New technologies adoption and diffusion patterns in developing countries. An empirical study for the period 2000-2011.

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Abstract

In recent years, enormous changes are noted worldwide when broad adoption of new Information and Communication Technologies (ICTs). These unique technologies – often perceived as economic development incentives – have a great ability to spread at high pace and low cost in world countries, bringing to people opportunities to contribute to economic development and growth. New Technologies play a special role in developing countries, where their in-country adoption lies in the centre of development strategies. ICTs are treated as tools which bring to people access to information, education and knowledge, offering unlimited possibilities for wealth-creation.
The paper, purely empirical in nature, reports on the pace of adoption of new Information and Communication Technologies in developing countries, and – additionally – investigates country-specific ICTs diffusion patterns. We expect to uncover the S-shape curve in the diffusion process in most of developing countries, as well as in the whole country sample.
For the analysis purposes we apply all counties, which – according to the World Bank nomenclature – are classified as low-income and lower-middle-income economies. Our sample covers 46 countries (upper-middle-income and high-income economies are excluded from the study purposely), which are classified as developing economies. The time framework is set for the period of 2000-2011. All data necessary for the analysis are derived from World Telecommunication/ICT Indicators Database 2012 (16th edition).

1. Introduction

In recent years, a pervasive explosion of new Information and Communication Technologies (ICTs) is

observed in a magnitude of world economies. The process of diffusion of ICTs is fully associated with

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the spread of new ideas, knowledge and all kinds of information. These technologies provide new ways of mass communication, process of storing and processing all kind of knowledge and information. ICTs are widely recognized as an effective tool for promoting economic growth and overall socio-economic development. By creating a bundle of possibilities on education, running a business or inclusion of socially and economically deprived groups, they provide a good basis for wealth creation. Wireless networks have enabled to open up economic "enclaves" by elimination of barriers such as i.e. geographical distance or information asymmetry. At a time, due to broad ICTs adoption, society members gain an opportunity for wide and unlimited access to different kinds of knowledge, information, which enable them to improve their professional skills.

The process of technology (ICTs) diffusion and adoption has been studied intensively in recent years. Following E.Rogers and his seminal works, diffusion includes "both planned and the spontaneous spread of new ideas" (Rogers, E. 1962, p.7). Massive empirical and theoretical literature has been developed on the issue, and some general conclusions can be derived from the studies. The most crucial conclusion is that, at a given point of time, substantial differences can be perceived among different countries when level of ICTs adoption and diffusion is taken into account. Despite many discussions on widening – or diminishing – digital divide, observed huge differences in the degree of diffusion of technology among countries remain unquestionable.

2. Technology diffusion – general conceptualization.

Conceptually, the discussion on the "technology diffusion" has started with Joseph Schumpeter (1934, 1947), and his pioneering work emphasising the crucial – for economic growth and development – process of technology (innovation) diffusion. In his works, Schumpeter – inspired by origin works of Charles Darwin (Darwin 1859), argued that the process of technology diffusion is mostly linear. However further studies on the phenomenon of the technology diffusion process accompanied by technological change, has shown that the process of adoption of invention is far from linear. In the fifties due to some theoretical discussion on technology diffusion, there emerged new concepts of

epidemic models of diffusion[2]. The models were based on some analogies between process of technology diffusion and diffusion of contagious diseases. The epidemic models were claimed to be correct by Mansfield (1968), Metcalfe (1988), Karshenas and Stoneman (1995), Stoneman (2001, 2005). In time, many started o claim that epidemic models of technology diffusion are "blind" for the dynamics of the process, and ignore some societal, educational, demographical or economic conditions which highly influence rate and pattern of technology diffusion.

Now, theoretical and empirical analysis of technology diffusion, mostly refer to the seminal concept of Everett Rogers (see Rogers 1962, 1995), explaining diffusion process of innovation (Rogers presumes that the word "technology" is a synonymous to "innovation". As consequence Rogers uses these two alternatively, along with the diffusion rates and stages. His concepts and theoretical framework (model) of technology diffusion are widely applied in political sciences, economics, public health policies, history or education. For Rogers (1962, 1995) the "technology" stands for "design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcomes" (Rogers, E. 1962, p.6). He (see Rogers, 1962, p.10) defines the diffusion "as a process by which an innovation (technology – author`s note) is communicated through certain channels over time among members of a social system". Following the previous, the process of technology diffusion covers 4 aspects (elements): innovation (defined as "an idea, practice, or project that is perceived as new (…) (Rogers, 1962, pp.12)), communication channels ("process in which participants create and share information", (Rogers, 1962, pp.5), time (time in behavioural studies is perceived as an element determining the strength of the process) and social system ("a set of interrelated units", (Rogers, 1962, pp.23). Also Gort and Klepper (1982) define technology diffusion as the "spread in the number of producers engaged in manufacturing a new product". The definition was slightly adjusted by Adres *et al.* (2007), to the needs of studies on new information and communication technologies across countries. They claim that the technology diffusion can also refer to the "number of consumers of Internet" (see Andres *et al.*, 2007).

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[2] Concepts derived from medicine sciences.

In accordance to the diffusion of innovation theory of Rogers E. (Rogers 1962), there emerged the concepts of theoretical diffusion patterns that countries shall follow, passing sequent steps (phases) in adoption process. The adoption patterns of technology, are assumed to follow the S-shaped curve. The group of S-shaped curves is originated from Pierre-Francois Verhulst, who in 1833 proposed to the public, first logistic equation, explaining natural population growth in time. The "natural growth" stands for particular ability of "species" (see Darwin, 1859) for multiplying in a specified period of time. In economic sciences, the term" species" refer to any kind of variable which tends to grow in time. The S-shaped trajectories are mainly observed when innovation (technology) diffuses over large societies. The curve shape explains adopter population dynamics in time, assuming the heterogeneity of the whole population. The theoretical trajectory shape shows that technology tends to spread at high pace in early stages of diffusion process, and afterwards the diffusion rates slow as the overall saturation (share of population using given technology) of the technology in a given society if growing. It is also assumed that, after passing the "inflection point", the rate of adoption shall slow down, as the higher percentage of population is having access to technology.

The general concept of the S-shaped curve explaining stages of technology diffusion is clarified in the Picture 1 (see below). Clearly, the process of technology diffusion is fully accounted for the nature of technology itself. Certain features of technology, absorptive capacities of society, its knowledge and skills, information asymmetries, channels of diffusion and further adoption, state policies – all these highly condition diffusion rates, creating friendly environment for technology diffusion or – reversely – posing barriers to the process.

Despite the above, the technology diffusion can be described as a long-run process, which results in broad spread of different kinds of innovations. It is widely agreed that the process enhances deep changes in economic structures, fosters economic growth and development, contributing to overall welfare of societies.

Picture 1. Theoretical S-shaped curve.
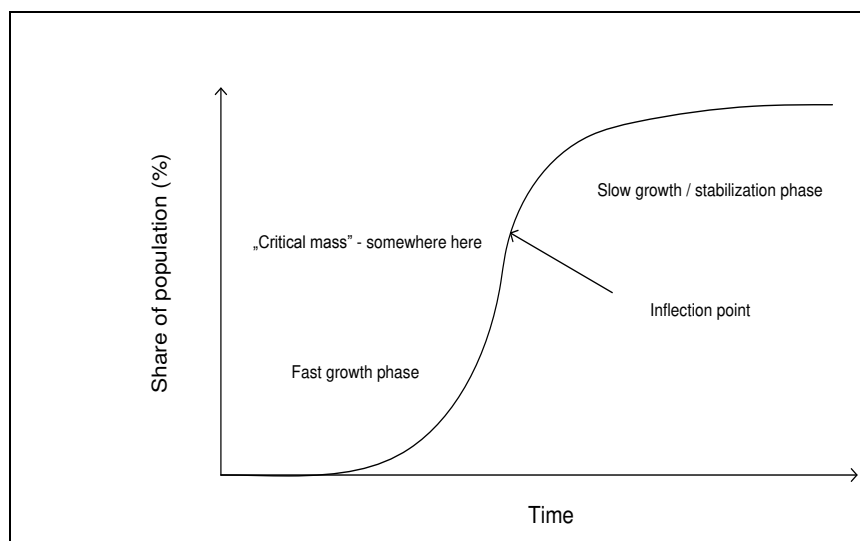
Source: own elaboration.

As stated before, in the following paper, by using the term "technology" we refer strictly to New Information and Communication Technologies, and the two terms – technology and ICTs – are used alternatively, as equivalent issues.

3. The data – preliminary analysis.

In the study we concentrate exclusively on low and lower-middle-income economies. We base on the broadly accepted country classification introduced by World Bank[3]. As results, our country sample covers 46 economies, where 15 countries are classified as low-income and 31 are classified as lower-middle-income ones. Full list of countries is available in the statistical appendix (see statistical Appendix 1). The applied time span is 2000-2011.

For the analysis purposes, we have selected 3 basic ICTs indicators, treated as proxy variables of information and communication technologies. They are thought to reveal the average level of usage and application of ICTs among society. In the study we use the following variables: share of total

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[3] World Bank classifies countries according to their per capita Gross National Income using Atlas Method as tool for international comparisons. The low-income countries are those were average annual GNI *per capita* does not exceed 1025 US dollars. The lower-middle-income countries are those were average annual GNI *per capita* varies from 1026 US dollars *per capita* to 4035 US dollars *per capita*.

population using (having access) to fixed telephone lines (FTL – abbrev.); share of population using mobile cellular phones (we use mobile cellular subscribers ratio; MCS – abbrev.); and share of population (individuals) using Internet (Internet users ratio, IU – abbrev.). All statistical data referring to the usage of ICTs were derived from World Telecommunication/ICT Indicators Database 2012 (16th edition) developed by ITU[4]. Internet Users ration data were derived directly from the ITU statistics. In case of FTL and MCS data, we have drawn absolute numbers of given ICTs users in each country and – in the next step – applying data on the absolute population number[5], we have calculated the shares of population using (having access) given ICTs tool[6]. Full, balanced panel dataset is put in the statistical Appendix 1.

To get a general idea about the variables values in low and lower-middle-income countries, we run a preliminary descriptive statistical analysis. For this purpose we use raw data for FTL, MCS and IU in the period 2000 and 2011.

In the following Table 1 (see below), we present basic descriptive statistics of the ICTs variables.

Table 1. FTL (% of total population), MCS (% of total population) and IU (% of total population) – descriptive statistics. Low and lower-middle-income countries – 46 economies. Years 2000 and 2011.

