DOES TECHNOLOGY ADOPTION MATTER FOR ECONOMIC DEVELOPMENT? AN EMPIRICAL EVIDENCE FOR LATIN AMERICAN COUNTRIES

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Abstract

Extraordinary spread of new information and communication (ICTs) technologies has been recognized worldwide. ICTs are broadly perceived as tools facilitating economic growth and development, especially in economically backward countries. They are relatively easy and cheap to adopt, require minimum skills for effective usage, bringing opportunities for disadvantaged societies. They enable education, knowledge dissemination and sharing, processing and storing all kinds of information. At a time, existence of extend causal relationships between technology diffusion and general economy performance is highly probable.

The paper seeks for empirical evidence in existing quantitative links between process of information and communication technologies (ICTs) adoption and dynamics of economic growth and development in Latin American countries. Preliminary we consider ICTs diffusion patterns in Latin American countries, approximating the diffusion process by S-shaped curves and estimating essential parameters of the curves. Afterwards, adopting a bundle of statistical and econometrical tools we aim to detect: if there is any quantitative relationship between ICTs adoption dynamics and economic growth and development; and we wish to estimate to what extend ICTs contribute to economic growth and development. We hypothesize on existing statistically significant and strong links between the two issues.

For the analytical purposes, we use panel data for Latin American economies, in the time framework 1990-2011. All necessary data are derived from World Telecommunication/ICT Indicators Database 2012 (16th edition) and World Development Indicators 2012.

Keywords*: technology, ICTs, economic development, economic growth, Latin America, cross-country study.*

JELCodes*: F43, O11, O33.*

Shedding light on New Technologies, growth and Latin American economies. General outline.

The so called New Technologies, in fact standing for New Information and Communication Technologies [ICTs], are widely recognized as one the most important engines of economic growth and development, social and structural changes. According to broadly accepted definition developed by OECD [see OECD Guide to Measuring Information Society 2011], ICTs are products[1] that "must primarily be intended to fulfill or enable the function of information processing and communication by electronic means, including transmission and display" [see *ibidem*, p.22]. It is widely agreed that ICTs are continuously having strong impact both on economic and social dimensions of life, and their adoption and use has broad and pervasive implications. Use of new technologies causes changes in enterprise sector, transforming way of doing business, creating new markets and demand, changing consumer preferences. It provides a perfect tool for making the business more effective; use of Internet as global trading platform, allows finding new partners, at marginal cost close to zero. Some say, that ICTs diminish geographic "distances" among markets. This is especially crucial for countries which are treated as peripheral due to its geographic location, lack of access to sea or navigable rivers. The "distance" among countries is also defined in terms of economic development. Counties economically backward are generally on the margin on global markets. ICTs create real possibilities for introducing these economies into these markets. On the other hand, use of new technologies enabled reduction in transactions costs and market friction. As result the positive impact shall be visible in growth of productivity which would be directly transmitted into growth of *per capita* output. The contribution of ICTs to national economies can be then pervasive, however, it is necessary to stress that technologies are causing dramatic changes in social life. They change societal interactions, by contributing to new means of communication, access to information and knowledge. The ICTs impact on society can be particularly seen through lens of education. Broad development of tools for knowledge and information access at any place and at any time, at minimal cost, is substantial for being better educated. This in effect creates shifts in country`s human capital.

In broad conceptual perspective, economic growth is highly based on technological progress, and knowledge [see i.e. Faberger 1994, Castellaci 2002, Comin&Hobijn 2003]. As Information and Communication Technologies enable diffusion on innovation they can be treated as tool of promoting economic growth and socio-economic development. In 2003, during the World Summit on Information Society, New Information and Communication Technologies have been declared as a key driver for economic development. At a time their unique influence on education, government, institution, poverty eradication has been strongly highlighted [World Summit 2003 in Geneva].

New technologies can be a powerful tool for economic growth, but despite this fact, we need to underline that their impact on economy and society is far from automatic and linear, and is supposed to be revealed in the long-run perspective. Reshaping social life, economic structures and productivity shifts are time-intensive processes, which are impacted by ICTs, but often not directly. What is even more, adoption of ICTs influences countries differently. Their effective use, so that real gains could be obtained, is additionally deeply depended on social and economic pre-conditions, country`s policies, market regulations and competition. It is widely thought that to benefit fully from the potential of new technologies, societies should "posses" certain stock of knowledge and skill, generally perceived as kind of prerequisites to adopt and use ICTs.

Along with previous there arise other aspects of new technologies adoption. Paradoxically, fast diffusion of technologies, can determine inter-country disparities, causing higher social and economic inequalities. If countries have different capabilities to absorb innovations, ICTs can rather worsen differences among countries. This happens mainly due to the fact that countries with high capacity to absorb and use new technologies can benefit from them which is demonstrated by high and stable economic growth. Reversely, countries with low capacities to absorb ICTs, are in real danger to lag behind. As effect, the economic gap will widen. With respect to new technologies, there also

[1] Note: in OECD definitions, "product" refers both to goods and services.

emerges a risk of the phenomenon defined as "digital divide" or "digital gap". The notion of digital gap refers to the disadvantageous situation when the distance between countries which are "technology-rich" and "technology-poor" is growing. There are few empirical evidence [see i.e. Castellacci 2001, Antonelli 2003, Golfarb&Prince 2008, Billonet *et al.* 2010] reporting on growing divides among countries with respect to new information and communication technologies. In fact, high diffusion rates of ICTs in one group of countries, while confronted with low diffusion rates in other group, create a risk of digital exclusion. Unfortunately, similar tendencies are observed within countries, among society members. Digital marginalization has become a fact in many countries, especially those experiencing high income inequalities.

The issues on new technologies adoption and usage are of special importance for Latin American economies. As all aspects of economic growth are under policy debates the discussion of promoting ICTs in the region reveals of high relevance. We need to note that countries in the region constitute a kind of mosaic. High inter-country heterogeneity in terms of income, human capital, quality of institutions or government policies, is reflected by different abilities to enter sustainable development paths. Still many countries in the region of Central and South America suffer from insufficient access to new technologies and innovations, which is perceived as an impediment for economic growth and development. In the world wide perspective, Latin American countries are still perceived as lagging behind in terms of ICTs adoption and use. What is even more, the Latin American countries readiness to acquire new technologies to benefit from them is estimated as relatively low. Due to these facts, promoting ICTs deployment in the region has become of crucial importance and the issues on public debates. In year 2000, more than 90 different ICTs projects were launched in Latin American countries. Along with the previous, 5 developed countries – Brazil, Chile, Mexico, Argentina and Uruguay, managed to start up the Information Society Programmes. All projects, are mainly aimed to help to expand new technologies usage for educational purposes. The programmes cover improvements in basic accessibility and affordability, are to provide free public "spots" for Internet access, training people how and for what purposes ICTs can be adopted. Despite that, many programmes aim to provide improvements in key infrastructure like wired and wireless telecommunication service, internet hosts, broadband penetration, all other elements which are essential for wide availability and access to ICTs tools. It is expected that ICTs adoption, in Latin American countries, shall help to eradicate some crucial problems that the regions is dealing with. The main long-term targets are, *inter alias*, creating solid base for growth of social cohesion, enabling e-commerce, significant reduction in costs of telecommunication, improvements in education and skills, creating higher productivity and crucial poverty reduction.

