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# TECHNOLOGY CONVERGENCE AND DIGITAL DIVIDES. A COUNTRY-LEVEL EVIDENCE FOR THE PERIOD 2000-2010.

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**Working Paper Series A (Economics, Management, Statistics)**

**No.3/2013 (3)**

**March 2013**

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# TECHNOLOGY CONVERGENCE AND DIGITAL DIVIDES. A COUNTRY-LEVEL EVIDENCE FOR THE PERIOD 2000-2010.

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### Abstract

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 year 2000, and during the 10 – year period were implementing ICTs at 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 – $\beta$-convergence, $\sigma$-convergence and quantile-convergence (q-convergence), to check if relative division between countries was growing or diminishing in the time span 2000-2010. Additionally we check if countries of the 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 are drawn from the International Telecommunication Union statistical databases[2].

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

***JEL codes:*** *C22, O11, O50, 033*

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[2] see www.itu.int

## 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 very fast adoption of ICTs in a wide set of countries is 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 high pace, along with their fast adoption in many countries, growing inequalities may appear. The unequal distribution of ICTs has already been in the interest on Schramm (1964), Sussman and Lent (1991), and later – for example – Schiller (1996). As proofed in works of the cited authors, fast diffusion of new technologies is broadly considered to be accompanied by their uneven distribution.

The growth rates showing the speed of changes on the ICTs` field are astonishing, and the period of (*for example*) 10 years can bring crucial changes on the world map. If we take into account i.e. indicators like Internet users or mobile cellular subscribers, the annual growth rates achieve average level of 50-60%[3]. As widely recognized, 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 fast growth in ICTs adoption causes increasing inequalities among countries on the field. Differences in the level of digitalization bring to mind a notion of "digital divide" also recognized as "digital gap", "technology divide" or "technology gap". In recent literature, there is a multitude of ways to define the digital divide. Different author conceptualize the digital divide differently, as well as adopt variety of ways to measure it. The most common definition of the digital gap is the one presented in the "Understanding digital divide" (OECD 2001), where the digital divide refers to the "gap between individuals,

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

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, however a very general, it expresses the very problem in nature. Whatever definition we would create, it always shall 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" reveals at a time. The simple notion of digital divides usually refers solely to technical access, which from analytical perspective is narrow. However, it is usually perceived as such – taking into account simple access to Internet and/or to other ICTs tools.

Authors like Berlot (2003) point significance of such dimension of digital divide like 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) they point out 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 (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 who lag behind in terms of ICTs adoption) or global (when some countries lag behind in terms of ICTs adoption) perspective.

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"[4] (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

[4] Software and databases

and measurement methods are implemented. In the following paper we imply reductionist definition of digital divides, assuming that it refers to a gap between those who have access to ICTs and are able to use it, and those who – regardless the reasons – does not have such opportunity.

## 2. Technology convergence – theoretical outline

As widely well known, the idea of the 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 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 long run perspective, GDP *per capita* growth rates are inversely related to initial level of the 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, nor any other factors that could possibly foster or impede the process. In the following paper, we assume the convergence to be perceived in technology terms only.

In the paper, we use the idea of unconditional $\beta$-convergence, $\sigma$-convergence and quantile-convergence. Despite being easy in nature, the estimates of $\beta$-convergence have few recognized limitations. The estimated coefficients report solely on the central tendency of the distribution ignoring behavior of a variable in its non-central locations. In such case, despite having confirmed – or rejected – the hypothesis on unconditional technology $\beta$-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)[5]. Since any number of quantiles can be applied in the analysis, it allows modeling arbitrary predetermined position of distribution[6]. Additionally, the methodology lets to learn about the 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 tests for the σ-convergence. The methodology gives a general idea about dynamics of the variability of the particular variables 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 a question about "rich" and "poor" countries group creation. 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 (Baumol 1986), in his study, distinguishes 3 types of convergence clubs. First one refers to high income, industrialized countries, which are suppose to converge strongly, the second – middle income countries when the catching-up hypothesis may or may not be confirmed (in any case the convergence is not supposed to be so strong as in the high income group), and third – low income countries, where the convergence is hardly visible. In literature (see Quah 1996), there is also a distinct classification of convergence clubs. First named as *"upward convergence"* – refers to group of relatively backward countries, which tend to catch-up with the rich ones; while the second is called *"downward convergence"* and is observed in group of relatively advanced economies where growth rates (for example GDP per capita) are at very low level – close to 0% *per annum*, or even happen to be negative. Note, that in such distinction, any

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

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 30-year period still is classified as such. Such 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 indicators values for countries within clusters (clubs) do not change. In fact, they do, however the changes are not so dynamic and strong enough to let a country move from bottom to top cluster.

## 3. Data – preliminary analysis

The data set we employ for the analysis consists of 145 countries, for which we managed to complete statistical data of 5 different ICTs variables. The time coverage is 2000-2010. The variables show country`s achievements in adoption of most common information technologies tools, and can be treated as proxies of country`s development on the given field. The indicators are: Fixed telephone lines[7] (FTL) per 100 inhabitants, Fixed internet 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[8].

A preliminary descriptive data analysis explains basic characteristics of chosen variables. The country sample is broad (it covers 145 economies) and lets 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

[7] In the following parts of text, we use abbreviations.
[8] Detailed definitions of each variable are put in Appendix 1.

variables – in 2000 as start year and in 2010 as 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[9], 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.