Variable	Average (%)	Min.Value (%)	Max.Value (%)	Lower(first) quartile (%)	Upper (third) quartile (%)	Gini coefficients
FTL2000	4,4	0,2	21,2	0,8	5,3	0,64
FTL2011	**7,3**	**0,3**	**33,2**	**1,3**	**10,5**	**0,63**
MCS2000	2,3	0,0	15,4	0,2	2,9	0,73
MCS2011	**76,9**	**21,3**	**144,9**	**55,8**	**99,3**	**0,25**
IU2000	0,7	0,0	6,0	0,2	1,0	0,68
IU2011	**17,5**	**1,3**	**51,0**	**7,0**	**28,0**	**0,46**

Source: own estimates based on data from World Telecommunication/ICT Indicators Database 2012 (16th edition)

In Table 1, each variable stands for share of total population using given telecommunication tool. As can be easily concluded, changes in FTL adoption are slight, and do not present any crucial increases. But, if we turn to the following 2 variables: MCS and IU, changes in their level of basis adoption and usage are enormous. In 2000, the average share of population having adopted MCS in low and lower-

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middle-income countries was at 2,3%, while – after 11 years of dynamic growth[7], the level is at 76,9%. In 2000, the best performing country was Paraguay – with 15,3% of population using MCS, and in 2011 it was Vietnam – 144,9% of population using mobile phones[8].

Similar conclusion can be drawn in case of IU. In 2000, the average level of population share defined as Internet Users was at 0,7%, while in 2011 – 17,5%. In 2000 the best performer was Belize with 5,95% of population (individuals) using Internet, and in 2011 – Morocco with the 51% of individuals using Internet.

The lower/upper quartile analysis also reports on huge changes on the field. For MCS (in 2000) in the 25% of countries (lower quartile) the share of population using MCS was below 0,2%, while in 2011, the analogous value reached the level of 55,8%. This, again, proofs highly dynamic diffusion and increase in usage of basic ICTs tools in low and lower-middle-income countries.

Additionally, we report on Gini coefficients for each variable, separately in 2000 and 2011 (see Table 1). For FTL variable, changes in value of Gini coefficients are not reported, and the degree of inequality was not affected by the process of FTL diffusion in given years. Just the opposite situation is reported in case of MCS and IU. For both variables, the process of ICT diffusion has affected significantly the magnitude of concentration. After 11-year period of dynamic diffusion of ICT – especially for MCS – the inequality in access to ICT has diminished, and the usage of basic ICT tools has become more common for all society members (for additional evidence on changes in inequalities, see Lorenz curves for FTL, MCS and IU in the Appendix 3).

4. Identifying ICTs diffusion patterns in low and lower-middle income countries.

The main aim of the study is to identify diffusion patterns of ICTs in low and lower-middle-income countries. As stated by Jovanovic and Lach (1989), there exists wide empirical evidence that technology diffusion patterns follow the logistic trajectories graphically approximated by S-shaped curve. Following

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[7] For detailed growth rates see Appendix 1.
[8] The number higher than 100% proof that one person subscribes more than one mobile phone.

the above, we expect to uncover the "classical" S-shaped diffusion curve in most of countries for ICTs diffusion process. The empirical part encompasses 3 sections. In section 1, we aim to detect changes in distribution of FTL, MCS and IU in all 46 economies, in the time framework 2000-2011. In the second section, we investigate potentially distinct ICTs diffusion patterns (for variables FTL, MCS and IU) across income levels. We base on the time-series data for FTL, MCS and UI in years 2000 and 2011. Finally, in the third section, we estimate the ICTs diffusion patterns of FTL, MCS and IU in country sub-samples: C_L (low-income countries) and C_{LM} (lower-middle-income countries), for the analogous time span.

4.1.   Distribution changes of ICTs in low and lower-middle-income countries.

In the first stage we seek for changes in the distribution of ICTs in the group of low and lower-middle-income countries. To capture these we apply densities functions approach, we analyze distributions of FTL, MCS and IU adoption in terms of per 100 inhabitants[9], in years 2000-2011 (see Charts 1,2 and 3 below).

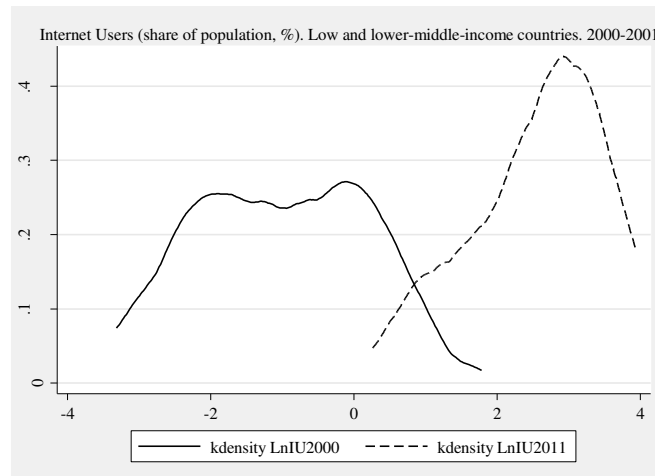Chart 1. Changes in distribution of FTL (per 100 inhabit). Low and lower-middle-income countries. Years 2000 and 2011.
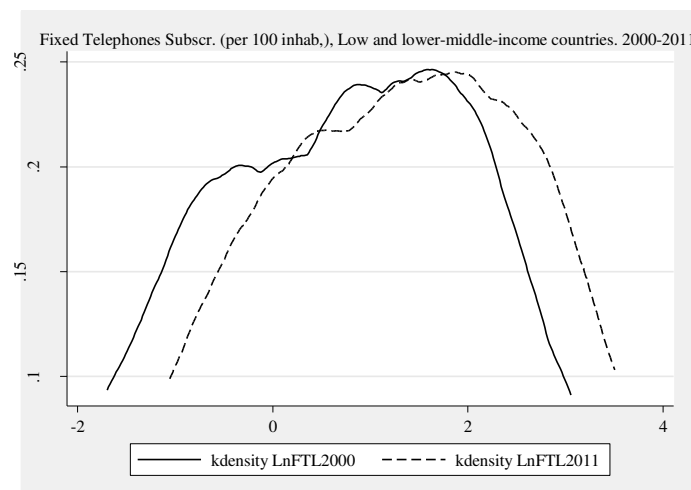
Source: own elaboration using data from World Telecommunication/ICT Indicators Database 2012.

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[9] On the axis, the values are expressed as natural logarithms of raw data.

The evidence shown in Chart 1 presents hardly no changes in distribution and average level of adoption on FTL, the solid line (standing for year 2000) and dash line (standing for year 2011) overlap. Analogous conclusion could be derived from descriptive statistics in Table 1, where the only slight growth in usage of fixed phones is detected.

A completely different picture presents Chart 2 (see below). In 2000, the average adoption/usage of mobile phones was at relatively low level, and the level of adoption/usage in the countries in the sample was highly uneven. In 2000, high diversification is evident[10]. After the 11 years (in 2011), the distribution line (dash line) has "moved" to the right and is highly peaked. It proofs much higher average level of MCS usage in the whole sample, and – on the other hand – decreases in inequalities. In terms of MCS usage, in the analyzed period, the group of low and lower-middle-income countries has become much more homogenous.

Chart 2. Changes in distribution of MCS (per 100 inhabit). Low and lower-middle-income countries. Years 2000 and 2011.
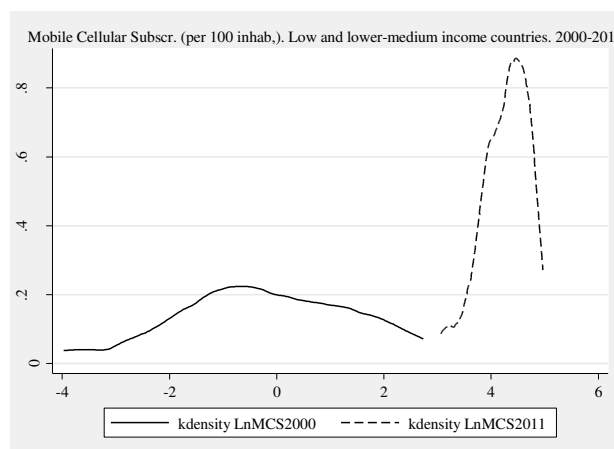
Mobile Cellular Subscr. (per 100 inhab,). Low and lower-medium income countries. 2000-2011.

kdensity LnMCS2000   kdensity LnMCS2011

Source: own elaboration using data from World Telecommunication/ICT Indicators Database 2012.

Finally, moving to the Internet Users (% of individuals), again we identify (see Chart 3 below), changes of high dynamics. In 2000 (solid line), the average share of individuals using Internet was significantly lower than in 2011 (dash line), and the distributions suggest relatively high inequalities (in 2000). Like in the case of MCS, the distribution line for the 2011, has "moved" to the right and one high peak has

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[10] Again for MCS.

emerged. It indicates diminishes in distributional disparities, and much higher average level of usage on Internet.

Chart 3. Changes in distribution of IU (% of individuals). Low and lower-middle-income countries. Years 2000 and 2011.

Internet Users (share of population, %). Low and lower-middle-income countries. 2000-2001.

Source: own elaboration using data from World Telecommunication/ICT Indicators Database 2012.

4.2. ICTs diffusion patterns in low and lower-middle-income countries.

The process of technology diffusion is widely discussed on the literature. Empirical works mainly concentrate on Internet diffusion patterns, explaining rate of diffusion and the extent to which Internet is adopted by potential users. Such analysis can be find in the works of Chong and Micco (2003), Klobas and Clyde (1998), Quibria (2002) or i.e. Estache *et al.* (2002). There are also several authors which intended to identify the S-shaped curve in technology adoption process in countries. The empirical evidence on the existence of S-shaped diffusion path can be found in works of Mansfield (1961), Jovanovic and Lach (1989), Comin *et al.* (2003), Andres (2008), Massenot (2008), Ania *et al.* (2011), or Shimogawa *et al.* (2012).

Following the logic, we assume that the technology diffusion – in each country, shall follow heterogeneous path, resulting in S-shaped curved as graphical illustration of the process. In early stages of diffusion the rate of diffusion is relatively low. Later on, the adoption rates are growing exponentially, finally achieving the inflection point. After passing the inflection point, the diffusion

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process is slowing down again, aspiring to stabilization phase when the saturation[11] (share of population using the given technology/innovation) is high (reaching 100% or above).