For last two decades, development, broad and dynamic diffusion of new technologies was tremendous. Astonishingly high changes are reported both for developed and developing countries, bringing to these economies crucial changes. For this purpose, extensive analysis of new technologies adoption has gained much attention recently. A great majority of studies, not only concentrates on diffusion process as such, but refer to its determinants and causes. Despite broad theoretical and empirical literature on the issues, we still lack hard quantitative proof that ICTs contribute to economic growth. Different analysis outcomes are usually not coherent and reveal no robustness. However, analysing potential impact of new technologies adoption on economy, we need to underline that capturing direct links is hardly possible. This is mainly due to multidirectional impact of ICTs on social, economic, political life and many others. We aim to contribute to the literature on economic development and new technologies by presenting detailed analysis of new technologies and economic growth in selected Latin American economies. To fulfil this, we target to concentrate on identification of diffusion process of new technologies, developing particular for each country, ICTs diffusion trajectories, estimating its growth parameters, and secondly, we aim to detect statistical relationships between new technologies adoption and economic growth in 20 Latin American countries.

Data explanation and empirical settings

In the paper we use panel data covering 20 Latin American economies. The panel is strongly balanced. For empirical analysis we apply three variables, namely: $MCS_{i,y}$, $IU_{i,y}$ and $GDPpcPPP_{i,y}$, where *i*-denotes country and *y*-year.. We treat $MCS_{i,y}$ and $IU_{i,y}$ as proxies of achievements on the ground of technological progress. These two variables explain perfectly level of society`s adoption and usage of ICTs. All data are derived from World Telecommunication/ICT Indicators Database 2012 [16th edition] and World Economic Outlook database 2013 [IMF].

To test for technologies diffusion process, we follow simple logistic growth model with upper growth limits imposed (upper asymptote). The crude version of simple growth model is specified as:

$$G(t) = e^{\alpha t+\beta} \quad (1),$$

where *t* – stands for time as independent variable, parameter α is growth rate, and β explains the location parameter which shifts the growth curve horizontally [Meyer 1994]. The expression (1) showing on exponential growth of variable, however simple in form it does not contain any upper growth limits which is rather common for "natural growth". As the systems usually have limited growth capacities, it is fully justified to impose arbitrary upper growth limits, expressed by κ:

$$\frac{dG(t)}{dt} = \alpha G(t)\left[1 - \frac{G(t)}{\kappa}\right] \quad (2).$$

As *G(t)* reaches κ, the $\alpha \rightarrow 0$, and the exponential curve stars to resemble the S-shaped trajectory. Following the above, we obtain a logistic growth equation:

$$G(t) = \frac{\kappa}{1+e^{-\alpha t-\beta}} \quad (3),$$

Where κ - denotes upper growth limit (upper asymptote), α - is the specific duration (growth time from 10% to 90% of saturation), and β - stands for the midpoint of the curve.

The equation (3) above alternatively can be transformed into:

$$G(t) = \frac{\kappa}{1+\exp\left[-\frac{\ln(81)}{\Delta t}(t-t_m)\right]} \quad (4).$$

In (4), the t_m defines $\beta = -t_m\alpha$, and stands for the midpoint of the growth process ($=\kappa/2$), while the Δt tells about the time needed to pass from 10% to 90% level of saturation (κ).

Secondly, to explore the relationship between $MCS_{i,y}$ and $IU_{i,y}$ [predictor variables] and *per capita* income - $GDPpcPPP_{i,y}$ [outcome variable], we apply longitudinal analysis. We aim to analyse the impact of explanatory variables [$MCS_{i,y}$ and $IU_{i,y}$] which vary over time, on $GDPpcPPP_{i,y}$, we use the fixed-effects models, defined as:

$$GDPpcPPP_{i,y} = \delta_i + \gamma_{MCS}(MCS_{i,y}) + \gamma_{IU}(IU_{i,y}) + \mu_{i,y} \quad (5),$$

Where δ_i explains country-specific intercept, γ_{MCS} and γ_{IU} stand for independent variables coefficient, and $\mu_{i,y}$ is the error term. The rationale behind using in the case fixed-effects models, is that it allows to remove the effect of time-invariant features from explanatory variables, allowing to assess the net effect of each predictor used. Additionally we test two different fixed-effects models by excluding MCS variable, and after – IU variable, so that the equations are specified as:

$$GDPpcPPP_{i,y} = \delta_i + \gamma_{IU}(IU_{i,y}) + \mu_{i,y} \quad (6)$$

and

$$GDPpcPPP_{i,y} = \delta_i + \gamma_{MCS}(MCS_{i,y}) + \mu_{i,y} \quad (7).$$

In the following section we present results of our estimates.

New Technologies diffusion and economic growth – evidence for Latin American countries.

As already stressed, the main targets of the paper are two-fold; hence we split the empirical section into two parts. Firstly we approximate New Technologies diffusion trajectories in 20 selected Latin American countries, and estimate logistic growth parameters for each country separately. Following the previous, by use of panel analysis, we detect the hypothetical relationship between adoption and usage of new technologies approximated by $MCS_{i,y}$ and $IU_{i,y}$ variables, and economic growth.

As short introductory analysis, we briefly present basic descriptive statistics of $MCS_{i,y}$ and $IU_{i,y}$ variables in 20 Latin American countries. It gives a general idea about the level of adoption and usage of two most commonly used means of mass communication (two ICTs tools), retrieving information and getting knowledge.

Table 1 [see below] draws a general picture on ICTs average penetration in Latin American economies. Not surprisingly, in year 2000, the average values both for usage of Internet by individuals [denoted as $IU_{i,y}$] and number of mobile cellular subscribers per 100 inhabitants [denoted as $MCS_{i,y}$], are relatively low, however $MCS_{i,2000}$ is twice higher than $IU_{i,2000}$. In 2000, the two worst performers in terms of $MCS_{i,2000}$ were Grenada and Peru with respective values $MCS_{Grenada,2000}$=4,24 and $MCS_{Peru,2000}$=4,93, which were far below the average [→ $MCS_{average,2000}$=10,58], while the two best performing countries were: Chile [$MCS_{Chile,2000}$=22,06] and Venezuela [$MCS_{Venezuela,2000}$=22,37]. After the 11-year period of tremendous growth and diffusion of mobile telephony, the average level of MCS adoption was 114,78 - more than ten times higher than in 2000. In 2011, the best scores were noted for Panama – 188,6, Surinam – 178,8 and Grenada – 154,9[2], while the most lagging countries were Belize – 69, Bolivia and Mexico – for both $MCS_{i,2011}$=82. The winners with respect to the level of average annual growth rate of mobile cellular subscriptions per 100 inhabitants were Honduras – 33% per *annum*, and Ecuador – 29% per *annum*, but it is worth noting that the

[2] Authors`s approximations based on time trends.

lowest annual growth rate was for Venezuela – 13% per *annum*, which – in any case – is astonishingly high. Venezuela, the country with lowest dynamic of MCS growth, in 2000 started with the level of $MCS_{Venezuela,2000}$=22, while in 2011 it was – 97,78. It shows that only 11-year period of dynamic growth was enough to guarantee almost full saturation of Venezuelan society with mobile telephony.