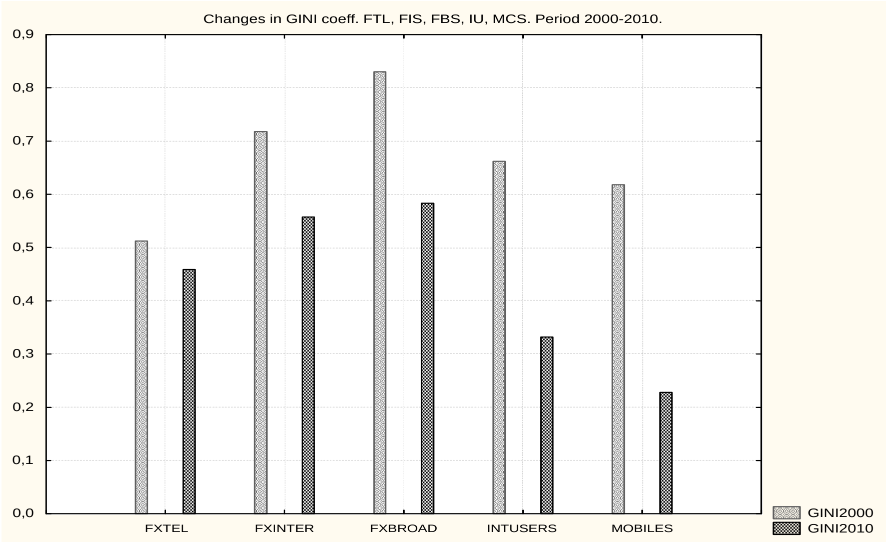
The sample consists of 145 world economies. Statistics in Table 1, give a general idea about the level of adoption of given ICTs in selected countries and presents preliminary data descriptive analysis results. Additionally we have estimated the Gini coefficient in 2000 and 2010, to check for changes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

[9] For Fixed Internet Subscr. data, the time span is 2000-2009.

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 year 2000, to 96,5 in 2010), as well as great increases in Min and Max values for each variable. That proofs 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 "technology revolution", and were adopting basic ICTs tools countrywide. The only exception constitutes the case of FBS, where still in year 2010; the Min value is zero for some countries, which means that they cannot benefit from broadband Internet tool[10]. 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).

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

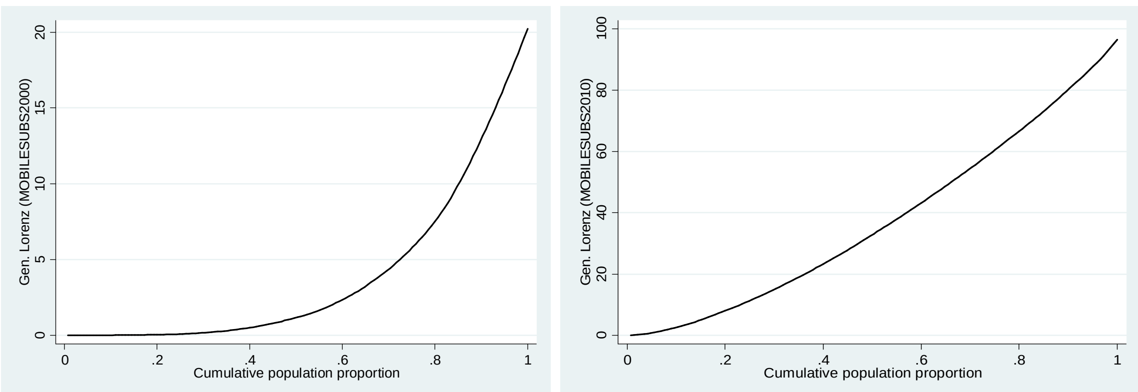
Chart 1. Changes in Gini coefficients for FTL, FIS, FBS, IU and MCS. Period 2000-2010.




Source: own elaboration using STATISTICA 10.0.

The greatest decrease in Gini coefficient are noted for IU – 33 percentage points decrease, and MCS – 39 percentage points decrease in the period 2000-2010. To have an idea about the magnitude of changes in inequalities, see Chart 2 (below) presenting Lorenz curve for MCS variables in 2000, after in 2010.

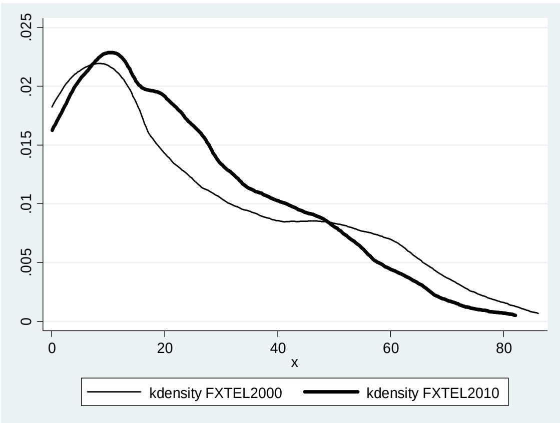
Chart 2. Lorenz curve for MCS variables in 2000 and in 2010.




Source: own elaboration using STATA 11.2.

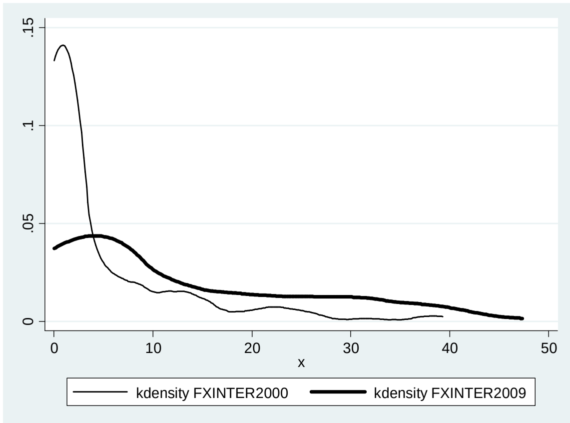
To learn more about the worldwide distribution of ICTs tools on country level, we estimate distributional graphs for each variable separately. The following 5 charts (Chart 4,5,6,7,8) show densities function estimates[11]. To show changes in distributions clearly we prepare two-way charts for each variable.

Chart 4. FTL distributions. 2000 and 2010.