Let us assume that technology diffusion rate is a function of time, where $\phi_j(t)$, for *j-country* in year *t*. Following the previous, the absolute technology saturation change for *j*-country in the period[12] *t*, for given T[13]-technology, can be formally expressed as:

$$\phi_{j,t,T} = \phi_{j,t,T} - \phi_{j,t-1,T} \tag{1}.$$

Now, let us assume 11 periods of growth[14] (years 2000-2011), so the absolute cumulative technology (T) saturation change *(Φ)* for *n=11* periods in *j*-country, shall be expressed as:

$$\Phi_{j,T,(2000-2011)} = \phi_{j1} + \phi_{j2} + \phi_{j3} + \dots \phi_{jn} = \sum_{n=1}^{N} \phi_n \tag{2},$$

where ϕ_{j1} represents saturation level in year(*1*), and ϕ_{jn} at the end of the period – year(*n*), in *j* country. If $\kappa_{j(2000)}$ stands for the initial saturation level with ICT (technology – *T*) in year 2000 in *j*-country, then the:

$$\vartheta_{j,T,(2011)} = \kappa_{j,T,(2000)} + \Phi_{j,T,(2000-2011)} \tag{3},$$

can be identified as the final saturation level ($\vartheta_{j,T,(2011)}$) with ICT in a *j*-country at the end of the period (in our study this shall be year 2011).

Finally we formulate the average absolute technology saturation change *(φ)* for *j*-country in *n*-year period. Again, assuming that *n=11*, this shall be formalized as:

$$\varphi_{j,T,(2000-2011)} = \{ \vartheta_{j,T,(2011)} - \kappa_{j,T,(2000)} \} / n \tag{4}.$$

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[11] The term „saturation" refers to the level of intensity, degree to which something is absorbed compared the maximum possible (usually expressed as percentage). See http://oxforddictionaries.com (accessed on April 2013).
[12] Assuming year-on-year estimates.
[13] The *T* can stand for FTL, MCS or IU alternatively.
[14] Diffusion.

Following the formulas specified above, we estimate the cumulative absolute technology saturation change $(\Phi_{j,T,2000-2011})$, average absolute technology saturation change $(\varphi_{j,T,2000-2011})$, and final saturation level with ICT in 2011 $(\vartheta_{j,T,2011})$ for each economy separately in the group of low and lower-middle-income countries (time span 2000-2011).

The evident inability of detailed analysis of all cases – on one hand, and – on the other hand – a danger of oversimplification if all cases (countries) would be analyzed jointly, in the empirical part we are forced to concentrates on four representative examples of countries. These are: Fiji[15], El Salvador[16], Paraguay[17], and Ukraine[18][19]. For each country we develop 3 different ICT diffusion patterns (for FTL, MCS and IU separately), along with basic quantification of diffusion process in each case. Charts 4-7 (see below), contain graphical approximation of country-specific FTL, MCS and IU diffusion curves for Fiji, El Salvador, Paraguay and Ukraine.

To clarify the picture and achieve more comparability among selected economies, in Charts 8-10 (see below), we apply mutually four diffusion curves strictly for one ICTs tool to see differences in spread and dynamic of the process in selected economies.

The most important finding is that in each of them, the diffusion patterns of MCS (dash-lines in Charts 4-7), they form nearly the classical S-shaped diffusion curve. Analogous conclusion we draw analyzing Chart 9. The process of MCS diffusion follows similar patterns in each country. In the period 2000-2004/2005, changes in saturation with MCS level are slow, which suggest that all four countries follow the early diffusion phase. At the turn of years 2003/2004 or alternatively 2004/2005, all countries experience the "take off", passing to the next phase of diffusion, where annual changes tend to grow exponentially. Fiji experienced the fast-growth phase in years 2004-2009 (in 2010 entering the

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[15] FJI – international country code.
[16] SLV – international country code.
[17] PRY – international country code.
[18] UKR – international country code.
[19] All classified as lower-medium-income countries.

stagnation/slow growth phase), In case of Fiji the estimates show that $\phi_{Fiji,MCS(2004)}$=17,36%[20], and

$\phi_{Fiji,MCS(2007)}$=63,46%, which indicates that $\Phi_{Fiji,MCS(2003-2007)}$ = 46,1%p. In 2008 and finally in 2011, the

$\phi_{Fiji,MCS(2008)}$=71,12% and $\vartheta_{Fiji,MCS(2011)}$=83,72%. For El Salvador the fast growth phase starts in 2003 -

$\phi_{Salvador,MCS(2003)}$=19,14%, ending in 2009 - $\phi_{Salvador,MCS(2009)}$=122,82%, so - $\Phi_{Salvador,MCS(2003-2009)}$=103,68%. In

year 2009/2010 the country passes the inflection point and diffusion rates slow down. In year 2010

$\phi_{Salvador,MCS(2010)}$=124,34%, finally in 2011 reaching $\vartheta_{Salvador,MCS(2011)}$=133,54% saturation level with MCS. In

Paraguay, the fast growth phase begins in 2005 when $\phi_{Paraguay,MCS(2005)}$=31,99%, and end in 2008 when

$\phi_{Paraguay,MCS(2008)}$=92,95%, which results in $\Phi_{Paraguay,MCS(2005-2008)}$=60,26%p. In the final year 2011, the

saturation level with ICT is reported at $\vartheta_{Paraguay,MCS(2011)}$=99,4%. For Ukraine, respective values are as

follows: $\phi_{Ukraine,MCS(2003)}$=13,59%, $\phi_{Ukraine,MCS(2007)}$=118,77%, $\Phi_{Paraguay,MCS(2003-2007)}$=105,18%p, and finally in

2011 - $\vartheta_{Paraguay,MCS(2011)}$=121,6%.

In four analyzed case, the MCS diffusion trajectory was similar and can identified with the theoretical innovation diffusion curve explained as S-shaped one. In each country, early MCS diffusion phases were characterized by relatively low absolute growths in saturation level (period 2000-2003/2004). In 2003 (El Salvador), 2004 (Fiji and Ukraine), and 2005 (Paraguay) the marginal increments in absolute cumulative saturation level with MCS tend to grow. After approximately 4 years of exponential growth, each country enters the stabilization phase experiencing diminishing marginal increments in absolute cumulative saturation level.

We also need to note, that the case of Ukraine is very particular. In the period 2000-2011, the MCS diffusion process has passed all "traditional" phases explained by S-shaped curve. In the initial period, the $\phi_{Ukraine,MCS(2000)}$=0,54%, which proofs that adoption and usage of mobile phones was at extremely low level – close to zero. While, after 11-year period of dynamic MCS diffusion, in 2011 the

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[20] All the following are author`s own estimates base on data from World Telecommunication/ICT Indicators Database 2012 (full version).

$\phi_{\text{Ukraine,MCS(2011)}}$=121,6%, which can identified as full saturation (a whole country population has access to MCS).

For the another two ICTs variables – FTL (solid-lines in Charts 4-7) and IU(dot-lines in Charts 4-7), the diffusion patterns – when compared to the diffusion pattern of MCS – are close to flat, which indicates that – in the years 2000-2011, changes in adoption of FTL and IU were relatively poor and characterized by relatively low dynamics in time.

Chart 4. FTL, MCS, IU diffusion patterns in Fiji. 2000-2011.
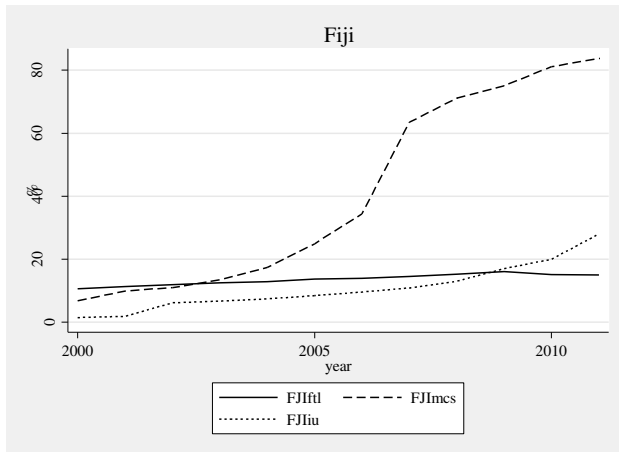
Source: own elaboration.

Chart 5. FTL, MCS, IU diffusion patterns in Paraguay. 2000-2011.
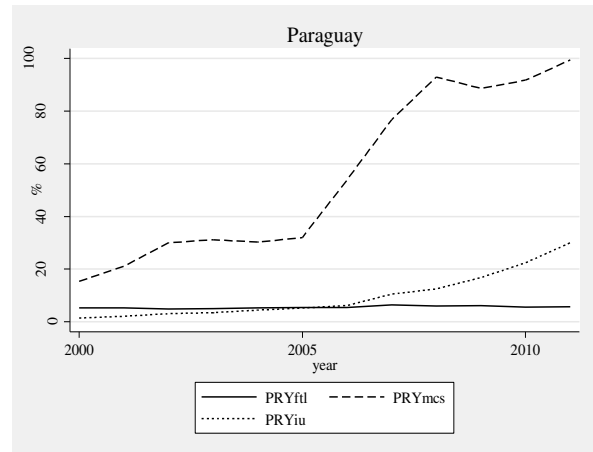
Source: own elaboration.

Chart 6. FTL, MCS, IU diffusion patterns in El Salvador. 2000-2011.
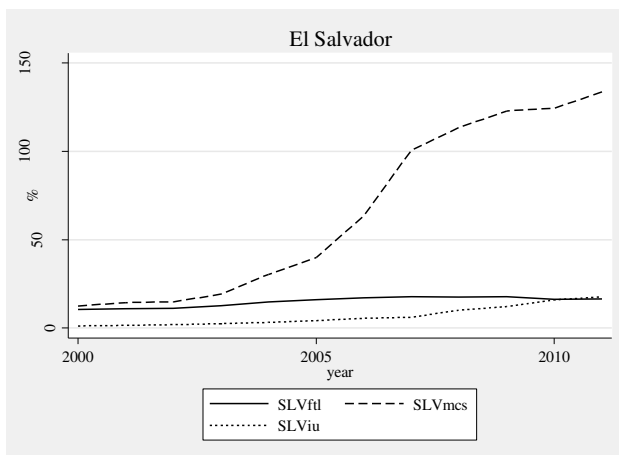
Source: own elaboration.

Chart 7. FTL, MCS, IU diffusion patterns in Ukraine. 2000-2011.

Source: own elaboration.