Table 1. Summary statistics for MCS and IU variables. Latin American countries. Years 2000-2011.

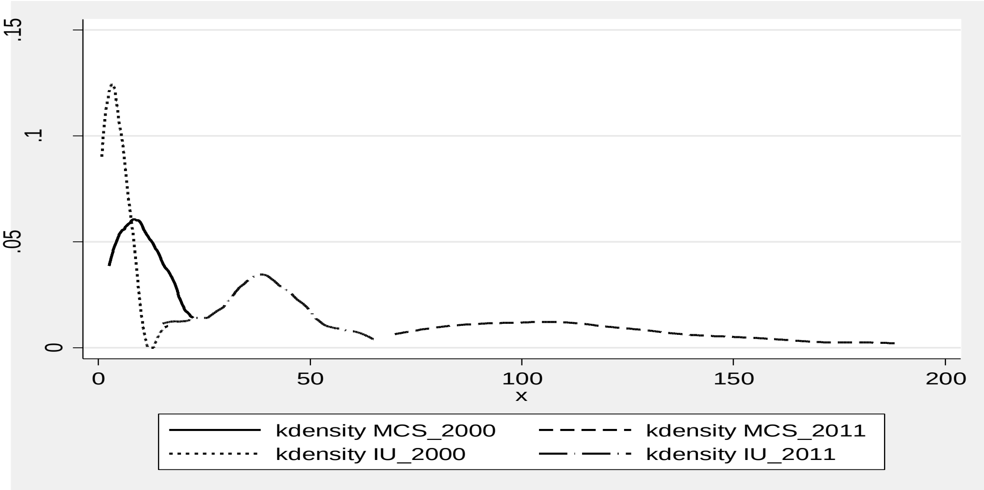
Variable	*Average*	*Min.value*	*Max.value*	*St.dev.*	*Skewness*	*Kurtosis*
MCS_{2000} *[per 100 inhab.]*	10,58	2,49	22,37	5,84	0,55	2,39
MCS_{2011} *[per 100 inhab.]*	114,78	69,95	188,60	32,34	0,84	2,91
IU_{2000} *[%]*	4,52	0,74	16,6	3,65	1,81	6,86
IU_{2011} *[%]*	37,34	15,18	65	13,06	0,04	2,69

Note: MCS variable – explains number of mobile cellular subscribers per 100 inhabitants; IU variables – explains percentage of individuals using Internet regardless place (venue) of usage.
Source: own estimates based on data derived from World Telecommunication/ICT Indicators Database 2012 [16th edition].

Likewise, the average achievements in case of Internet diffusion follow similar pattern, however the general scores are slightly worse than noted for $MCS_{i,y}$. The average share of total population using Internet, in 2000, was only 4,52%, while in 2011 – 37,34%. In 2000, countries most lagging behind were Paraguay – $IU_{Paragauy,2000}$=0,7%, Honduras – $IU_{Honduras,2000}$=1,2%, and El Salvador – $UI_{ElSalvador,2000}$=1,2%, while the best performers were Chile - $IU_{Chile,2000}$=16,6%, Trinidad&Tobago and Argentina with similar score of $IU_{i,2000}$=7,7%. The picture has changed significantly in 2011, when most of countries enjoyed crucially higher levels of usage of Internet. The minimum value of Internet use ($IU_{i,y}$) has reached the level 15,2%, which equals approximately the best score achieved in 2000 [see case of Chile]. In 2011, on one extreme we have countries like Bahamas ($IU_{Bahamas,2011}$=65%), or Trinidad&Tobago ($IU_{Trinidad\&Tobago,2011}$=55,2%), which managed to improve significantly their achievements in terms of usage of Internet by individuals, while – on the other side – we note countries where average achievements on the field are relatively poor, i.e. see cases of Belize, El Salvador or Honduras.

The picture of average usage of basic ICTs in Latin American countries is supplemented with graphical approximations of new technologies (again use of Internet and mobile telephony) distribution, both in 2000 and 2011. The Chart 1 [see below] portrays changes in inter-country distribution on $MCS_{i,y}$ and $IU_{i,y}$. As revealed on the picture, in year 2000, the densities functions – both for $MCS_{i,y}$ and $IU_{i,y}$ – are shaped as one-peak lines. At a time, we again see that average adoption of the two means of communication was rare and not in common use. After 11-year period of astonishingly dynamic growth of new technologies adoption level, a dramatically different picture is revealed. The lines explaining distribution of $MCS_{i,y}$ and $IU_{i,y}$ are totally differently shaped, which supports the thesis on significant changes which took place when referring to ICTs diffusion in Latin American countries. The density line for $MCS_{i,2011}$ is flat, with no visible peaks. It shows that in 2011, Latin American countries were highly differentiated with regard to mobile telephony subscriptions. High heterogeneity in the case is revealed. Some countries like *i.e.* Panama, Surinam, Grenada or Argentina are forging ahead, while economies like Belize or Mexico are relatively lagging behind in 2011. Similar in kind, however not so tremendous changes, are visible when $IU_{i,y}$ is considered. The density line drawn for $IU_{i,2000}$ was highly peaked (close to vertical), while in 2011 the shape is unimodal and much flatter. It proofs positive changes, showing growth of average level of adoption of Internet by individuals but, also on higher variability in level of $IU_{i,2011}$ among countries.

Chart 1. Distribution of MCS and IU *vars* in 2000 and 2011. Latin American countries.



Note: density lines elaborated using raw data.
Source: own elaboration based on data derived from World Telecommunication/ICT Indicators Database 2012 (16th edition).

In line with the previous, we run a detailed analysis of $MCS_{i,y}$ and $IU_{i,y}$ diffusion trajectories in the period 2000-2011. As adoption of Internet and mobile telephony in Latin American countries was not broad before year 2000, it allows as approximating almost full diffusion curve including very first years of adoption of given technology. Here below, we develop diffusion curves, both for $MCS_{i,y}$ and $IU_{i,y}$ variables, for each country individually. We draw diffusion trajectories as two-way charts (for $MCS_{i,y}$ and $IU_{i,y}$) aiming to capture differences in curves shapes, growth rates and saturation levels achieved in given society with regard to each variable separately. In Table 2 [see below], we present results of logistic growth model estimates exclusively for one depended variable which is $MCS_{i,y}$. As can be easily concluded from diffusion trajectories in Chart 2, we see that for Internet Usage variable no S-shaped diffusion patterns are revealed. In such case, it is not justified to estimate the logistic growth model for the $IU_{i,y}$ as the results could be highly misleading and far from true.