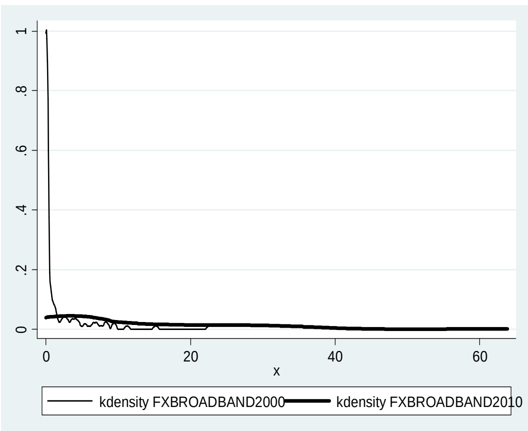

Source: own estimates applying STATA 11.2.

Chart 5. FIS distributions. 2000 and 2009.



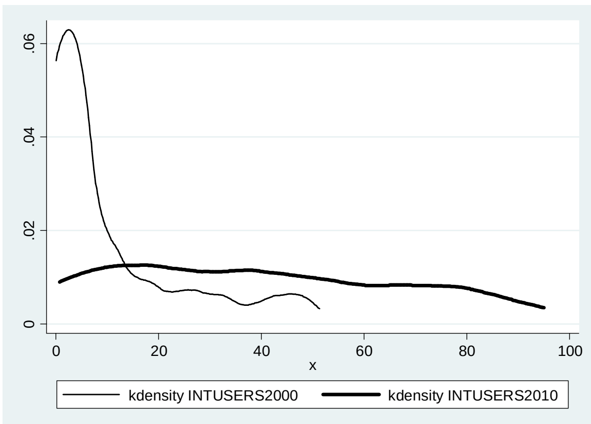

Source: own estimates applying STATA 11.2.

Chart 6. FBS distributions. 2000 and 2010.




Source: own estimates applying STATA 11.2.

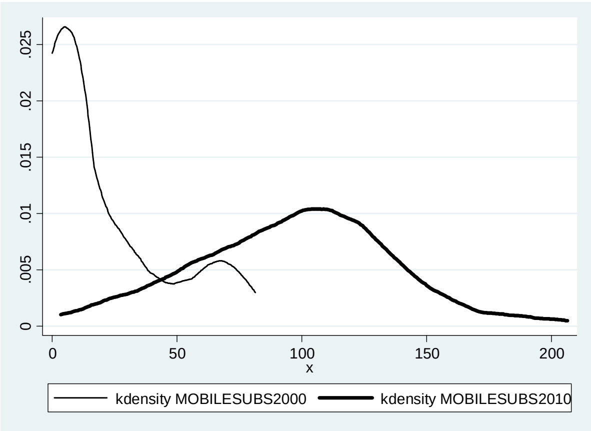
Chart 7. IU distributions. 2000 and 2010.




Source: own estimates applying STATA 11.2.

[11] We each case we apply Gaussian Kernel densities.

Chart 8. MCS distributions. 2000 and 2010.




Source: own estimates applying STATA 11.2.

For FTL, we hardly observe any changes in distribution. The densities functions look very similar both for year 2000 and 2010. Analogues 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 proofs the existence of numerous group of countries where the ICTs adoption was at 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 has changed significantly. Looking again at the same charts (see Chart 5,6,7), but for densities functions in year 2010, we note that line shapes differ substantially drawing a different picture if the issue. The densities lines show highly advanced stratification process 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, which were experiencing high level of deprivation from ICTs in year

2000, already in 2010, could enjoy using new technologies at acceptable level. The ICTs diffusion process, despite having an unquestionable positive impact, also has led to 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 8 refers to world distribution of mobile cellular subscribers in countries included in the sample. In the year 2000, we observe clear polarization – see twin-peak density function, on the world map. Each peak stands for a relatively homogenous group of economies with similar level of MCS, while the differences between the two groups are high. High left peak of distribution stands for low income (and probably low-middle income) countries with relatively poor adoption of mobiles in their societies. The right peak of distribution stands for a group of relatively rich countries, which enjoy higher level of mobiles usage. The polarization disappeared in the year 2010, when we observe a sole, centered peak. Such changes show great increase in usage of mobile phones, especially in low and medium income countries.

## 4. Do countries converge on the field of technology?

As presumed in section 2, we intend to verify the hypothesis on inter-country technology convergence in the time span 2000-2010. To learn about the convergence tendencies – or 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 a explanatory variables are 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 analogus as in section 2.

a) The β-convergence testing – 1-step.

As assumed, each regression shall have just one regressor – the initial level[12] 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:

$Y_j(FTL_{2000\text{-}2010}) = a + \beta_j(ln\_FTL_{2000}) + \varepsilon_j$ (1a)
$Y_j(FIS_{2000\text{-}2010}) = a + \beta_j(ln\_FIS_{2000}) + \varepsilon_j$ (2a)
$Y_j(IU_{2000\text{-}2010}) = a + \beta_j(ln\_IU_{2000}) + \varepsilon_j$ (3a)
$Y_j(FBS_{2002\text{-}2010}) = a + \beta_j(ln\_FBS_{2002}) + \varepsilon_j$ (4a)[13]
$Y_j(MCS_{2000\text{-}2010}) = a + \beta_j(ln\_MCS_{2000}) + \varepsilon_j$ (5a)

Where, $Y_j$ denotes the average annual growth rate of a given technology indicator in *j*-country. The $\beta$ coefficient reported in a set of regression is crucial to verify the hypothesis on existence the convergence among the set of countries. If the $\beta$ 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. $\beta$-convergence estimation results. ICTs variables, time coverage 2000-2010.

| *variable* | *_cons* | *β-coeff.* | *R-squared* |
|---|---|---|---|
| *FTL* | *6,33* | ***-1,96***[14] *(-10,57)*[15] | *0,438* |
| *FIS* | *15,89* | ***-2,99*** *(-7,96)* | *0,307* |
| *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[16] in each case. The negative $\beta$ parameter, let us to confirm the hypothesis on existence of unconditional technology convergence among the 145 countries applied for the

[12] In the year 2000.
[13] Estimates for 108 countries.
[14] 0,05 significance level
[15] *t*-statistics in parenthesis
[16] For each equation the p-value < 0,05.