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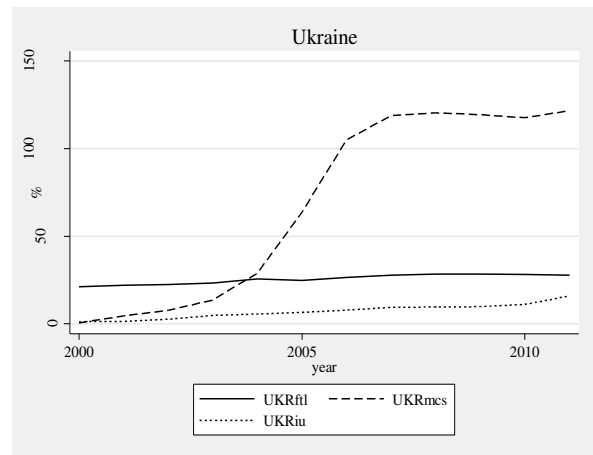
Chart 8. FTL diffusion patterns in Fiji, El Salvador, Paraguay and Ukraine. 2000-2011.
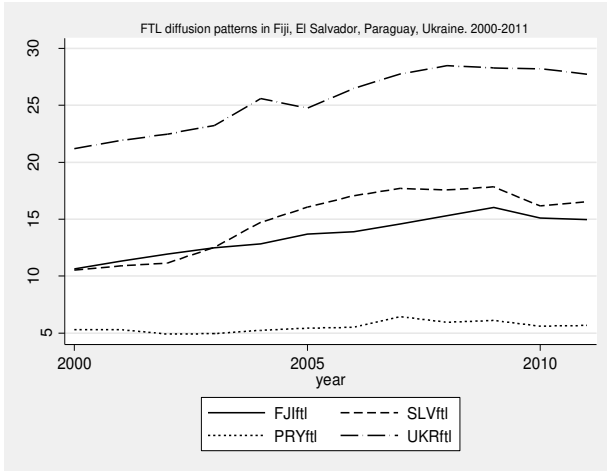
Source: own elaboration.

Chart 9. MCS diffusion patterns in Fiji, El Salvador, Paraguay and Ukraine. 2000-2011.
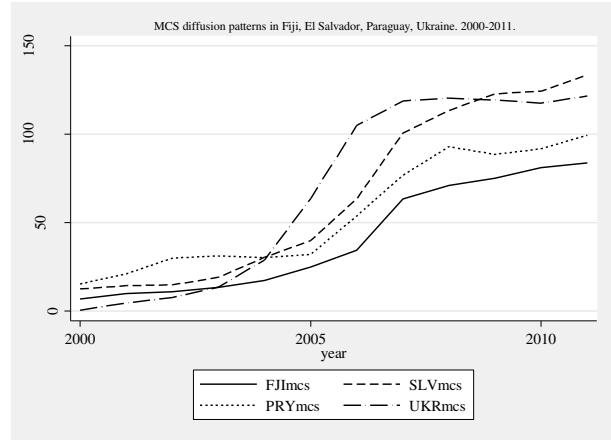
Source: own elaboration.

Chart 10. IU diffusion patterns in Fiji, El Salvador, Paraguay and Ukraine. 2000-2011.
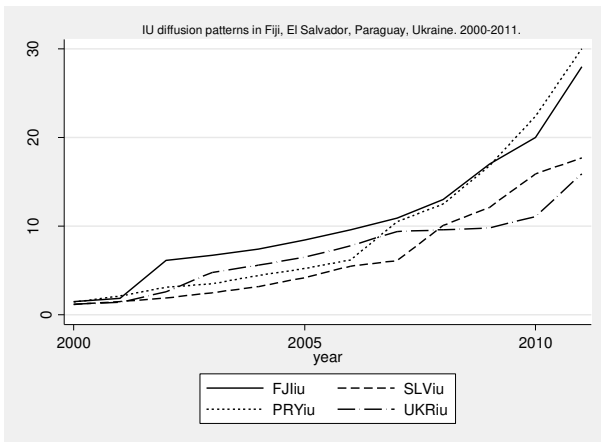
Source: own elaboration.

Giving a close look at specific diffusion trajectories of FTL and IU, we draw more detailed conclusions on the process features. Chart 10, specifies diffusion trajectories of IU in the period 2000-2011. Graphical analysis provides rather evident conclusion, that in 4 cases we deal with the early stages of IU diffusion process. Intuitively, we can conclude that – in year 2010 – Fiji, Paraguay and Ukraine are "taking-off" and enter path of exponential growth of IU. A common observation is that, in each country in the period 2000-2011, the $\phi_{j,t,T}$ values vary significantly year-to-year, resulting in no regularity. Not surprising, in case of FTL diffusion we observe only minimal changes in saturation levels. For analyzed economies, in the time span 2000-2011, the diffusion characteristics are specified as: for El

Salvador - $\Phi_{Salvador,FTL(2000-2011)}$=6,01%p., $\vartheta_{Salvador,FTL(2011)}$=16,54%, and $\varphi_{Salvador,FTL(2000-2011)}$=0,54%; for Fiji - $\Phi_{Fiji,FTL(2000-2011)}$=4,31%p., $\vartheta_{Fiji,FTL(2011)}$=14,95%, and $\varphi_{Fiji,FTL(2000-2011)}$=0,39%; for Paraguay - $\Phi_{Paraguay,FTL(2000-2011)}$=0,38%p., $\vartheta_{Paraguay,FTL(2011)}$=5,67%, and $\varphi_{Paraguay,FTL(2000-2011)}$=0,034%; and for Ukraine - $\Phi_{Ukraine,FTL(2000-2011)}$=6,56%p., $\vartheta_{Ukraine,FTL(2011)}$=27,74%, and $\varphi_{Ukraine,FTL(2000-2011)}$=0,59%. Although these countries enjoy different saturation levels with FTL, in the analyzed period changes on the values are visibly low. In 3 countries, in the 11-year period, approximately 6% of population gained access to fixed telephones lines[21]. Fixed telephony is perceived as "old ICT", and such low rates of growth are probably due to substitution of this of form of mass communication by mobile telephony. This is especially evident in low and lower-medium-income countries with poor infrastructure. Adoption of mobile telephony does not require so high financial resources as in case of fixed telephiony, providing analogous functionalities at a time.

In Table 2, (see below) we present summary estimates of the dynamics of ICT diffusion process in the analyzed countries. Again, we see that in 2011, the saturation levels with MCS result to be much higher, than in case of FTL and IU. For all 4 countries, the $\vartheta_{j,MCS(2011)}$ reaches the level of almost 100% or even higher. This implies that almost 100% of country`s population enjoys access to given ICT tool. Also, solely in case of MCS, developed diffusion trajectories seem to be described by S-shaped pattern.

Table 2. Cumulative absolute technology saturation growth ($\Phi_{j,T,2000-2011}$), average absolute technology saturation growth ($\varphi_{j,T,2000-2011}$), and final saturation level with ICT in 2011 ($\vartheta_{j,T,2011}$). Estimates for Fiji, El Salvador, Paraguay and Ukraine. Time coverage 2000-2011.

Country	$\Phi_{j;T(2000-2011)}[\%p]$			$\varphi_{j;T(2000-2011)}[annually, \%p]$			$\vartheta_{j;T(2011)}[\%]$		
Fiji	FTL	MCS	IU	FTL	MCS	IU	FTL	MCS	IU
	4,31	76,9	26,5	0,39	6,9	2,4	14,95	83,7	28
El Salvador	FTL	MCS	IU	FTL	MCS	IU	FTL	MCS	IU
	6,01	121	16,5	0,54	11	1,5	16,54	133,5	17,6
Paraguay	FTL	MCS	IU	FTL	MCS	IU	FTL	MCS	IU
	0,38	84	23,1	0,03	7,64	2,1	5,67	99,4	23,9
Ukraine	FTL	MCS	IU	FTL	MCS	IU	FTL	MCS	IU
	6,56	121	29,8	6,56	11	2,71	17,74	121	30,6

Source: own calculations.

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[21] In Paraguay it is only another 0,38% of population.

4.3. ICTs diffusion patterns in country sub-samples.

In the final section, we investigate the ICT diffusion curves in 2 country sub-samples (sub-groups) – C_L (low-income) and C_{LM} (lower-middle-income countries). Again we seek for S-shaped diffusion trajectories revealed in time, but this applying average values for FTL, MCS and IU as variables. Chart 11 plots the evidence of the ICT diffusion paths in C_L and C_{LM} separately. Finally, we conclude on the historical evolution of the ICTs diffusion in the 2 heterogeneous country groups. Despite the fact, that growth rates of ICTs diffusion differ significantly, regarding differences among variables and among countries, in both cases the ICT diffusion trajectories result to be quite similar in shape. In low-income countries (15 countries in the group), the highest saturation level is reported for MCS (for variable-specific diffusion patterns see Chart 12(b)) – in 2011, the average level of $\overline{\vartheta}_{MCS(2011),Low} = 58{,}62\%$ (average share of population using MCS), with the average annual diffusion growth rate 43%. The 2 best performing economies were Kyrgyzstan and Cambodia, with the share of population using MCS equivalent to $\vartheta_{MCS(2011)}=113\%$ and $\vartheta_{MCS(2011)}=96\%$ respectively.

Charts 11(a),11(b). ICT diffusion curves (FTL, MCS and IU) in low-income and lower-middle-income countries. 2000-2011.
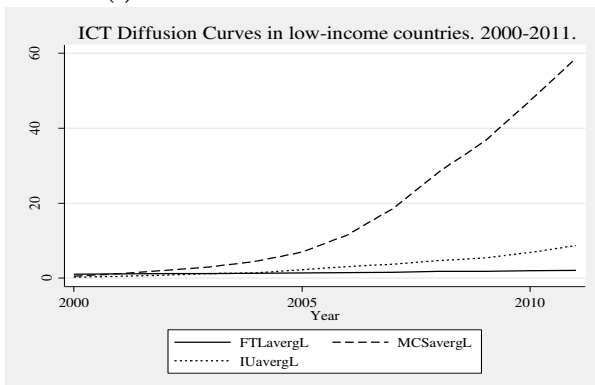
Chart 11(a)   Chart 11(b)
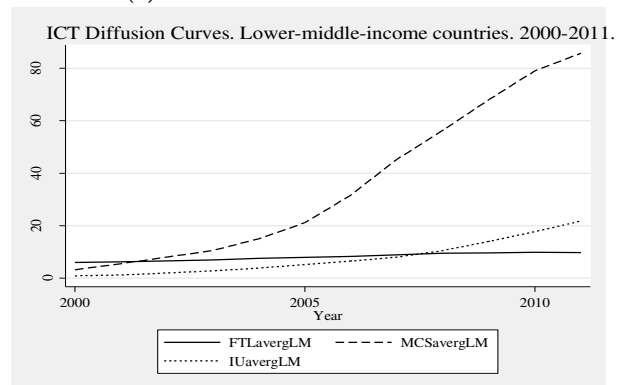
Source: own elaboration.