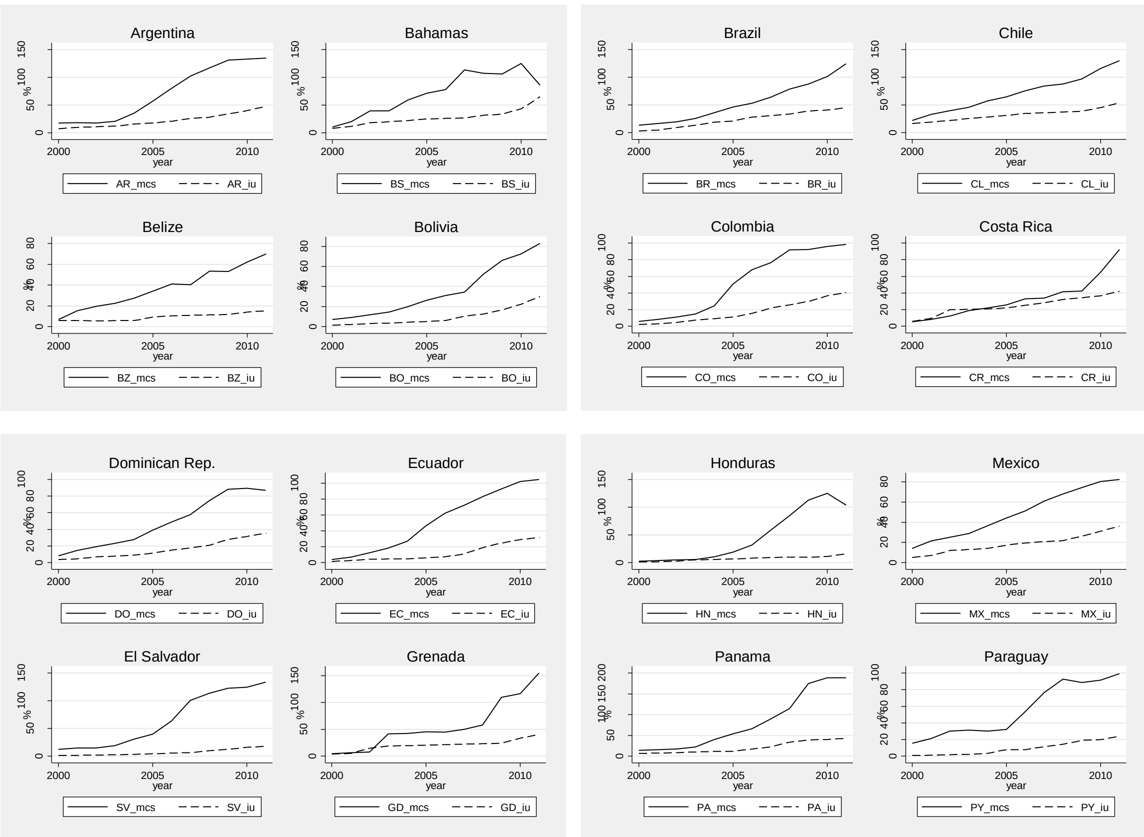
Pictures in Chart 2, provide information on the longitude of the process of Internet and mobile telephony adoption in Latin American countries. Reversely to what was expected, $MCS_{i,y}$ and $IU_{i,y}$ diffusion patterns in analyzed countries are far from homogeneous. One of the first things to notice is that in most of the cases, data on $MCS_{i,y}$ fit the theoretical S-shaped curve. The S-shaped $MCS_{i,y}$ diffusion trajectory can be easily detected for counties like Argentina, Bolivia, Colombia, Dominican Republic, Ecuador, Honduras, El Salvador, Panama, Paraguay, Peru, Surinam. For countries listed above, we observe almost "full" growth path with easily distinguishable characteristic phases of diffusion process [it is relatively slow in the first years of adoption, then it "starts-up" entering exponential growth phase, and afterwards by passing the inflection point it slows down reaching upper asymptote]. After the 11-year period [2000-2011] of extraordinarily dynamic growth, 11 – out of 20 – countries the total saturation of societies with mobile telephony exceeded 100%. This is for the case of Panama [$MCS_{Panama,2011}$=188%], Surinam [$MCS_{Surinam,2011}$=178%], Grenada [$MCS_{Grenada,2011}$=154%], Trinidad&Tobago [$MCS_{Trinidad\&Tobago,2011}$=135%], further more for Argentina, El Salvador, Chile, Brazil, Peru, Ecuador or Honduras[3]. In case of the 9 "last" countries, we observe the saturation below 100%, however the values are still high. Note, that for the "worst" country, the values of $MCS_{i,2011}$ is 69% [case of Belize] which is high anyway. In case of countries like Brazil, Chile or Mexico, no S-

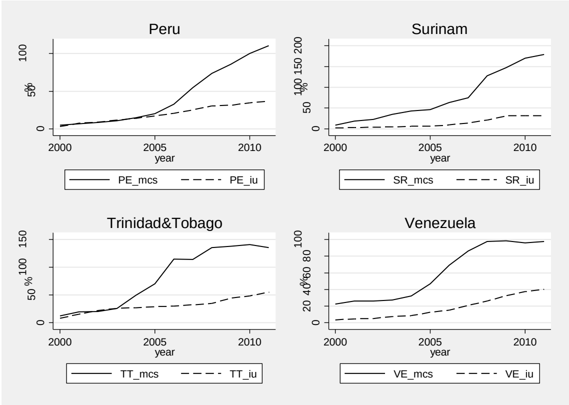
[3] For detailed numbers see Appendix.

shaped curve is revealed. The process of diffusion of mobile telephony is stable in terms of growth rates, which results in "smoothed" time-trends.

As reported in Table 3, the country which passed the inflection point of S-shaped trajectory was Bahamas - $\beta_{Bahamas}$= 2004. In the year 2005, three more countries entered the "slowing down" phase on diffusion trajectory. These were: Colombia, Trinidad&Tobago and Venezuela. Next 6 countries [Argentina, Dominican Republic, Ecuador, El Salvador, Mexico and Paraguay] passed the midpoint in year 2006, furthermore in 2007 – next two countries [Belize and Honduras], in 2008 – 5 countries [Chile, Costa Rica, Grenada, Peru, Surinam] and finally – in 2009, the last three countries [Boliva, Brazil, Panama]. We can also conclude that relatively "late" year reported as "midpoint β" is positively correlated with value of parameter α, determining the specific duration. For countries which achieved the midpoint in 2005 or 2006, the reported value of α is low, which specifies short time needed to pass from 10% to 90% level of saturation. This is especially characteristic for Trinidad&Tobago, El Salvador and Colombia. Additionally it is right to conclude that countries with low α and low β, experienced very high average annual diffusion rates of mobile telephony [to compare see Table in the Appendix].

Chart 2. New Technologies diffusion trajectories. Latin American countries.
Time series for 11-year period [2000-2011].





Source: own elaboration based on data derived from World Telecommunication/ICT Indicators Database 2012 [16th edition].

