 2000–2010 another 37 countries managed to join the rich group. Unfortunately, which is highly undesirable in the analyzed case, we have observed that two economies (Congo and Ethiopia) were classified as lagging behind countries (Cluster III).

[23] The highest value was noted for Liechtenstein—63.8.

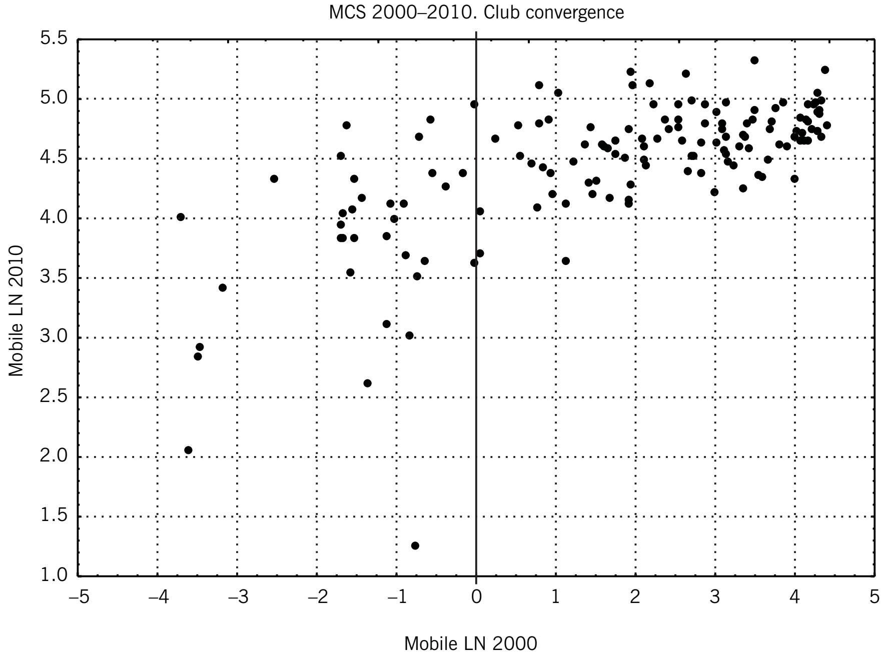

Chart 14.

Convergence club for MCS. 2000–2010

Source: own elaboration using STATA 11.2.

Chart 14 (see above) pictures a slightly different situation than in the previous cases. The group constituting Cluster II is still quite numerous (35 countries), and no countries have been classified as lagging behind and/or marginalized. The "construction" of Cluster I, however, is extraordinary. There are many countries that were classified as very poor in the year 2000, and achieved the level of MCS indicator of highly developed economies in 2010. This proves that process of mobile phones diffusion was very dynamic in the period of 2000–2010. It should be born in mind that similar conclusions were drawn from descriptive statistics analysis and then from convergence process analysis. In the period of 2000–2010, the average mobile phones subscribers level increased from 20.2 to 96.5, while the maximum level grew from 81.48 to 206.62[24]. Cluster I was significantly diversified internally. Along with the highly developed countries such as Germany or Sweden, there are economies like Swaziland, Togo, Senegal or Belize, traditionally classified as low developed countries. Such fast changes are possible mainly due to a very low cost of mobile phone adoption in a society, and relatively low human skill requirements to use them effectively. This confirms again the hypothesis on the catching-up process taking place especially in low developed economies.

[24] Always in terms of per 100 inhabitants.

Table 5.