For the analogous variable, in lower-middle-income countries, the average saturation level equals for

$\overline{\vartheta}_{MCS(2011),Lower-middle} = 85{,}69\%$, with the average annual diffusion growth rate at 30% (the 2 best

performers are El Salvador and Ukraine, with $\vartheta_{MCS(2011)}=133\%$ and $\vartheta_{MCS(2011)}=121\%$ respectively).

Charts 12(a), 12(b), 12(c). FTL, MCS and IU diffusion patterns low and lower-middle-income countries. 2000-2011.

Chart (12(s))
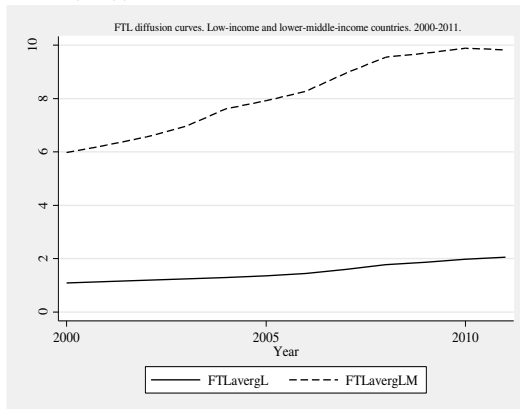
Chart 12(b)
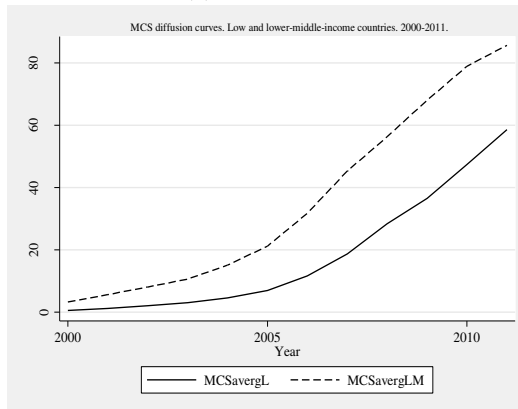
Chart 12 (c)
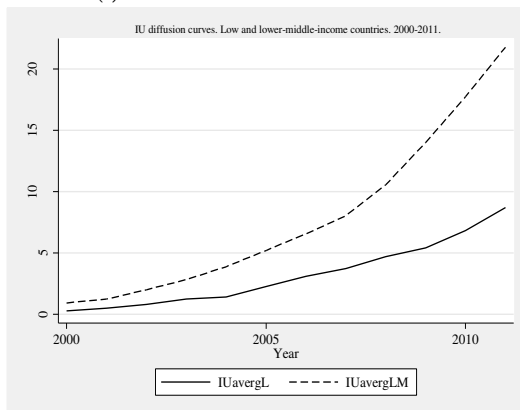
Source: own elaboration.

In case of IU, the diffusion trajectories stand for the initial "parts" of the theoretical S-shaped curve, indicating that the IU diffusion, both on C_L and C_{LM}, refer to the early stages of diffusion process. For the given variable, in low-income countries the $\overline{\vartheta}_{IU(2011),Low} = 8,69\%$, and in lower-middle-income ones - $\overline{\vartheta}_{IU(2011),Lower-middle} = 21,78\%$. In low-income economies the Internet usage is still at relatively low level, however in 2010 and 2011 the average absolute change in saturation level are: $\overline{\phi}_{IU(2010),Low} = 1,44\%p$, and $\overline{\phi}_{IU(2011),Low} = 1,86\%p$ respectively, which predicts entering the exponential growth phase of diffusion process. In lower-middle-income countries, marginal increments

in total saturation level begin to grow slowly right in 2000, in 2008 and 2009 achieving the average level of $\overline{\phi}_{IU(2007/2008),Lower-middle} = 1,05\%p$ and $\overline{\phi}_{IU(2008/2009),Lower-middle} = 0,93\%p$ respectively.

The FTL diffusion process is hardly visible in both country groups, revealing little higher dynamic in lower-middle-income countries than in low-income ones. The average saturation level in 2011, for C_L and C_{LM}, results as $\overline{\vartheta}_{FTL(2011),Low} = 2,06\%$ and $\overline{\vartheta}_{FTL(2011),Lower-middle} = 9,82\%$. At a time, no logistic curve is displayed. This again confirms the hypothesis on growing substitution of "old" ICTs by "new" ones. In low-income and lower-middle-income economies the process of substitution can be noticed by no difficulties. This is mainly due to special features of ICTs. Easiness for adoption and usage, minimum financial and infrastructural requirements constitute them an attractive development tool especially in low and lower-middle-income countries.

Summary findings

Diffusion is a process of spread of innovation over social system over time. Our empirical investigation encompasses ICTs diffusion (Fixed Telephones Lines subscribers, Mobile Cellular Subscribers and Internet Users) process in the sample of low and lower-middle-income countries (46), over the period 2000-2011. Most of countries applied for the study, have undergone massive digital revolution, where ICTs have diffused at high pace. Concluding again from preliminary descriptive statistics, the average adoption has increased significantly in case of MCS and IU, being rather stable for FTL. In the graphical analysis, the process of ICT diffusion is relatively well characterized by an S-shaped trajectory. The S-shape-like diffusion curve is particularly clearly identified in case of MCS diffusion in both country groups. Most of countries in lower-middle-income group have already passed the "classical" diffusion path stages, achieving close to maximum (100%) saturation level. This finding suggests that in these countries almost 100% of country`s population enjoys access to mobile telephony. Such extraordinary results in MCS implementation, explain why the fixed telephony network has hardly diffused in the analogous period. The process of Internet spread, in most countries, still remains in early stages of diffusion. The evidence of existence of S-shape trajectory is not evident. In 2011, the

share of population identified as Internet users, was still at relatively low level. At a time, the process of IU diffusion was not characterized by such high dynamics as in case of MCS.

Our analysis was not the long-term one (2000-2011), and was limited strictly to the analysis of low and lower-middle-income countries. In a general view, it can be concluded that despite diversity in ICTs diffusion paths in countries, the process is characterized by high dynamics and wide spread of new technologies is observed. The finding is seminal, for further economic growth and development perspectives in backward economies.

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Statistical Appendix 1.

Table 1. Basic ICTs statistics for low-income and lower-middle-income countries (47 countries. Low-income countries are put in bolds). Years 2000 and 2011.

|		Fixed-telephone subscriptions. Share of total population having access to fixed-telephone lines (%).			Mobile-cellular telephone subscriptions. Share of population with active mobile-cellular telephones (%).			Percentage of individuals using the Internet (%)		
		FTL in 2000	FTL in 2011	FTL average annual exponential growth rate in 2000-2011 (approximations)	MCS in 2000	MCS in 2011	MCS average annual exponential growth rate in 2000-2011 (approximations)	IU in 2000	IU in 2011	IU average annual exponential growth rate in 2000-2011 (approximations)
Albania	ALB	4,97	10,54	7%	0,97	96,39	42%	0,11	49,00	55%
Armenia	ARM	17,34	18,63	1%	0,57	103,57	47%	1,30	32,00	29%
Bangladesh	**BGD**	**0,38**	**0,65**	**5%**	**0,22**	**56,06**	**51%**	**0,07**	**5,00**	**39%**
Belize	BLZ	14,31	8,09	-4%	6,73	62,37	21%	5,96	15,19(a)	8%
Bolivia	BOL	6,15	8,71	3%	7,01	82,82	22%	1,44	30,00	28%
Burkina Faso	**BFA**	**0,43**	**0,83**	**6%**	**0,21**	**45,27**	**49%**	**0,08**	**3,00**	**33%**
Cambodia	**KHM**	**0,25**	**3,70**	**25%**	**1,05**	**96,17**	**41%**	**0,05**	**3,10**	**38%**
Cote d'Ivoire	CIV	1,59	1,33	-2%	2,85	86,06	31%	0,23	2,20	20%
Djibouti	DJI	1,33	2,04	4%	0,03	21,32	59%	0,19	7,00	33%
El Salvador	SLV	10,53	16,54	4%	12,52	133,54	22%	1,18	17,69	25%
Fiji	FJI	10,64	14,95	3%	6,78	83,72	23%	1,50	28,00	27%
Georgia	GEO	11,51	29,98	10%	4,41	98,73	29%	0,48	36,56	39%
Ghana	GHA	1,11	1,14	0%	0,68	84,78	44%	0,15	14,11	41%
Honduras	HND	4,80	7,86	4%	2,50	103,97	34%	1,20	15,90	23%
India	IND	3,08	2,63	-1%	0,34	72,00	49%	0,53	10,07	27%
Indonesia	IDN	3,12	15,94	15%	1,72	103,09	37%	0,93	18,00	27%
Kenya	**KEN**	**0,93**	**0,68**	**-3%**	**0,41**	**67,49**	**46%**	**0,32**	**28,00**	**41%**
Kyrgyzstan	**KGZ**	**7,68**	**9,12**	**2%**	**0,18**	**113,98**	**59%**	**1,04**	**20,00**	**27%**
Lao PDR	LAO	0,77	1,71	7%	0,24	87,16	54%	0,11	9,00	40%
Lesotho	LSO	1,13	1,76	4%	1,10	56,17	36%	0,21	4,22	27%
Madagascar	**MDG**	**0,36**	**0,65**	**5%**	**0,41**	**40,65**	**42%**	**0,20**	**1,90**	**21%**
Malawi	**MWI**	**0,41**	**1,13**	**9%**	**0,44**	**25,69**	**37%**	**0,13**	**3,33**	**30%**
Mauritania	**MRT**	**0,72**	**2,04**	**10%**	**0,58**	**93,60**	**46%**	**0,19**	**4,50**	**29%**
Moldova	MDA	16,04	33,15	8%	3,82	104,38	31%	1,28	38,00	31%
Mongolia	MNG	4,87	6,70	3%	6,41	105,08	25%	1,26	20,00	25%
Morocco	MAR	4,95	11,05	7%	8,13	113,26	24%	0,69	51,00	39%
Nepal	**NPL**	**1,09**	**2,77**	**8%**	**0,04**	**43,81**	**63%**	**0,20**	**9,00**	**34%**
Niger	**NER**	**0,18**	**0,53**	**10%**	**0,02**	**29,52**	**67%**	**0,04**	**1,30**	**33%**
Nigeria	NGA	0,45	0,44	0%	0,02	58,58	71%	0,06	28,43	55%
Pakistan	PAK	2,11	3,24	4%	0,21	61,61	52%	1,11(a)	9,00	19%
Paraguay	PRY	5,29	5,67	1%	15,36	99,40	17%	0,75	23,90	31%
Philippines	PHL	3,96	3,75	0%	8,35	99,30	23%	1,98	29,00	24%
Rwanda	**RWA**	**0,22**	**0,36**	**4%**	**0,48**	**40,63**	**40%**	**0,06**	**7,00**	**43%**
Sri Lanka	LKA	4,02	17,29	13%	2,25	87,78	33%	0,65	15,00	29%
Swaziland	SWZ	3,15	7,10	7%	3,26	71,79	27%	0,93	18,13	27%
Syria	SYR	10,48	20,87	6%	0,19	63,00	53%	0,18	22,50	44%
Tanzania	**TZA**	**0,51**	**0,35**	**-3%**	**0,32**	**55,53**	**47%**	**0,12**	**12,00**	**42%**
Togo	**TGO**	**0,89**	**3,90**	**13%**	**1,04**	**50,45**	**35%**	**0,80**	**3,50**	**13%**
Uganda	**UGA**	**0,25**	**1,35**	**15%**	**0,52**	**48,38**	**41%**	**0,16**	**13,01**	**40%**
Ukraine	UKR	21,18	27,74	3%	0,52	121,60	39%	0,72	30,60	34%
Uzbekistan	UZB	6,71	6,57	0%	0,22	86,71	55%	0,48	30,20	38%
Vanuatu	VUT	3,59	2,54	-3%	0,20	55,76	51%	2,11	9,06(a)	13%
Vietnam	VNM	3,28	11,58	12%	1,02	144,94	45%	0,25	35,07	45%
Yemen	YEM	1,96	4,33	7%	0,18	47,05	51%	0,08	14,91	47%
Zambia	ZMB	0,82	0,64	-2%	0,97	60,59	38%	0,19	11,50	37%
Zimbabwe	**ZWE**	**1,99**	**2,79**	**3%**	**2,13**	**72,13**	**32%**	**0,40**	**15,70**	**33%**