Table 2. Logistic growth model estimates. Latin American countries. Years 2000-2011.

country	upper asymptote [κ]	specific duration [α]	midpoint [β]
Argentina	118,4	4,9	2006
Bahamas	99,9	6,4	2004
Belize	76	12,7	2007
Bolivia	100,9	9,6	2009
Brazil	153	11,4	2009
Chile	142	13,5	2008
Colombia	90,9	4,8	2005
Costa Rica	67,4	10,4	2008
Dominican Rep.	90,5	8,1	2006
Ecuador	104,5	7,2	2006
El Salvador	119,3	4,6	2006
Grenada	170,1	10,4	2008
Honduras	117	4,2	2007
Mexico	74,7	9,3	2006
Panama	153,8	11,4	2009
Paraguay	86	6,1	2006
Peru	67,4	10,4	2008
Suriname	217,2	9	2008
Trinidad & Tobago	126,1	4,4	2005
Venezuela	112,4	10,2	2005

Note: Depended variable – Mobile Cellular Subscribers. Predictor variable – time. Parameter κ - specifies the hypothetical level of saturation achievable if current growth dynamics is assumed; α - stands for specific number of years needed to pass from 10% to 90% level of saturation [it depends strictly of annual growth rates of variable]; β - denotes a specific year when the variable passes from exponential growth phases and diffusion process starts to slow down tending to upper limits.
Source: own estimates based on data derived from World Telecommunication/ICT Indicators Database 2012 (16th edition).

Analysing shapes of diffusion patterns of Internet, approximated by the variable $IU_{i,y}$, we need to state that specific S-shaped trajectories are not revealed in none of the cases. The general picture suggests that most of countries are rather "located" in the early parts of diffusion curves. It implies rough conclusion that, in all analysed Latin American countries, the diffusion of Internet was rather in the initial phase. Going into deeper analysis of graphical approximations of country-specific Internet diffusion curves, we can conclude that Latin American countries are about to enter the exponential growth phase, as in years 2005-2011 were passing the "take-off" phase. This is also supported by outcomes of descriptive analysis of the data [see previous sections].

The evidence show, that in each of analyzed countries, developed Internet and mobile telephony diffusion paths – analyzed as parallel – are far from homogenous. Significant differences in both trajectories are reported. This is mainly due to highly differentiated growth rates of the two "technologies". Relatively faster spread of mobile telephony than Internet is actually not very surprising, especially when low and lower-middle-income countries are considered. Adoption and usage of mobile telephony requires minimal skills and knowledge, and can be used at low costs. Reversely, broad adoption and common use of Internet – regardless if it is as fixed or wireless – requires hard infrastructure, hardware, financial resources, and finally higher skills to use it effectively. In effect, diffusion of mobile telephony is just easier and cheaper for societies in developing countries. Prominent examples of such disadvantageous situation are Surinam, Panama, El Salvador and Grenada. The calculated "gap" ["divide"] between the value of $MCS_{i,y}$ and $IU_{i,y}$ [expressed in percentage points] in year 2011, results as, respectively: $GAP_{MCS-IU(Surinam)}$=146%pp., $GAP_{MCS-IU(Panama)}$=145%pp., $GAP_{MCS-IU(ElSalvador)}$=115%pp., and $GAP_{MCS-IU(Grenada)}$=114%pp. In listed countries the extraordinary high level of use of mobile phones is accompanied by relatively low level of Internet adoption and usage.

Finally, we concentrate on detecting quantitative links between gross domestic product (GDP) *per capita* expressed in purchasing power parity – $GDPpcPPP_{i,y}$, and new technologies adoption approximated by $MCS_{i,y}$ and $IU_{i,u}$. Assuming that adoption and diffusion of new technologies contributes significantly to the general economic performance, we hypothesize on finding strong, positive and statistically significant links between the $GDPpcPPP_{i,y}$ variable and two selected regressors. To test for the relationships we estimate models (5), (6) and (7) and we summarize the results in Table 3 [see below].

Table 3. Gross domestic product and new technologies. Latin American countries. Years 2000-2011.

$GDPpcPPP_{i,y}$	*coeff.*	*std error*	*t*	$P>\|t\|$
γ_{MCS}	0,14	0,012	10,98	0,00
γ_{IU}	0,063	0,015	4,22	0,00
_cons	8,3	0,021	389,6	0,00
sigma_u	0,423			
sigma_μ	0,074			
rho	0,969			
R-sq within = 0,84	No of obs. = 240	F(2,218) = 611,35		
R-sq between =0,73	No of groups = 20	Prob>F=0,00		
$GDPpcPPP_{i,y}$	*coeff.*	*std error*	*t*	$P>\|t\|$
γ_{MCS}	0,19	0,0059	33,45	0,00
γ_{IU}	-	-	-	-
_cons	8,3	0,021	384,0	0,00
sigma_u	0,44			
sigma_μ	0,077			
rho	0,9703			
R-sq within = 0,83	No of obs. = 240	F(1,219) = 1118,91		
R-sq between =0,42	No of groups = 20	Prob>F=0,00		
$GDPpcPPP_{i,y}$	*coeff.*	*std error*	*t*	$P>\|t\|$
γ_{MCS}	-	-	-	-
γ_{IU}	0,213	0,007	26,7	0,00
_cons	8,51	0,021	400,01	0,00
sigma_u	0,389			
sigma_μ	0,092			
rho	0,946			
R-sq within = 0,76	No of obs. = 240	F(1,219) = 713,12		
R-sq between =0,66	No of groups = 20	Prob>F=0,00		

Note: Longitudinal models estimates. Fixed effects (within) regressions. Standard errors – default. Confidence – 0,95 in each case. Regressors – $MCS_{i,y}$ and $IU_{i,y}$, depended var. – $GDPpcPPP_{i,y}$. Sigma_u stands for standard deviation of residuals within groups, and sigman_μ - explains standard deviation of residuals (overall error term).
Source: own estimates.