Members (countries) of Cluster II for FTL, FIS, FBS, IU, MCS

FTL	FIS	FBS	FBS cont.	IU	MCS
Angola	Albania	Argentina	Mexico	Albania	Albania
Cambodia	Angola	Armenia	Moldova	Angola	Angola
Eritrea	Armenia	Azerbaijan	Mongolia	Azerbaijan	Armenia
Ethiopia	Azerbaijan	Bahrain	Morocco	Bangladesh	Bangladesh
Lao Rep.	Belarus	Bahrain	New Caledonia	Benin	Belarus
Malawi	Bolivia	Belarus	Oman	Bhutan	Benin
Mauritius	Bosnia and Herz.	Bolivia	Panama	Burkina Faso	Bhutan
Togo	Bulgaria	Bosnia and Herz.	Peru	Burundi	Burkina Faso
	Cape Verde	Brazil	Philippines	Cambodia	Burundi
	China	Brunei	Poland	Djibouti	The Comoros
	Colombia	China	Puerto Rico	Egypt	Congo
	Costa Rica	Colombia	Qatar	Erithrea	Djibouti
	Djibouti	Costa Rica	Romania	Georgia	Eritrea
	Dominican Rep.	Cyprus	Russia	Ghana	Ethiopia
	Ecuador	Czech Rep.	Saudi Arabia	Indonesia	Ghana
	Fiji	Ecuador	Slovak Rep.	Iraq	India
	Georgia	Egypt	South Africa	Kenya	Iraq
	India	Faroe Islands	Sri Lanka	Lao RP	Kenya
	Jordan	French Polynesia	Surinam	Madagascar	Kyrgyzstan
	Maldives	Georgia	Thailand	Malawi	Lao Rep.
	Moldova	Grenada	Tonga	Mauritania	Madagascar
	Mongolia	Ireland	Trinidad & Tobago	Morocco	Malawi
	Morocco	Jamaica	Tunisia	Nepal	Mauritania
	Namibia	Jordan	Turkey	Nigeria	Nepal
	Pakistan	Kuwait	United E.A.	Paraguay	Nigeria
	Paraguay	Latvia	Venezuela	Rwanda	Pakistan
	Peru	Lebanon		Senegal	Rwanda
	Philippines	Lithuania		Sri Lanka	Syrian Rep.
	Russia	Malaysia			Tanzania
	Rwanda	Maldives			Tonga
	Salvador	Mauritius			Uganda
	Sri Lanka				Uzbekistan
	Surinam				Vanuatu
	Swaziland				Yemen

FTL	FIS	FBS	FBS cont.	IU	MCS
	Syrian Rep				
	Tanzania				
	Thailand				
	Tunisia				
	Ukraine				
	Uzbekistan				
	Vanuatu				
	Yemen				

Source: own elaboration based analysis results from section 5.

6. Final remarks

The main scope of the study was to examine cross-national disparities in the field of new information and communication technologies adoption and usage. In order to achieve this aim, we have run basic descriptive statistical analysis (Table 1.), checked for changes in five different ICTs tools worldwide distributions (Charts 3–7), confirmed the hypothesis of the catching-up process taking place (applying beta, sigma and quantile convergences approach), and finally, we have checked for convergence clubs formation in the assumed country sample. The general conclusions, drawn on the basis of the 145-country sample in the period of 2000–2010, are the following:

a. In most countries the process of ICTs diffusion is fast and dynamic.
b. With regard to 4 ICTs indicators a huge increase in theirs average per 100 inhabitants adoption level has been observed (except for fixed telephone lines, where slight changes occurred).
c. In the year 2000, the characteristic twin-peak shape distribution line was observed, which proved the existence of two homogenous groups of countries that differed significantly in terms of ICTs adoption. Reversely, in 2010, the twin-peak curve disappeared and in the global ICTs distribution we can observe stratification, rather than polarization, tendencies. In the year 2010 the group of 145 countries was much more diversified in terms of ICTs adoption than in 2000.
d. Also, substantial decrease in Gini coefficients for all five technology indicators took place. Which provides evidence of the fact that along with the process of fast ICTs tools diffusion across countries, the inequalities in their implementation are declining, which is taken to be a very positive phenomenon.
e. The greatest changes in ICTs adoption and usage have been observed in the group of relatively low income countries. Many backward economies managed to make a huge step forward in the new technologies implementation. However, there still remains quite a numerous group of countries

which find themselves in a very unfavorable position, and are still lagging behind in terms of ICTs implementation.

f. Analysis results also show a dynamic technology convergence among countries—regardless of the methodology applied. If so, the catching-up process occurs at the same time.
g. We have managed to identify different technology convergence clubs (clusters). In the case of each ICTs indicator, there are many countries belonging to Cluster II which constitutes a group of countries that were classified in the year 2000 as underdeveloped[25], where the ICTs adoption growth rates were higher than in the highly developed countries. The extraordinary growth dynamics let them to catch-up with the developed economies, and in the year 2010 they achieved a level of ICTs adoption comparable with that of the highly developed economies.
h. Still, in the case of all 5 indicators, there are a few economies in Cluster III—those are countries which were permanently lagging behind and did not manage to catch up with highly developed economies in the period of 2000–2010.
i. Fortunately, only in the case of Internet users (IU) four countries were classified as Cluster IV economies, constituting a club of marginalized countries.