Source: Own estimates based on data derived from World Telecommunication/ICT Indicators Database 2012 (16th edition) and World Development Indicators 2012. (a) – estimates based on time-trend exponential growth rates (author`s own calculations).
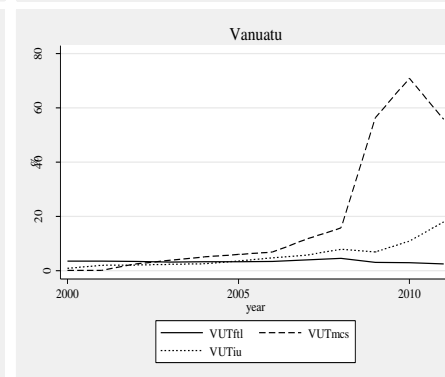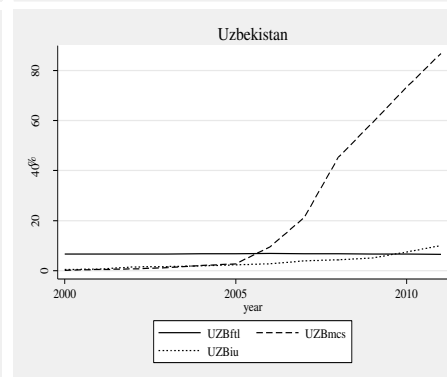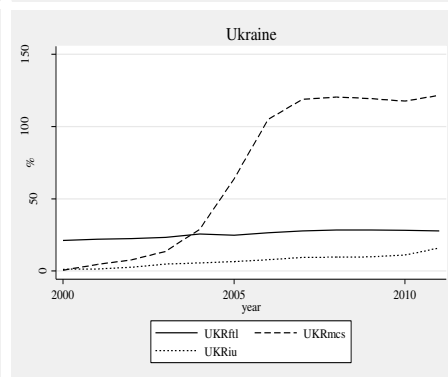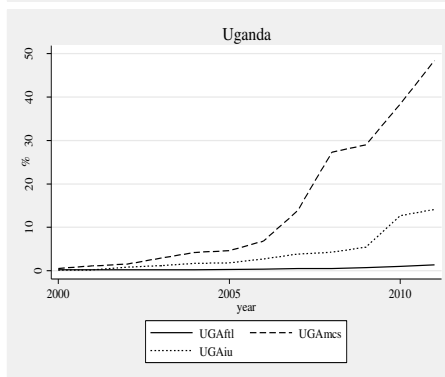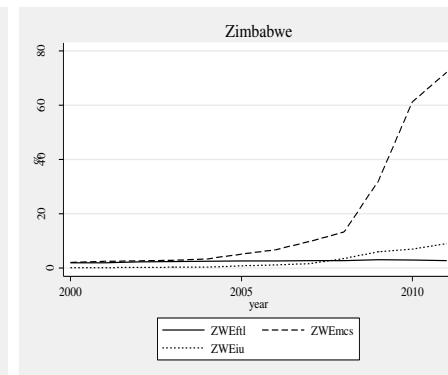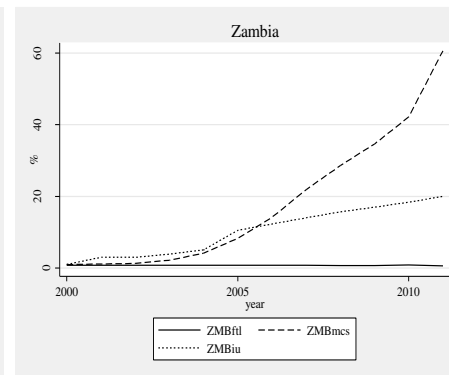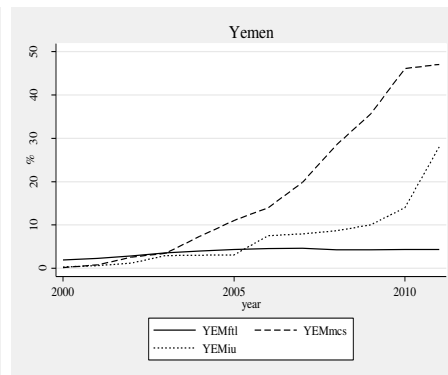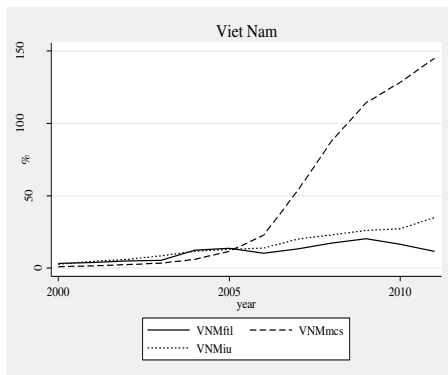
Appendix 2. Country-specific diffusion curves for FTL, MCS, IU. Low and lower-middle-income countries. 2000-2011.
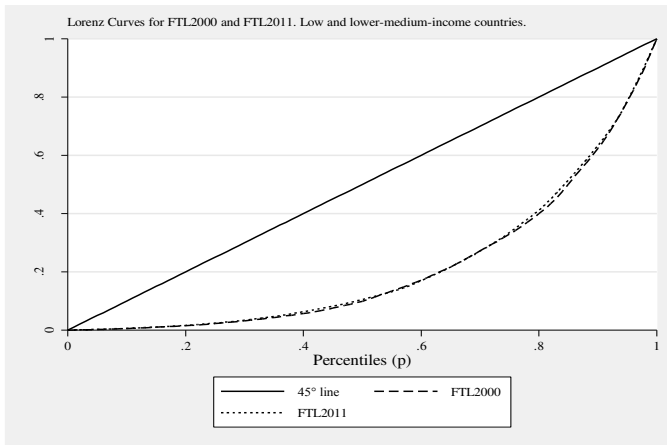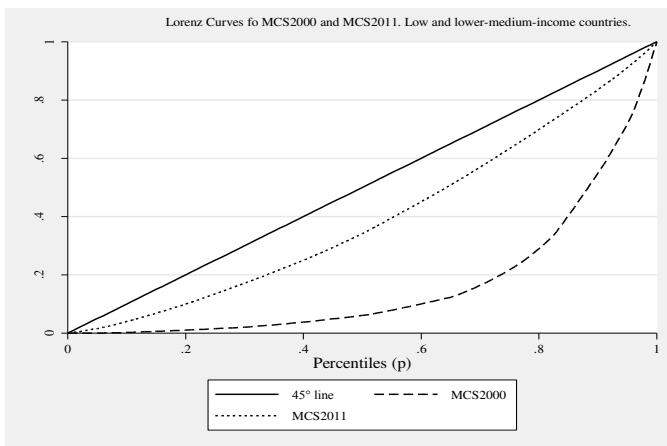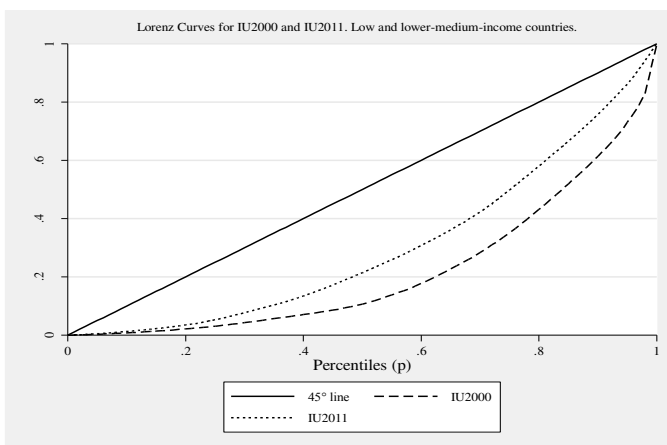