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 a surprise that the its adoption does not play a crucial role in the economy. In 63 countries out of the 145, the growth rates presenting changes in per inhabitant fixed lines are negative. This proofs a substitution of traditional means of communication by modern ones. In the case, we would conclude on substitution of fixed line by mobile phones.

In regressions *(2a), (3a), (4a)* and *(5a)* the $\beta$ coefficients are still negative and relatively high. It reports on dynamic unconditional technology convergence process among analyzed countries. The best score we obtained in case of MCS indicator. The coefficient at (-8,14) together with the very high negative correlation coefficient (-0,96)[17] show that process of mobiles phones implementation is very dynamic. 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 in the year 2000 had relatively low level of ICTs adoption, in the period 2000-2010 tended to grow at enormously high pace. 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 on 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 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.

[17] 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 let us find out more on variables` behavior in non-central locations of respective distributions. We use a set of mathematical formulas to estimate technology convergence – if reported – on arbitrary assumed quantiles.

$Y_{ji}(FTL_{2000\text{-}2010}) = a + \beta_{ji}\,(ln\_FTL_{2000}) + \varepsilon_j$ (1b)
$Y_{ji}\,(FIS_{2000\text{-}2010}) = a + \beta_{ji}\,(ln\_FIS_{2000}) + \varepsilon_j$ (2b)
$Y_{ji}(IU_{2000\text{-}2010}) = a + \beta_{ji}\,(ln\_IU_{2000}) + \varepsilon_j$ (3b)
$Y_{ji}\,(FBS_{2002\text{-}2010}) = a + \beta_{ji}\,(ln\_FBS_{2002}) + \varepsilon_j$ (4b)[18]
$Y_{ji}\,(MCS_{2000\text{-}2010}) = a + \beta_{ji}\,(ln\_MCS_{2000}) + \varepsilon_j$ (5b)

The *i* stands for an $i_{th}$ quantile of the growth distribution of the indicator. The author arbitrary 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 the Table 3 (see below).

Table 3. Fixed Telephone Lines, Fixed Internet Subscribers, Fixed Broadband Subscribers[19], Internet Users, Mobile Cellular Subscribers. The *q*-convergence estimates. 145 countries. Years 2000 – 2010.

| | Q-convergence (*the $\beta$ coefficients*) | | | |
|---|---|---|---|---|
| *Indicator* | *20$^{th}$ quantile*[20] | *40$^{th}$ quantile* | *60$^{th}$ quantile* | *80$^{th}$ quantile* |
| *FTL* | -1,28<br>*(-5,10)*[21] | -1,73<br>*(-8,79)* | -2,06<br>*(-10,18)* | -2,52<br>*(-18,37)* |
| *FIS* | -1,85<br>*(-3,82)* | -2,25<br>*(-7,04)* | -3,47<br>*(-17,30)* | -5,20<br>*(-16,56)* |
| *IU* | -4,24<br>*(-13,73)* | -5,22<br>*(-30,05)* | -6,29<br>*(-38,79)* | -6,95<br>*(-38,52)* |
| *FBS*[22] | -5,73<br>*(-1,34)* | -6,98<br>*(-24,49)* | -8,07<br>*(-26,56)* | -9,36<br>*(26,75)* |
| *MCS* | -7,71<br>*(-41,37)* | -8,38<br>*(-50,06)* | -8,63<br>*(-57,61)* | -9,03<br>*(-47,71)* |

Source: own estimations using STATA 11.2.

18 Estimates for 108 countries.
19 For the MCS the regressions are run for 99 economies, in the period 2002-2010.
20 The estimates for the sequent quantiles are always run in the whole country sample.
21 The *t* statistics are put in the parenthesis.
22 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, there are reported *q*-regression coefficients 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$^{th}$ one. For FTL, FIS, FBS, IU and MCS the coefficients result to be higher in 4$^{th}$ quantile than in case of inclusion the whole distribution. That is because the 4$^{th}$ quantile`s estimate do not include long right tail of the variables` distributions.

The overall results clearly show that in countries with 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 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 report on increase or decrease in the coefficients of variation of certain ICTs variables. Such 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 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, 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 2000-2010. For the convergence analysis, we have chosen three methods: $\beta$-convergence, $\sigma$-convergence and $q$-convergence. As proxies of ICTs adoption level we have chosen 5 indicators: fixed telephone lines, fixed Internet subscribers, Internet users, fixed broadband subscribers and mobile cellular subscribers. Given statistics draw clear picture of overall basic ICTs tools usage in each of 145 countries. General results from convergence testing – regardless the methodology, are similar and proof 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 the 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, one shall note that fast technology convergence does not imply directly that the technology gaps will disappear. This is a long-term process and requiring 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 the worldwide perspective.