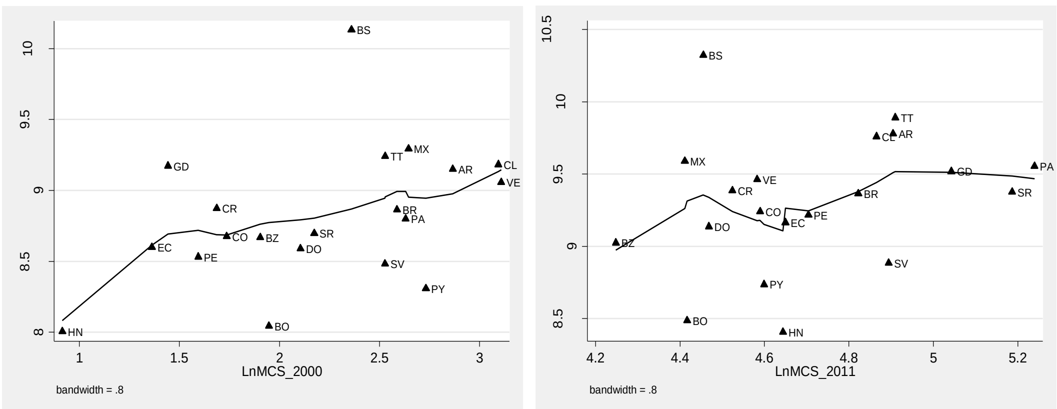
Econometric estimations clearly reveal that, in Latin American countries, there exists statistically significant relationship between *per capita* income and level of adoption of new technologies. Following the theoretical model explained in equation (5), we estimate γ_{MCS} and γ_{IU} parameters, reporting on strength of impact of ICTs adoption and usage on the level of country`s *per capita* output. The estimations results are $\gamma_{MCS}$=0,14 and $\gamma_{IU}$=0,063, in both cases statistical significant as *p-value*<0,05. As model estimates are run for variables values expressed in logs, the parameters` values can be interpreted as "elasticity" of $GDPpcPPP_{i,y}$ variable as $MCS_{i,y}$ and/or $IU_{i,y}$ are changing [growing or diminishing]. If γ_{MCS}=0,14 it states for 0,14% growth of $GDPpcPPP_{i,y}$ as $MCS_{i,y}$ grows at 1%. Again the interpretation of γ_{IU}=0,063 is analogous. As Prob>F is zero, we can assume that the model is correct, while its coefficients are different than zero. Estimated parameter rho=0,969, identified as interclass correlation, indicates that 96,9% of variance is due to differences across panels.

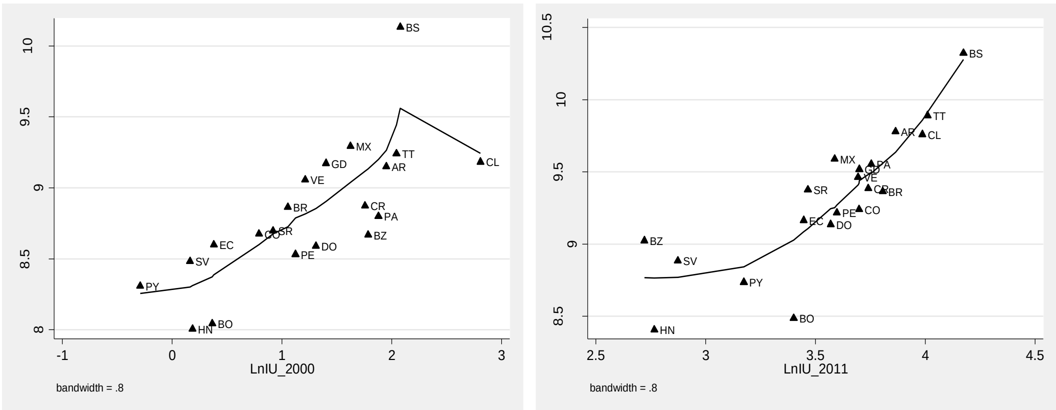
The reported potential impact of mobile telephony adoption on GDPpcPPP is crucially higher than in case of Internet usage. Following basic intuition we would rather state that the relationship shall rather be reverse. Broader use of Internet as mean of mass communication, processing knowledge, global platform for education, trade and new forms of doing business shall potentially contribute stronger to economic growth than wide use of mobile telephony. Such unexpected results might probably be the consequence of uneven growth of $MCS_{i,y}$ and $IU_{i,y}$ in analyzed period in Latin American countries. We also need to underline that many countries in the panel are classified developing nations which experience substantially more dynamic economic growth that upper-middle and high-income economies. The positive effects are then much stronger than would be revealed in case of developed countries.

However we it is highly probable that obtained results are far from robust. We expects that exclusion/inclusion of countries, as well as changes in the analyzed period, could change significantly the picture. We suppose that discovered relationships are of high volatility, and what is important, we need to remember that the analyzed period [2000-2011] is rather exceptional with regard to extraordinary high rates of new technologies diffusion, even if economically backward countries are included in the sample. This might suggest that all results shall be interpreted with high cautious.

To contribute more general picture, we provide graphical approximations of discussed relationships. To complete the above, we use Loess smoother, and develop 4 separate scatter plots [see Chart 3], revealing the relationships for pairs of variables: LnMCS_2000 *vs* LnGDP_2000; LnMCS_2011 *vs* LnGDP_2011; LnIU_2000 *vs* LnGDP_2000 and LnIU_2011 *vs* LnGDP_2011.

Chart 3. New Technologies and economic growth. Latin American countries. Years 2000 and 2011.





Note: graphical approximation using LOESS smoother. Values of $GDPpcPPP_{i,y}$, $IU_{i,y}$ and $MCS_{i,y}$ in logs.
Source: own elaboration based on data derived from World Telecommunication/ICT Indicators Database 2012 (16th edition).

The results are rather consistent with previous econometric evidence, and again support the hypothesis on existing relationships between *GDPpcPPP* level and adoption of Internet and mobile telephony. First two figures present Loess line illustrating bivariate relationship between $GDPpcPPP_{i,y}$ and $MCS_{i,y}$ variables, decomposed for year 2000 and 2011. Dots [triangles] on charts presenting countries are concentrated along the loess line which reflects existing links between paired variables. Countries performing better in terms of mobile telephony diffusion and usage, they also enjoy higher level of personal income. In 2000, the worst performer was Honduras, achieving the poorest results both in terms of GDP per capita and mobile telephony use. Similarly poor scores for $GDPpcPPP_{i,y}$ were observed for Bolivia, however in terms of $MCS_{i,y}$ the country was doing relatively better. Bolivia`s achievement in $MCS_{i,y}$ in 2000 were comparable to those that we can note for Dominican Republic, Belize or Surinam, however in the three countries listed the gross national income was slightly higher. At the other "end" of Loess line, we observe countries like: Argentina, Chile and Venezuela. All enjoying highest levels for $MCS_{i,y}$ and $GDPpcPPP_{i,y}$. The picture also reveals some outliers. These are definitely Bahamas, and already mentions Honduras and Bolivia. In Bahamas we observe the highest gross national *per capita* income in 2000, which is accompanies by relatively high adoption of mobile telephony. Analysing the picture for the variables, but in 2011, we still confirm existence of strong correlations, however some countries managed to change its position in the group. The country most lagging behind, both in terms of mobile telephony adoption and national per capita income, is Belize, while the best performers are: Panama, Surinam and Grenada. As already was discussed, the diffusion of mobile telephony noted for the period 2000-2011 was extremely high, which allowed this countries to become the "leaders" in terms of use this kind of new technology. In countries like Honduras and Bolivia we hardly observe any growth in GDP, however they countries made strong progress in terms of mobile telephony adoption. This was especially tremendous in Honduras, where in 2000 the $MCS_{Honduras,2000}$= 2,5 while in 2011 – $MCS_{Honduras,2011}$=103,9. In Bolivia changes on the field were only slightly worse: $MCS_{Bolivia,2000}$=7, and $MCS_{Bolivia,2011}$=82,8. Despite such enormous growth of mobile telephony users, these countries did not make any significant progress in economic growth. They still remain as poorer countries in the region.