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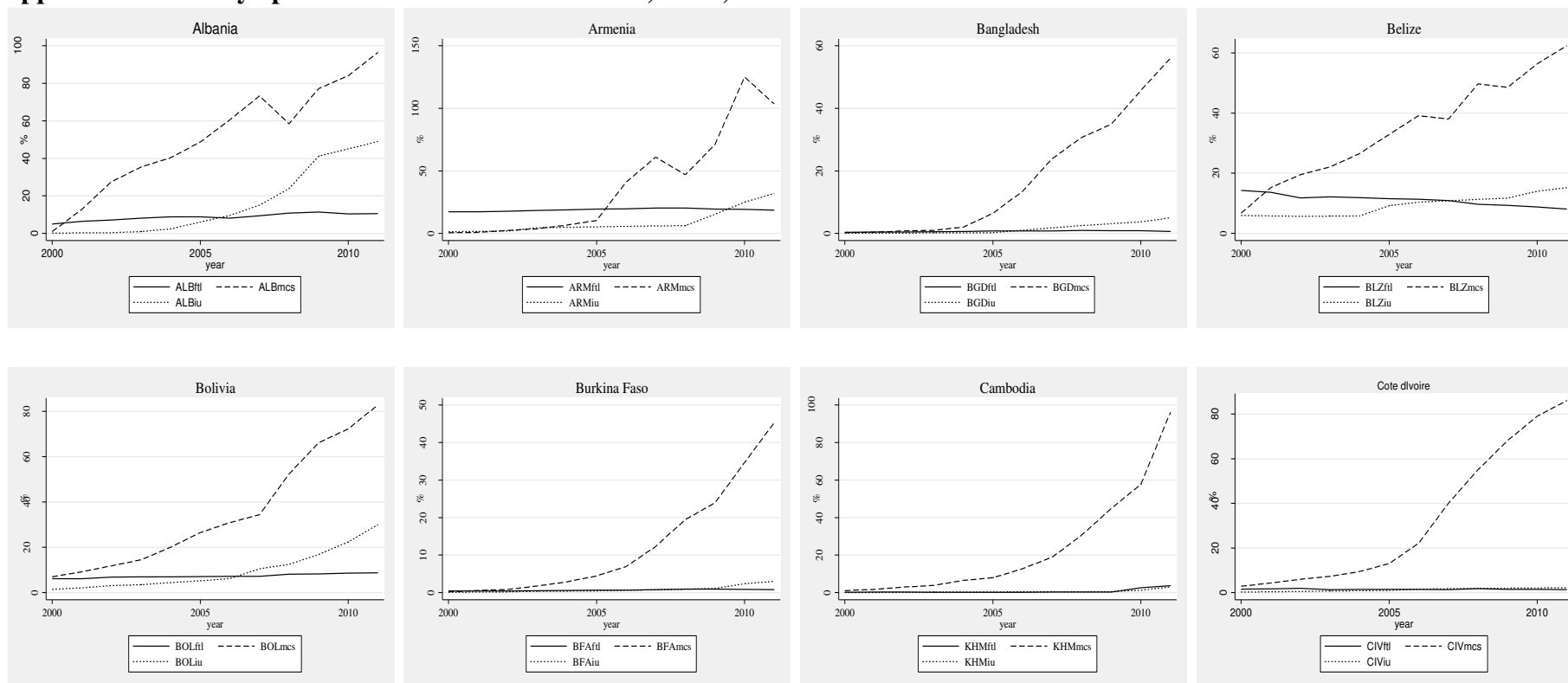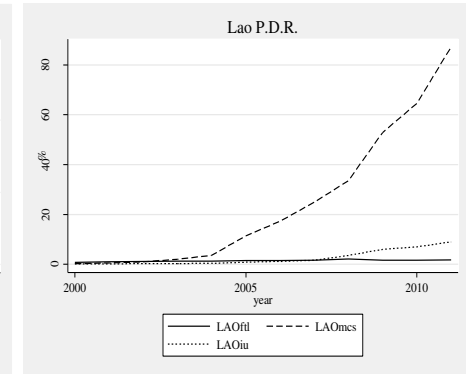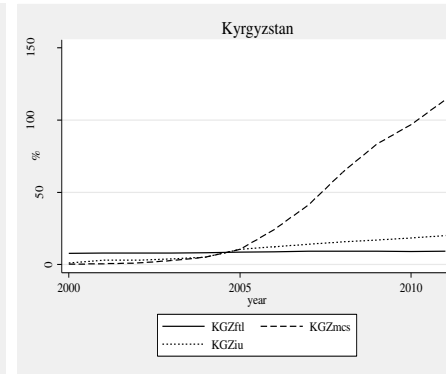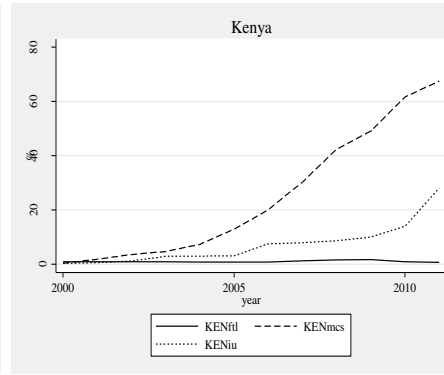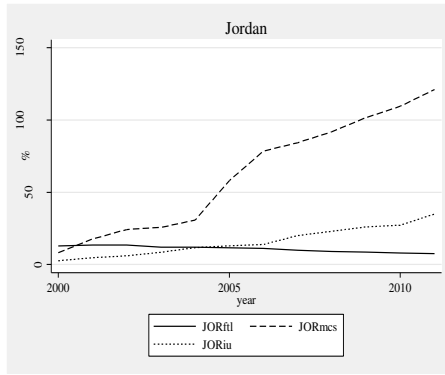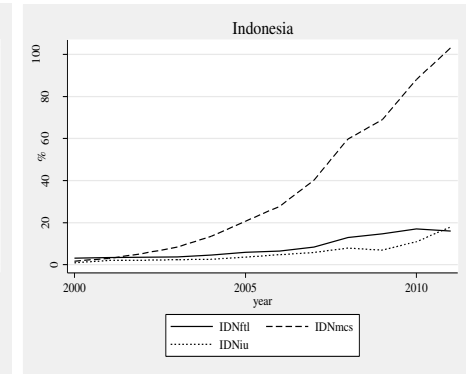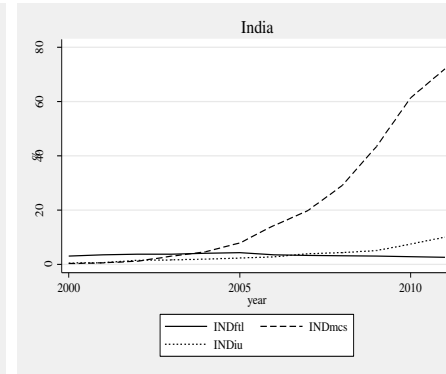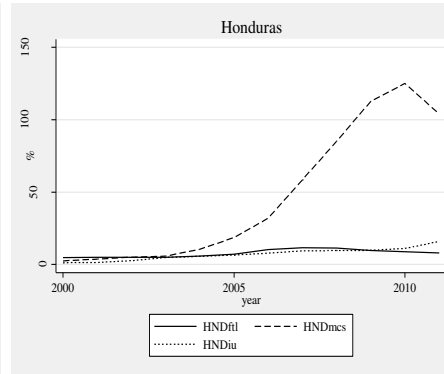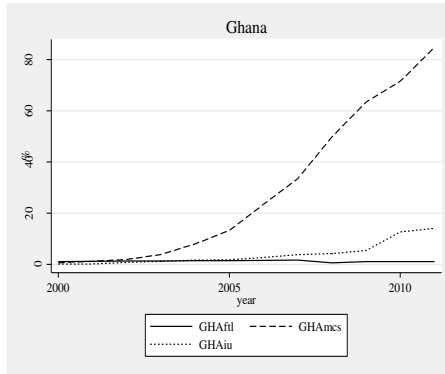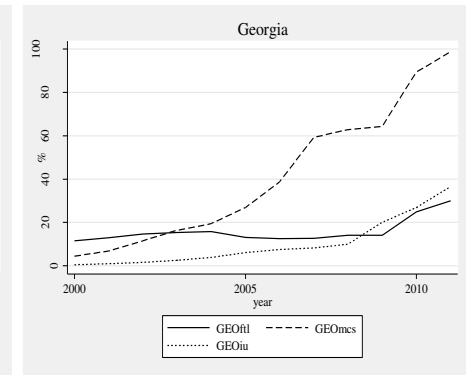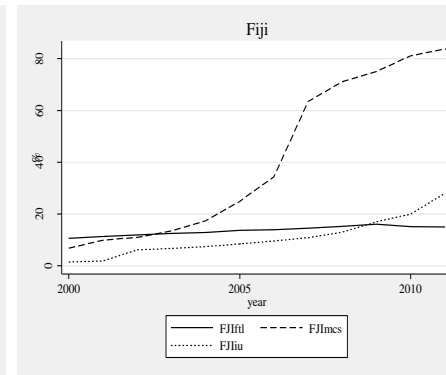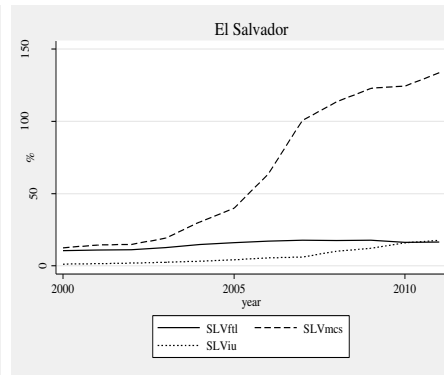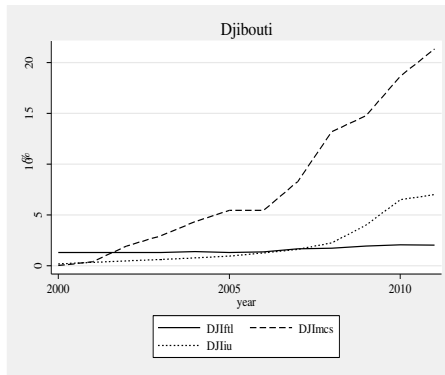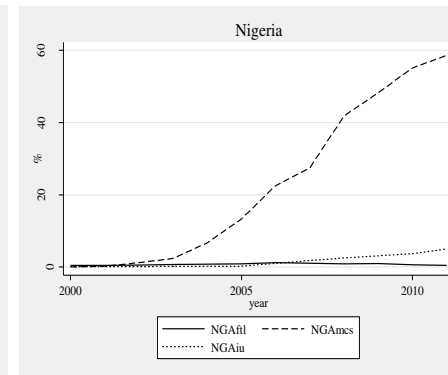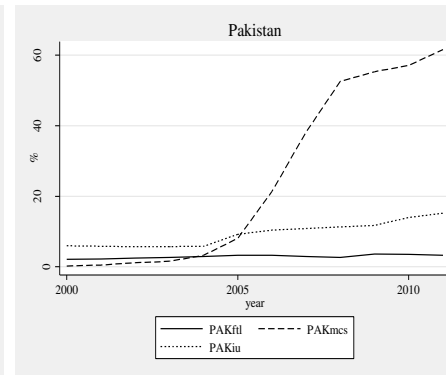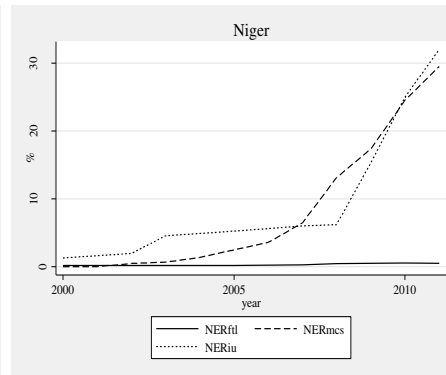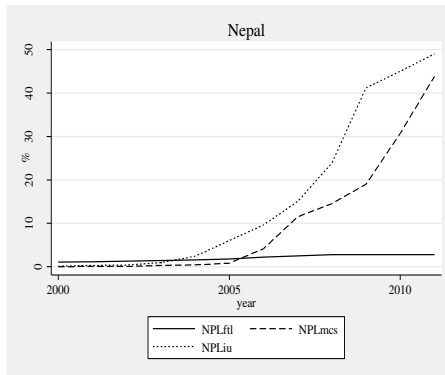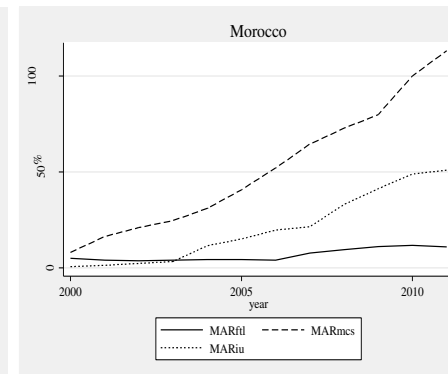