## 5. And what about technology club convergence?

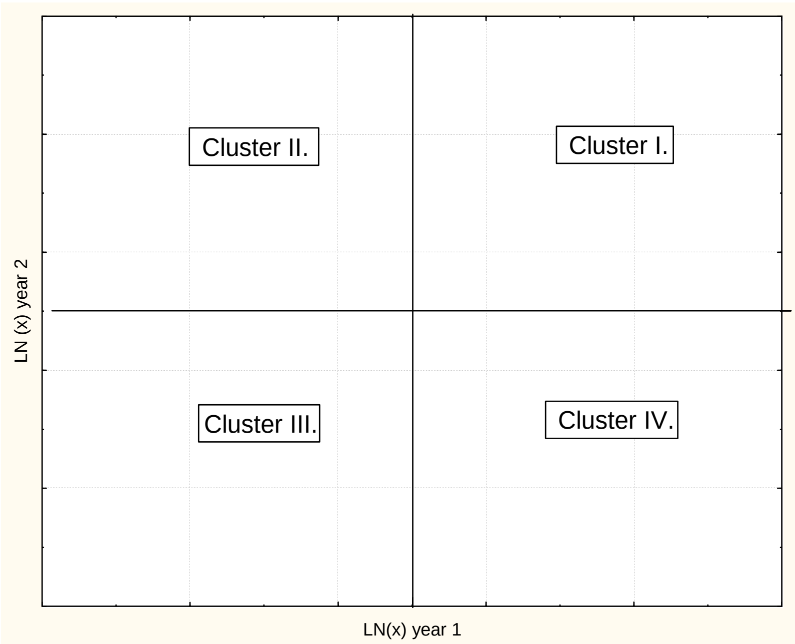
As stated in the first section, the objectives of the paper are twofold. Firstly we checked for catching-up (determined by technology convergence) effects in the group of selected 145 countries (which is confirmed), and secondly we aim to identify the convergence clubs formation within the same group of economies. Following the Schumpeterian[23] model of convergence clubs we assume that countries differ significantly among 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`s ability to adapt and use new technologies is a prerequisite to change the club.

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 2000-2010. To shed more light on the idea of countries 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 relatively highest level of development); Cluster II (club II) – countries that in the assumed time span managed to change

[23] Kang S.J. (2002)

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.

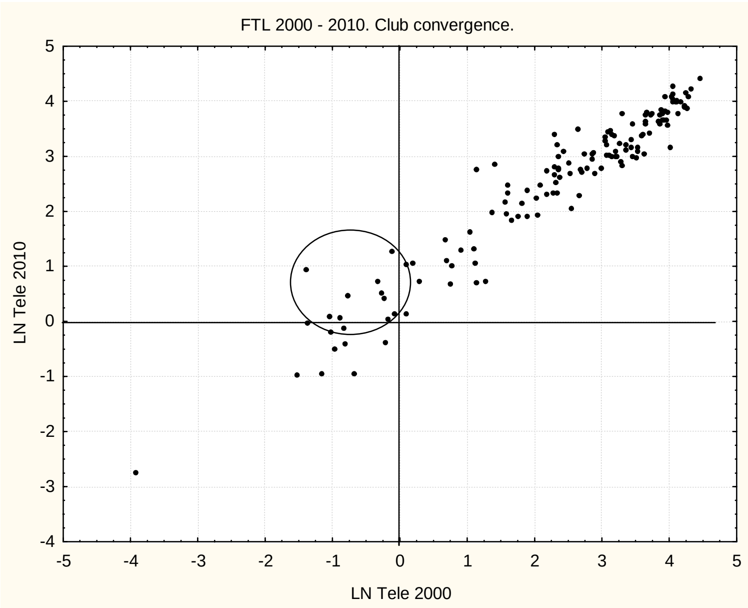



Source: own elaboration.

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 part, 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 the case, the initial value “1” for a given indicator – in year 2000, is assumed a threshold for initial classifying 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 case of fixed telephone lines (see Chart 10).

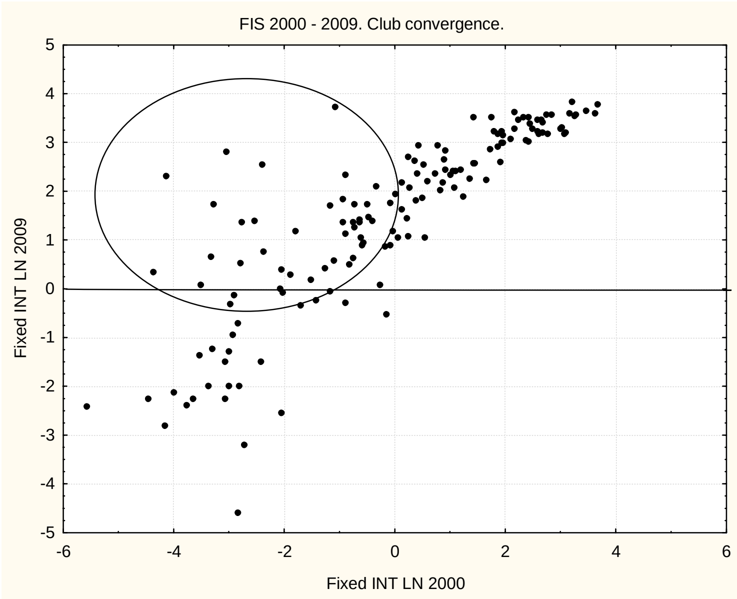
Chart 10. Convergence club for FTL. 2000-2010.




Source: own elaboration using STATA 11.2.

Most of the 145 countries belong to the 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 third quarter of the coordinate system into the second one. Very few countries still stay in the Cluster III, which means that they are still lagging behind in terms of FTL.

Chart 11. Convergence club for FIS. 2000-2009.

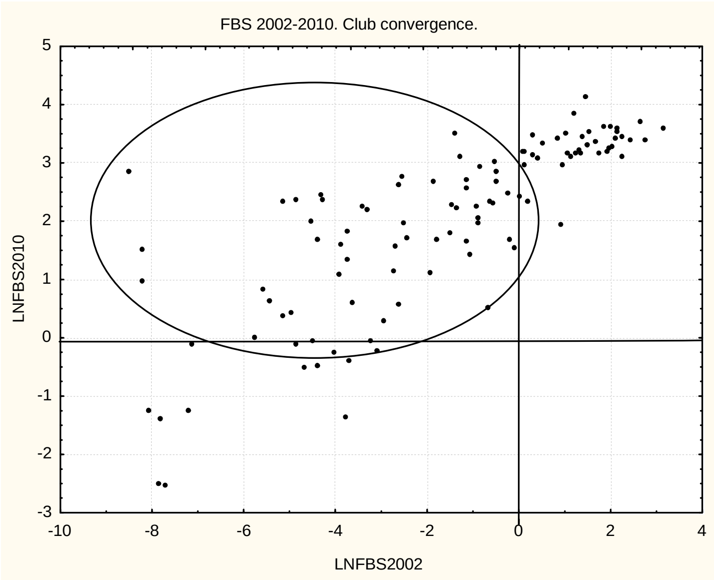



Source: own elaboration using STATA 11.2.