Looking at the issues discussed from a broader, global perspective, the convergence process in terms of ICTs adoption can be easily observed. That leads to the simple conclusion the low-income countries which are also the ones with an initial low ICTs implementation, have a great ability to catch-up with highly developed ones, which is mainly due to the unique ability of ICTs to spread at a high pace, and at low cost at the same time. In the period of 2000–2010 quite a number of underdeveloped countries managed to change their position in world ranking, achieving levels of ICTs adoption comparable to the ones we have observed in highly developed economies.

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Appendix 1

Table A1.

Information and Communication Technology indicators

Indicator	Definition	Source
Fixed telephone lines per 100 inhabitants	Fixed telephone lines refer to telephone lines connecting a subscriber's terminal equipment to the public switched telephone network (PSTN) and which have a dedicated port on a telephone exchange. This term is synonymous with the terms "main station" and "Direct Exchange Line" (DEL) that are commonly used in telecommunication documents. It may not be the same as an access line or a subscriber. The number of ISDN channels, public payphones and fixed wireless subscribers are included.	Core ICT Indicators 2010, ITU
Fixed Internet subscribers per 100 inhabitants	Fixed Internet subscribers refer to the total number of Internet subscribers with fixed access, which includes dial-up and total fixed broadband subscribers: cable modem, DSL Internet subscribers, other fixed broadband and leased line Internet subscribers.	Core ICT Indicators 2010, ITU
Fixed broadband Internet subscribers per 100 inhabitants	Fixed broadband Internet subscribers refer to entities (e.g. businesses, individuals) subscribing to paid high-speed access to the public Internet (a TCP/IP connection). High speed access is defined as being at least 256 kbit/s, in one or both directions. Fixed broadband Internet includes cable modem, DSL, fibre and other fixed broadband technology (such as satellite broadband Internet, Ethernet LANs, fixed wireless access, Wireless Local Area Network and WiMAX). Subscribers to data communications access (including the Internet) via mobile cellular networks are excluded.	Core ICT Indicators 2010, ITU
Internet users per 100 inhabitants	Internet users are those who use the Internet from any location. The Internet is defined as a world-wide public computer network that provides access to a number of communication services including the World Wide Web and carries email, news, entertainment and data files. Internet access may be via a computer, Internet-enabled mobile phone, digital TV, games machine etc. Location of use can refer to any location, including work.	Telecommunication Indicator Handbook, ITU

Indicator	Definition	Source
Mobile cellular telephone subscriptions per 100 inhabitants	Mobile cellular telephone subscriptions refer to subscriptions of portable telephones to a public mobile telephone service using cellular technology, which provides access to the PSTN. This includes analogue and digital cellular systems, including IMT–2000 (Third Generation, 3G). Both postpaid and prepaid subscriptions are included. Prepaid subscriptions are those where accounts have been used within a reasonable period of time (e.g. 3 months). Inactive subscriptions, that is, prepaid cards where a call has not been made or received within the last 3 months, are excluded.	Core ICT Indicators 2010, ITU

Source: compilation based on *Core ICT Indicators 2010*, and *Telecommunication Indicator Handbook*, ITU.

Abstract

Technology convergence and digital divides. A country-level evidence for the period 2000–2010

The paper, mostly empirical in nature, investigates issues on cross-national new information and communication technologies (ICTs) adoption patterns and growth directions.

In the period of 2000–2010, a great number of countries underwent substantial changes on the field of ICTs implementation. Many of them made a great "jump" starting with almost "zero level" of ICTs adoption in the year 2000 and during the ten- year period were implementing ICTs at an astonishingly high pace. Despite the obvious positive impact that ICTs have on overall society and economy condition, rapid changes can also generate higher inequalities on the field. The paper focuses mainly on capturing these changes. It also aims to confirm or reject the hypothesis on growing inter-country inequalities in ICTs adoption.

The target of the paper is twofold. Firstly, we explain the magnitude of past and present differences in digitalization level among countries; secondly, we concentrate digital technology convergence. We apply three approaches to convergence—β-convergence, σ-convergence and quantile-convergence (q-convergence), to check if relative division between countries was growing or diminishing in the time span of 2000 to 2010. Additionally, we check if countries of a given sample tend to form convergence clubs in the relevant years.

The analysis is run for the sample consisted of 145 economies and the time coverage is 2000–2010. All data applied in the research is drawn from the International Telecommunication Union statistical databases [see www.itu.int].

Key words: technology, convergence, ICTs, quantile convergence, clusters, technology clubs

JEL codes: C22, O11, O50, 033