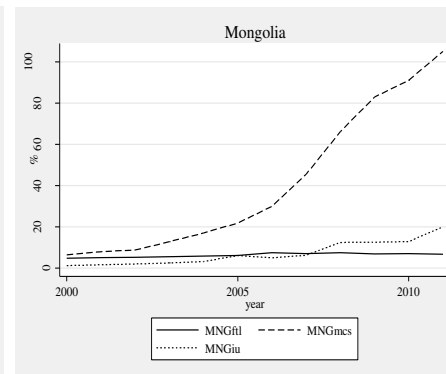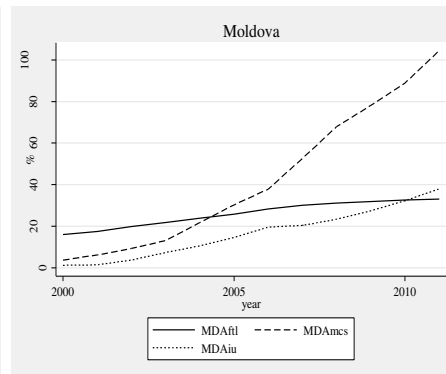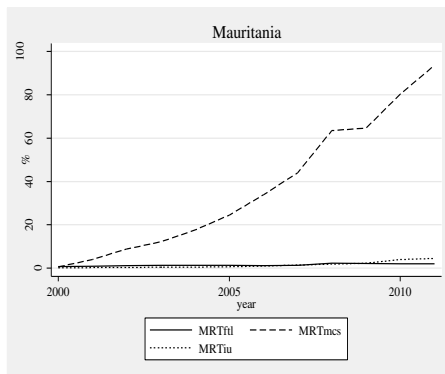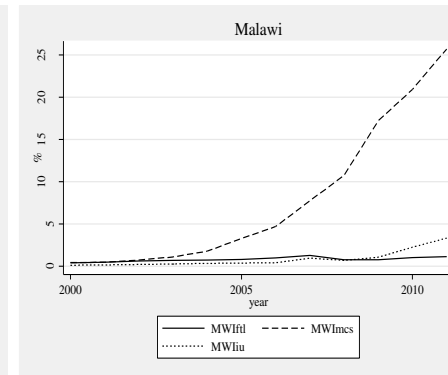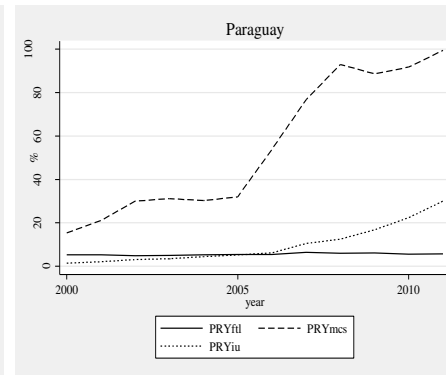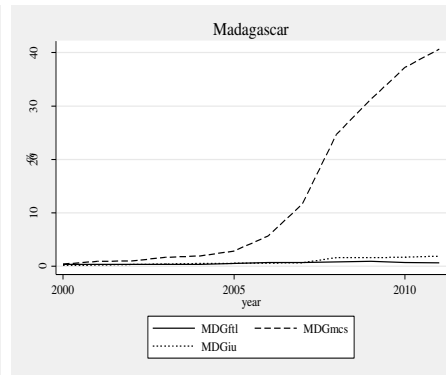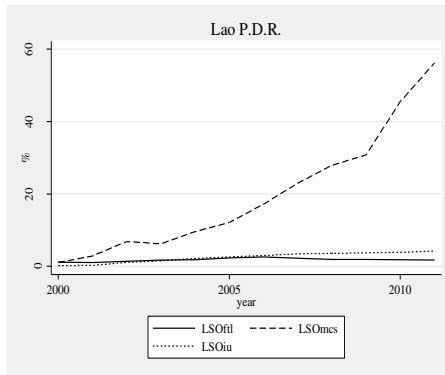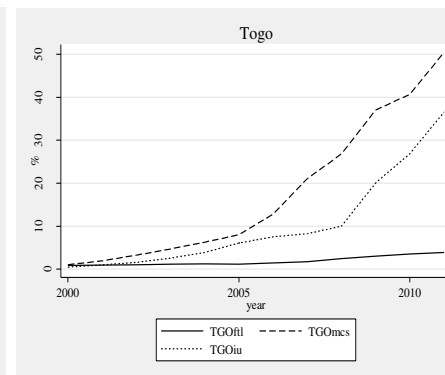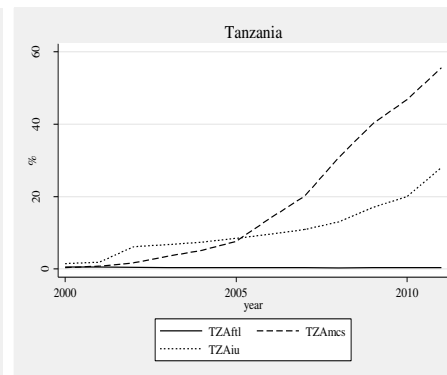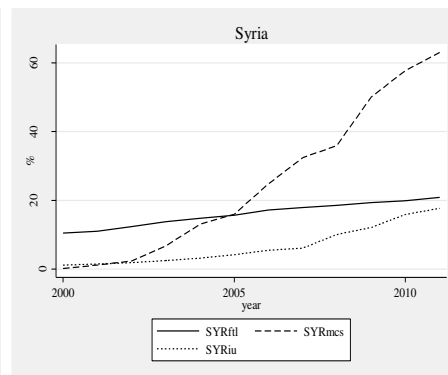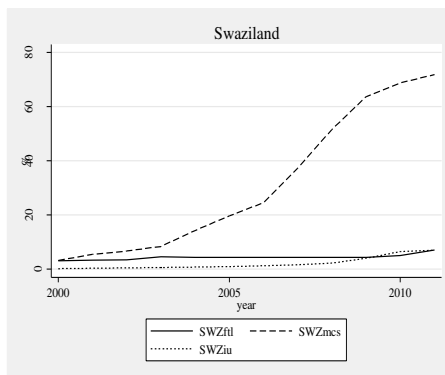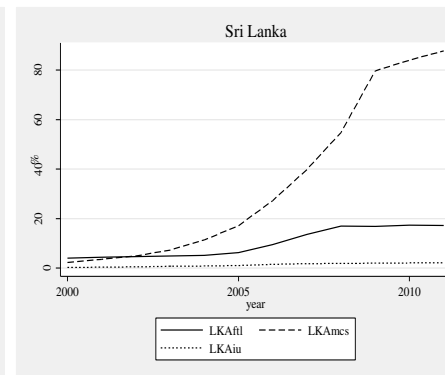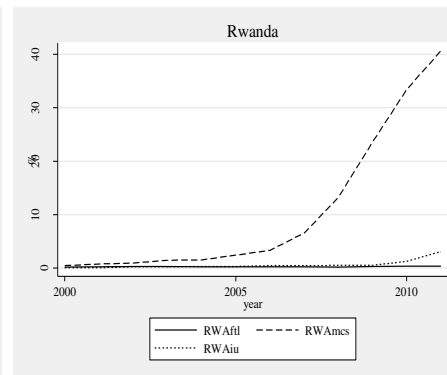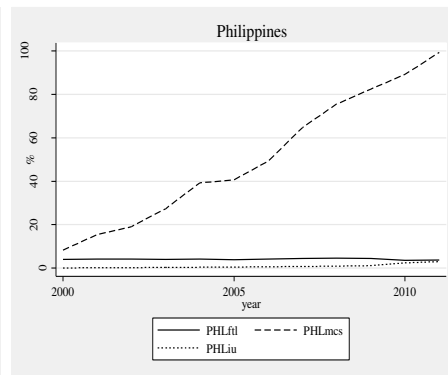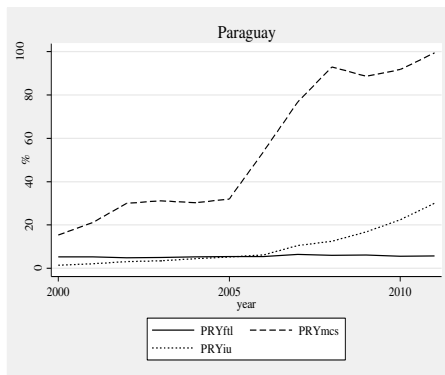
Appendix 3. Lorenz curves for FTL, MCS, IU. Years 2000 and 2011. Low and lower-middle-income countries.

Source: own elaboration.

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