The second plot (Chart 11), shows club convergence for FIS indicator. In the case 42 economies (list of economies is specified in Table 5, see below) belong to Cluster II – these are fast following countries that in the period 2000-201 managed to change their relative position in the world ranking. However, still many countries stayed in the lagging behind group. It proofs that in the countries the process of fixed Internet adoption was not dynamic enough to be classified as the member of Cluster II. The average per 100 inhabitants fixed Internet implementation in countries from Cluster III, although slightly higher than in year 2000, in 2010 was still at very low level – below 1[24] in each country.

[24] 1 per 100 inhabitants

Chart 12. Convergence club for FBS. 2002-2010

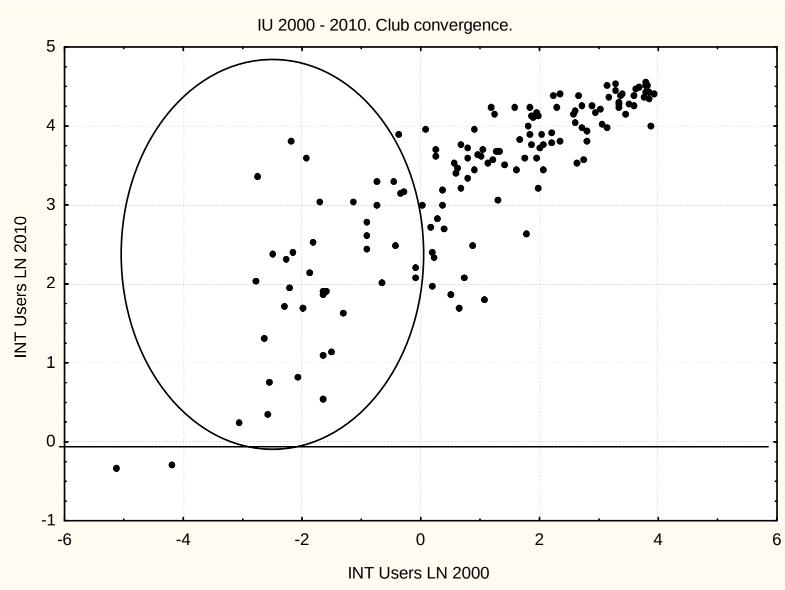



Source: own elaboration using STATA 11.2.

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. We should underline that all the 57 economies, in the year 2002 were classified as poor in terms of FBS. In year 2002 the average per 100 inhabitants fixed broadband adoption level was considerably below 1 per 100 inhabitants. Contrary, in year 2010, each of the country enjoyed 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 is about 30-40 units per 100 inhabitants[25], there are many economies that the analogues values are just little above 0. Hopefully in case of FBS, the Cluster III is poorly populated and no country is classified as marginalized economy.

[25] The highest value is noted in Liechtenstein – 63,8.

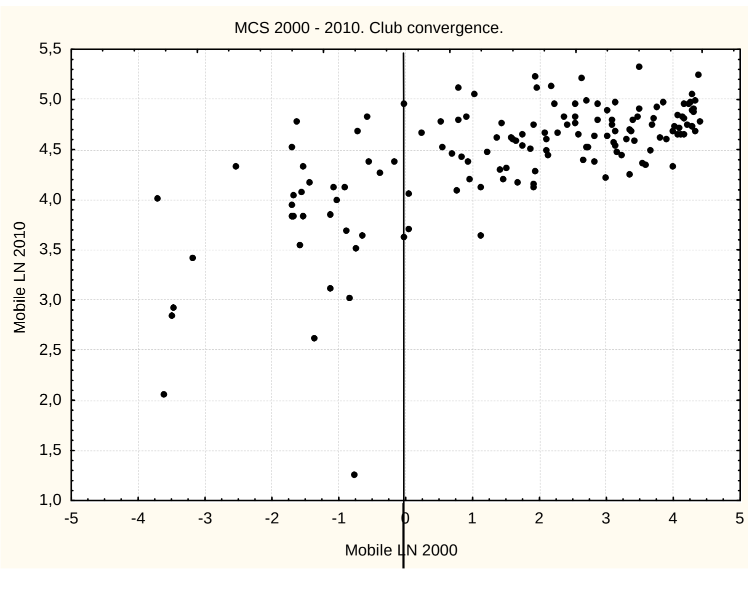
Chart 13. Convergence club for IU. 2000-2010




Source: own elaboration using STATA 11.2.

When analyzing following indicator – Internet user (IU), we find highly positive situation. Many countries are classified as rich ones – Cluster I, and in the period 2000-2010, next 37 countries managed to join the rich group. Unfortunately, what is highly undesirable in the case, we observe that 2 economies (Congo and Ethiopia) are classified as lagging behind countries (Cluster III).

Chart 14. Convergence club for MCS. 2000-2010




Source: own elaboration using STATA 11.2.