Analysing plots illustrating relationships between $IU_{i,y}$ and $GDPpcPPP_{i,y}$ dots are relatively less dispersed than in the previous case. This would bring to mind that the relationship between income and level of Internet use is even stronger than for pair of variables: $GDPpcPPP_{i,y}$ and $MCS_{i,y}$. However evidence from econometric analysis does not support the thesis [remind coefficients reported in table 3]. Anyway, for the two variables the relationship reported is evident. Countries which enjoy higher level of Internet use among individuals, are also countries which are doing better in terms of GDPpcPPP. This is observed bot for 2000 and 2011. In year 2000, relatively the worst country was Paraguay, were Internet adoption was at 0,7%. This suggests that in Paraguay, in 2000, hardly no individuals were using Internet. Countries performing a bit better, in 2000, were Honduras, Bolivia and El Salvador, however we need to note that percentage of total population using Internet in cited countries was still at very low level. The noted level of Internet use was: $IU_{Honduras,2000}$=1,2%, $IU_{Bolivia,2000}$=1,44% and $IU_{ElSalvador,2000}$=1,88% for respective countries. In 2011, the situation remained highly similar. Still El Salvador, Honduras and Paraguay were countries most lagging behind in terms of Internet use. The group of "lagers" was joint by Belize. In the period 2000-2011, the dynamics of Internet diffusion was the lowest in the group, and finally in 2011, the value of $IU_{i,y}$ for Belize was lowest in the group of Latin American countries. Still the pictures let to identify some outlying economies. Surprisingly, for both years of analysis we found Bahamas to be reported as an outlying economy.

Here comes to mind the question about reveres causality between variables. Assuming that broader adoption of new technologies contributes significantly to economic growth is correct, however, the reveres hypothesis that higher income enables faster and wider diffusion on ICTs is hard to be neglected. Effective use of new technologies enables people to be better educated, acquire higher skills, offers new opportunities for business creation and gaining income. It also contributes positively to information asymmetry elimination, as all kind of information and knowledge ban be easily accessed, stored and proceeded by use of new means of mass communication. ICTs provide effective and relatively cheap tools for doing business regardless geographic distance, reducing costs and widening markets for products and services. It let us to assume that new technologies are important driver of economic growth and development. But, looking at the issue from the different perspective, it is also fully justified to explain adoption rates and levels by differences in national income, which in case of Latin American countries are significant. Undoubtedly access to financial resources, constitutes an important driver of new technologies adoption letting to finance ICTs growth. In such sense, economic growth determines diffusion of new technologies.

Concluding remarks

The study focused exclusively on analyzing new technologies diffusion patterns and their statistical correlation with national *per capita* income. We concentrated solely on 20 Latin American countries in the time framework 2000-2011. Several conclusion can be derived both from descriptive and econometric analysis. The first thing to notice is that the period 2000-2011, highly unique and unprecedentedly dynamic of new information and communication technologies took place in each of the studied countries. Such tremendous changes are enabled by two significant factors. Primary, the unique characteristics of new technologies is to spread across countries at high pace and low cost. Additionally they are relatively easy to be absorbed and used, requiring minimal skills of users. What is more, the picture presenting country-specific diffusion patterns of $MCS_{i,y}$ proofs that in most of cases theoretical S-shaped trajectory is revealed. But, at the same time, high heterogeneity across nations is shown. Countries vary with regard to diffusion speed; year defined as the midpoint or reported saturation in 2011. In many countries, the saturation reached the 100% or close, which proofs that almost each society member enjoys access to mobile telephony. There also some outliers noted, i.e. El Salvador, Panama or Grenada, where $MCS_{i,y}$ approached nearly 200% [*sic*!]. The picture revealed in case of Internet diffusion is slightly different. However the process of $IU_{i,y}$ was also highly dynamic, non of analyzed countries managed to reach full saturation with Internet. The best score in 2011 was reported for Bahamas [65%], Chile [53%], Trinidad&Tobago [55%]. But what is clearly visible, many countries are located in the early phase of diffusion process.

Secondly, econometric analysis revealed existence of strong links between level of adoption of new technologies and actual level of *per capita* income. Outcomes of panel analysis, show that both $MCS_{i,y}$ and $IU_{i,y}$ variables exhibit positive correlation with $GDPpcPPP_{i,y}$. Reported coefficients are positive and statistically significant. Same conclusion can be derived from pure graphical analysis [remind Chart 3].

However, as was already noticed in previous section, the econometric analysis outcomes might be random, and shall be interpreted with high caution. Despite the fact, that results obtained seem to confirm the hypothesis on existing causal links between countries development on the field of new technologies and its general economic performance, we claim that use and adoption of new technologies is not automatically translated into economic growth. The relationship between technological progress and economic growth, however highly probable, is not straightforward. Economic development and growth are long-run process determined by multitude of factors, usually of qualitative kind. We suppose that in the case of new technologies` impact on economic growth there is revealed causality is two-way. In practice, detecting "the true" direction of impact is hardly possible. New technologies foster economic growth, but at the same time, economic growth constitute a substantial prerequisite to acquire ICTs. Defining "cause" and "effect" is interchangeably in the case. Regardless all these, it is broadly accepted that information and communication technologies` impact on economies` performance, bur the impact is claimed to exhibit in the long-run perspective. Having in mind the fact that ICTs` impact economic growth is hardly quantifiable, this can be only fully confirmed when is converted into human development.

References:

1. Akpan, P.I. (2010). Basic-needs to globalization: are ICTs the missing link?. *Information Technology for Development*, 10:4, pp.261-274.
2. Anand. S, Sen, A.K. (1996). Sustainable human development: concepts and priorities. *Office of Development Studies Discussion Paper*, No.1, UNDP, New York.
3. Antonelli, C. (2003). The Digital Divide: Understanding the Economics of New Information and Communication Technology in the Global Economy, *Information Economics and Policy* 15, pp. 173-199.
4. Baliamoune-Lutz, M. (2003). An analysis of the determinants and effects of ICT diffusion in developing countries. *Information Technology for Development* 10 (2003), pp.151-169.
5. Billon, M., Lera-Lopez, F., Marco, R. (2010). Differences in digitalization levels: a multivariate analysis studying the global digital divide. *Review of World Economy* (2010), 146, pp. 39-73.
6. Bousquet, A., and M. Ivaldi. (1997). Optimal pricing of telephone usage: An econometric implementation. *Information Economics and Policy* 9: 219–39.
7. Cabral, L. (2006). Equilibrium, epidemic and catastrophe: Diffusion of innovations with network effects. In *New frontiers in the economics of innovation and new technology: Essays in honor of Paul David*, ed. C. Antonelli, B. Hall, D. Foray and E. Steinmueller, 427–37. London: Edward Elgar.
8. Castellaci F. (2002). Technology gap and cumulative growth: models and outcomes. *International Review of Applied Economics*, 16 (3), pp. 333-346
9. Castellacci F. (2011). Closing the technology gap?. *Review of Development Economics*, 15(1), pp.189-197
10. Castellacci F. (2006). Convergence and divergence among technology clubs, DRUID Working Paper No. 06-21
11. Chinn, M. and R. Fairlie (2006). ICT Use in the Developing World: An Analysis of Differences in Computer and Internet Penetration. *IZA Discussion Paper*, N. 2206, July.
12. Chong, A., Micco, A. (2003). The Internet and the ability to innovate in Latin America. *Emerging Markets Review* 4, 53-72.
13. Comín, D., Hobijn, B. (2003). Cross-Country Technology Adoption: Making the Theories Face the Facts. *Paper prepared for the Carnegie Rochester Conference on Public Policy*.
14. Davies, S. (1979). The diffusion of process innovation. Cambridge University Press.
15. De Guio, R., Kucharavy, D. (2007). Application of S-shaped curves. Published in "*TRIZ-Future Conference 2007: Current Scientific and Industrial Reality*", Frankfurt 2007.
16. DiMaggio, P., Hargittai, E., Celeste, C., and S. Shafer (2004). Digital Inequality: From Unequal Access to Differentiated Use. In Social Inequality, Neckerman, K.M. (Ed.), Russell Sage Foundation, New York, pp. 355–400.