The chart 14 (see below) pictures slightly different situation than in 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. However, the "construction" of Cluster I however is extraordinary. There are many countries that in year 2000 very classified as poor, and in 2010 achieved the level of MCS indicator of highly developed economies. It proofs that process of mobile phones diffusion was very dynamic in the period 2000-2010. Remind those similar conclusions were drawn from descriptive statistics analysis, and next – from convergence process analysis. In the period 2000-2010, the average mobile phones subscribers level increased from 20,2 to 96,5; and the maximum level grew from 81,48 to 206,62[26]. The Cluster I is diversified intensively internally. Along with highly developed countries i.e. Germany or Sweden, there are economies like Swaziland, Togo, Senegal or Belize, traditionally classified as low developed countries. Such fast changes are mainly possible due to very low cost of mobile phone adoption in a society, and relatively low human skill requirements to use them effectively. This again confirms a hypothesis on catching-up process taking place especially in low developed economies.

[26] 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 | Bosna and Herz. | Peru | Burundi | Burkina Faso |
| | Cape Verde | Brazil | Philippines | Cambogia | Burundi |
| | China | Brunei | Poland | Djibouti | 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 |
| | Syrian Rep | | | | |
| | Tanzania | | | | |
| | Thailand | | | | |
| | Tunisia | | | | |
| | Ukraine | | | | |
| | Uzbekistan | | | | |
| | Vanuatu | | | | |
| | Yemen | | | | |

Source: own elaboration based analysis results from section 5.

## 6. Final remarks

The main scopes of the study were to learn on cross-national disparities on the field of new information and communication technologies adoption and usage. In order to achieve the aims, we have run basic descriptive statistical analysis (Table 1), checked for changes in 5 different ICTs tools worldwide distributions (Charts 3-7), confirmed a hypothesis on 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 145-country sample in the period 2000-2010, are following:

a. In most of countries the process of ICTs diffusion is fast and dynamic.
b. In case of 4 ICTs indicators are noted huge increase in theirs average per 100 inhabitants adoption level (with except of fixed telephone lines, where slight changes were observed).
c. In year 2000 the characteristic twin-peak shape distribution line was observed, which proofed 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 world ICTs distribution we observe stratification – rather than polarization – tendencies. In year 2010 the group of 145 countries was much more diversified in terms of ICTs adoption, than in year 2000.
d. Also substantial decrease in Gini coefficients for all 5 technology indicators took place. It proofs that along with the process of fast ICTs tools diffusion across countries; the inequalities in their implementation are lowering, which is thought to be very positive.
e. Greatest changes in ICTs adoption and usage are observed in the group of relatively low income countries. Many backward economies managed to make a huge step forward in new technologies implementation. However, there is still quite numerous group of countries which find themselves at very unfavorable position, and are still lagging behind in terms of ICTs implementation.
f. Analysis results also show dynamic technology convergence among countries – regardless the methodology applied. If so, the catching – up process is identified at a time.
g. We have managed to identify different technology convergence clubs (clusters). In case of each ICTs indicator, there are many countries belonging to the Cluster II – which constitutes group of countries, which in year 2000 were classified as underdeveloped[27],

[27] Always in terms of ICTs.

where the ICTs adoption growth rates were higher than in the high developed countries. The extraordinary growth dynamics let them to catch-up with the developed economies, and in year 2010 achieved comparable level of ICTs adoption as high developed economies.

h. Still, in case of all 5 indicators, there are few economies in Cluster III – these are countries which are permanently lagging behind and in the period 2000-2010 did not manage to take up with high developed economies.

i. Fortunately, only in case of Internet users (IU) there are 4 countries belonging to the Cluster IV, constituting a club of marginalized countries.

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

## References

Abramowitz, M. (1986). Catching up, forging ahead, and falling behind. *Journal of Economic History,* Vol.46, Issue 2, pp.385-406.

Adriani, F., Becchetti, L. (2003). Does digital divide matter? The role of Information and Communication Technology in cross-country level and growth estimates?. *CEIS Tor Vergata – Research Paper Series*, Vol.2, No.4.

Aghion, P., Durlauf, S.N. (2008). *Handbook of Economic Growth Volume 1A*. Elsevier.

Bagchi, K. (2005). Factors contributing to global digital divide: some empirical results. *Journal of Global Information Technology Management* 8(1), pp.77-83.

Baumol, W.J. (1986). Productivity growth, convergence and welfare: what the long run data show. *American Economic Review* 76(5), pp.1072-1085.

Barro, J.R., Sala-i-Martin, X. (1997). *Economic Growth*. The MIT Press, 2004.

Ben-David, D. (1997). *Convergence clubs and diverging economies*. NBER and CEPR.

Berenger, V., Verdier-Chouchane, A. (2007). Multidementional measures of well-being: standard of living and quality of life across countries. *World Development* Vol. 35.

Bernard, A.B., Jones, C.I. (1996). Technology and convergence. *The Economic Journal*, Vol. 106, Issue 437, pp.1037-1044.

Billon, M., Lera-Lopez, F., Marco, R. (2010). Differences in digitalization levels: a multivariate analysis studying the global digital divide. *Review of World Economy* 146:39-73.

Castellacci, F. (2011). Closing the technology gap?. *Review of Development Economics*, 15(1), pp.189-197.

Castellacci, F. (2006). Convergence and divergence among technology clubs. *DRUID Working Paper* No. 06-21.

Castellaci, F. (2008). Technology clubs, technology gaps and growth trajectories. *Structural Changes and Economic Dynamics* 19 (2008), pp.310-314.

Comin, A.D., Eastely, W., Gong, E., (2008). Was the wealth of nations determined in 1000 B.C.?. *Harvard Business School*, Working Paper 09-052.

Corrocher, N., Ordanini, A. (2002). Measuring the digital divide: a framework for the analysis of cross-country differences. *Journal of Information Technology* 17(1), pp.9-19.

Davis, L., Owen, A., Videras, J. (2008). Do all countries follow the same growth process?. see: http://ideas.repec.org/p/pra/mprapa/11589.html.

Desdoigts, A. (2004). Neoclassical convergence versus technological catch-up : a contribution for reaching a consensus. *Problems and Perspectives in Management* 3/2004.