17. Fagerberg J. (1994), Technology and international differences in growth rates, Journal of Economic Literature 32, pp.1147-1175
18. Gancia G., Zilibotti F. (2009), Technological change and the wealth of nations, Annual Review of Economics, Vol.1
19. Geroski, P.A., (2000). Models of technology diffusion. *Research Policy* 29 (2000), pp.603-625
20. Grazzi, M. and Vergara, S. (2008). What Drives ICT Diffusion in Developing Countries? Evidence from Paraguay. Paper presented at the 13th *LACEA Annual Meeting* 2008, Rio de Janeiro.
21. Goldfarb, A. and J. Prince (2008). Internet Adoption and Usage Patterns are Different: Implications for the Digital Divide. *Information Economics and Policy,* 20, 2-15.
22. Helpman, E. (1998). General Purpose Technologies and Economic Growth". *MIT Press*, Cambridge and London.
23. Hitt L.M. (1999). Information Technology and Firm Boundaries: Evidence from Panel Data. *Information Systems Research,* Volume 10 Issue 2.
24. Hobijn, B., Comin, D. (2003). Cross-country technology adoption: making the theories face the facts. *Journal of Monetary Economics* 51(2003), pp.39-83.
25. James J. (2003). *Bridging the global digital divide*. Edward Elgar
26. Jovanovic, B., Lach, S. (1989). Entry, Exit, and Diffusion with Learning by Doing. *American Economic Review*, vol. 79, No. 4, September, pp. 690-699.
27. Kucharavy, D. , Guio de, P. (2008). Logistic substitution model and technological forecasting. *TRIZ Future 2008* – Synthesis in Innovation.
28. Meade, N., Islam, T. (2006). Modeling and forecasting the diffusion of innovation. *International Journal of Forecasting,* Vol. 22.
29. Metcalfe, J.S. (1988). The diffusion of innovation: an interpretive survey. In Technological Change and Economic Theory (ed. G. Dosi *et al.*). Pinter, London.
30. Modis, T. (2007). From my perspective. Strengths and weaknesses of S-curves. *Technology Forecasting & Social Change* 74 (2007) 866-972.
31. Oliner, S. D. and D. E. Sichel (1994). Computers and Output Growth Revisited: How Big is the Puzzle?", Brookings Papers on Economic Activity, 1994(2): 273-334.
32. Rogers, M.E. (1962). Diffusion of innovation. The Free Press, London.
33. Soete, L., Verspagen, B. (1993). Technology and growth: the complex dynamics of catching-up, falling behind and taking over. *Explaining Economic Growth*, Elsevier. Downloadable at: http://ideas.repec.org/p/ner/maastr/urnnbnnlui27-6312.html.
34. Stilianos, A. (2013). *Convergence clubs and spatial externalities. Model and applications of regional convergence in Europe*. Springer-Verlag.
35. Stoneman, P. (2001). The economics of technological diffusion. Blackwell. Oxford.
36. Vicente, M.R. and A.J. López (2006). Patterns of ICT Diffusion across the European Union. *Economic Letters,* 93, 45-51.
37. World Bank (2008). *Global Economic Prospects: Technology Diffusion in the Developing World*. World Bank, Washington DC.

Appendix

New technologies statistic for Latin America countries.

	Internet Users (% of total population)			**Mobile Cellular Subscribers (per 100 inhab.)**		
Country	*year*2000	*year*2011	average annual growth rate (%)	*year*2000	*year*2011	average annual growth rate (%)
Argentina	7,04	47,70	17,40	17,57	134,92	18,5
Bahamas	8,00	65,00	19,04	10,59	86,06	19,0
Belize	5,96	*15,19*[(a)]	17,40	6,71	69,96	21,3
Bolivia	1,44	30,00	27,59	7,01	82,82	22,4
Brazil	2,87	45,00	25,02	13,29	124,26	20,3
Chile	16,6	53,89	10,71	22,06	129,71	16,1
Colombia	2,21	40,40	26,43	5,68	98,45	25,9
Costa Rica	5,80	42,12	18,02	5,40	92,20	25,8
Dominican Rep.	3,70	35,50	20,54	8,21	87,22	21,5
Ecuador	1,46	31,40	27,88	3,91	104,55	29,9
El Salvador	1,18	17,69	24,63	12,52	133,54	21,5
Grenada	4,06	*40,45*[(a)]	17,40	4,24	*154,90* [(a)]	18,5
Honduras	1,20	15,90	23,46	2,50	103,97	33,9
Mexico	5,08	36,15	17,84	14,08	82,38	16,1
Panama	6,55	42,70	17,04	13,88	188,60	23,7
Paraguay	0,75	23,90	31,50	15,36	99,40	17,0
Peru	3,08	36,50	22,49	4,93	110,41	28,3
Suriname	2,51	32,00	23,15	8,79	178,88	27,4

Trinidad & Tobago	7,72	55,20	17,88	12,53	135,64	21,7
Venezuela	3,36	40,22	22,57	22,37	97,78	13,4

Note: Average annual growth rate calculated as exponential growth. (a) – own estimates based on time trends. Source: author`s compilation based on data derived from *World Telecommunication/ICT Indicators Database 2012 (16th edition)*. Growth rates – own calculations.

Country international codes:

Argentina	*AR*	Ecuador	*EC*
Bahamas	*BS*	El Salvador	*SV*
Belize	*BZ*	Grenada	*GD*
Bolivia	*BO*	Honduras	*HN*
Brazil	*BR*	Mexico	*MX*
Chile	*CL*	Panama	*PA*
Colombia	*CO*	Paraguay	*PY*
Costa Rica	*CR*	Peru	*PE*
Dominican Rep.	*DO*	Suriname	*SR*

Source: own elaboration.

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