Dewan, S., Riggins, F.J. (2005). The digital divide : current and future research directions. Forthcoming as the lead article in a special issue of the Journal of the Association for Information Systems.

Devaraj, S., Kohli, R., (2003). Performance impacts of information technology : is actual usage the missing link ?. *Management science* 49, pp. 273-289.

Dijk van, J.A.G.M. (2005). *The deepening divide : inequality in the information society*. Sage Publications Inc.

Fei, J.C.H., Ranis, G. (1999). *Growth and development from evolutionary perspective*. Blackwell Publishers.

Gancia, G., Zilibotti, F. (2009). Technological change and the wealth of nations. *Annual Review of Economics*, Vol.1.

Grandville de la, O. (2009). *Economic growth. A unified approach*. Cambridge University Press.

Goldfarb, A., Prince, J. (2008). Internet adoption and usage patterns are different: implications for the digital divide. *Information Economics and Policy* 20, pp.2-15.

Hao, L., Naiman, D.Q. (2009). *Quantile regression*. SAGE Publications.

Haslam, P.A., Schafer, J., Beaudet, P. (2008). *Introduction to International Development*. Oxford Univeristy Press.

Hewitt de Alcantara, C.(2001). The development divide in a digital age. An issues paper. *United Nations Research Institute for Social Development.*

Howard, P.N. (2007). Testing the leap-frog hypothesis. The impact of existing infrastructure and telecommunications policy on the global digital divide. *Information, Communication & Society*, Vol. 10, No.2, pp. 133-157.

James, J. (2003). *Bridging the global digital divide*. Edward Elgar.

Kan,g S.J. (2002). Relative backwardness and technology catching up with scale effects. *Journal of Evolutionary Economics*, 12, pp.425-441, Springer-Verlag.

Kauffman, R.J., Techatassanasoontorn, A.A. (2005). Is there a global digital divide for wireless phone technologies?. *Journal of the Association for Information Systems* Vol.6, No. 12, pp.338-382.

Koop, G. (2009). *Analysis of economic data*. Wiley.

Kubielas, AS. (2009). *Innowacje i luka technologiczna w gospodarce opartej na wiedzy. Strukturalne i makroekonomiczne uwarunkowania*. Wydawnictwo Uniwersytetu Warszawskiego, Warszawa.

Maurseth, P.B. (2001). Convergence, geography and technology. *Structural Change and Economic Dynamics* 12.

Meier, G.M., Rauch, J.E. (2005). *Leading issues in economic development.* Oxford University Press.

Mookherjee, D., Ray, D. (2001). *Readings in the theory of economic development.* Blackwell Publishers.

Neumayer, E. (2003). Beyond income: convergence in living standards, big time. *Structural changes and Economic Dynamics* 14(2003).

Ocampo, J.A. (2007). *Growth Divergences. Explaining differences in economic performance*. Zed Books.

Panek, T. (2009). *Statystyczne metody wielowymiarowej analizy porównawczej*. Szkoła Główna Handlowa.

Quah, D. (1993). Galton`s fallacy and tests of the convergence hypothesis. *Scandinavian Journal of Economics*, 95, pp. 427-443.

Quah, D.T. (1996). Empirics for economic growth and convergence. *European Economic Review* 40, pp.1353-1375.

Ranis, G., Stewart, G. (2005). Dynamic links between the economy and human development. *DESA Working Paper* No.8.

Ray, D. (1998). Development economics. Princeton University Press.

Redding, S., Schott, P.K. (2003). Distance, skill deepening and development: will peripheral countries ever get rich?. *Journal of Development Economics* 72, pp.515-541.

Rostow, W.W. (1980). *Why the poor get richer and rich slow down*?. Austin University of Texas Press 1980.

Schiller, H.I. (1996). *Information Inequality: the deepening social crisis in America*. Routledge.

Schramm, W.L. (1964). *Mass media and national development: the role of information in developing countries.* Stanford University Press.

Seligson, M.A. (2008). *Development and underdevelopment.* Lynn Rienner Publishers.

Servon, L.J. (2002). *Bridging the Digital divide*. Blackwell Publishers. Spanning the digital divide. Understanding and tackling the issues. A report by briges.org, 2004.

Stilianos, A., Tomkins, J. (2010). Technology adoption and club convergence. MPRA 21260.

Stoneman, P. (2002). *The economics of technological diffusion*. Blackwell Publishers.

Sussman, G., Lent, J.A. (1991). *Transnational Communication: wiring the third world*. Sage Publications.

Thirlwall, A.P. (2006). *Growth and Development with special reference to developing economies*. Palgrave.

Todaro, M.P., Smith, S.C. (2009). *Economic Development*. Pearson Education.

Wolff, E.N. (2009). *Poverty and income distribution*. Wiley-Blackwell.

Woźniak, M.G. (2008). *Wzrost gospodarczy. Podstawy teoretyczne*. Wyd. Uniwersytetu Ekonomicznego w Krakowie.

Vehovar, V., Sichel, P. (2006). Methodological Challanges of Digital divide measurement. *The Information Society*, 22.

Verbeek, M. (2012). *A guide to modern econometrics*. Wiley.

Yusuf, S., Deaton, A., Dervis, K., Easterly, W., Ito, T., Stiglitz, J. (2009). *Development economics through decades*. The World Bank.

Zhu, K., Kraemer, K.L. (2005). Post-adoption variations in usage and value of e-business by organizations: cross-country evidence from the retail industry. *Information Systems Research* 16, pp.61-84.

**Appendix 1**
**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 |
| **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

**Original citation**:
Lechman, E. (2013). Technology convergence and digital divides. A country-level evidence for the period 2000-2010 . GUT FME Working Paper Series A, No. 3/2013(3). Gdansk (Poland): Gdansk University of Technology, Faculty of Management and Economics.

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