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Measuring the global information society – explaining digital inequality by economic level and education standard

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Abstract

A main focus of this research paper is to investigate on the explanation of the *'digital inequality'* or *'digital divide'* by economic level and education standard of about 150 countries worldwide. Inequality regarding GDP per capita, literacy and the so-called UN Education Index seem to be important factors affecting ICT usage, in particular Internet penetration, mobile phone usage and also mobile Internet services. Empirical methods and (multivariate) regression analysis with linear and non-linear functions are useful methods to measure some crucial factors of a country or culture towards becoming information and knowledge based society. Overall, the study concludes that the convergence regarding ICT usage proceeds worldwide faster than the convergence in terms of economic wealth and education in general. The results based on a large data analysis show that the digital divide is declining over more than a decade between 2000 and 2013, since more people worldwide use mobile phones and the Internet. But a high digital inequality explained to a significant extent by the functional relation between technology penetration rates, education level and average income still exists. Furthermore it supports the actions of countries at UN/G20/OECD level for providing ICT access to all people for a more balanced world in context of sustainable development by postulating that policymakers need to promote comprehensive education worldwide by means of using ICT.

1. Introduction

Indeed, one of the most important terms in the field of information society is 'digital divide'. Historically, it was high on the agenda of the European Union [26], a topic of the World Summit on the Information Society (WSIS) took place in Geneva in 2003 [33] and Tunis in 2005 [34] as well as at the World Summit on Sustainable Development (WSSD) in Johannesburg [32]. Nowadays, a lot of issues related to 'digital divide' are discussed at the UN Internet Governance Forum [11, 12, 13] by using the term 'digital inequality' as a more adequate and precise description of the technological situation of a country.

1.1 Terms

As we know, good infrastructure (traffic infrastructure, technological infrastructure, housing infrastructure, energy infrastructure etc.) is one of the most important components of wealth and economic power [27]. The economic strength of a country can be quantified by the (financial) value of all goods and services produced within a given time period in a country [20]. GDP per capita (*GDPpC*) is one of the main indicators of economic analysis, both in spatial and in temporal international comparisons. For international analysis, the purchasing power parity (PPP) is used. The social balance or the distribution of income is, in addition to GDP per capita, an important parameter for understanding the social situation in a country. It is empirically and theoretically well known that neither too much nor too little inequality is good for a country [17] [35].

A country needs to invest in education and research to maintain economic welfare. In a global perspective, it is still important to observe the number of people being able to read and write. The adult literacy rate is the percentage of the population age 15 and above who can read and write a short, simple statement concerning their everyday life [29]. Generally, literacy also encompasses numeracy, the ability to make simple arithmetic calculations like adding numbers. The UN Education Index is a more complex measure to compare between different educations standards in countries. It is a combination of expected and average school time of individuals in a country [465]. Statistically possible repetitions of classes are included. From a mathematical viewpoint, the expected years of schooling is of a predictive character.

Innovation and technology promote economy and education, enabling convenience in communication, which is the basic operation of a society with enormous effects on the performance of a country [19]. One index for the technological development of a country, in terms of technological deployment and communication, is to measure the percentage of population using any (digital) technology, while ignoring the type of access (private/ shared), connection (wired/wireless) or location (household, school, office, cafe). For example, the Internet penetration rate (IPR) is the estimated number of Internet users out of a total population. This includes those using the Internet from any device (including mobile phones) over the last 12 months, measured through household surveys. If household surveys are not available, an estimate can be derived based on the number of Internet subscriptions [15].

The mobile phone connection is becoming more and more important due to the fact of technological convergence which provides the use of the Internet from any mobile device. The mobile phone penetration rate (MPR) includes both the number of mobile phone subscriptions and the number of active prepaid accounts that have been used within the last three months. It does not include the connections via data cards or USB - modems, connections of public mobile data services, private trunked radio, telepoint, radio paging and telemetry services [14].

1.2 Data and Methods

The World Bank provides data regarding the economic development level (GDP, GDPpC, income distribution) of countries [31]. Technology penetration rates (MPR, IPR) are available (partly free of charge) on the International Telecommunication Union website [16], where also some other ICT key indicators can be downloaded. Data for measuring the education level of a country and its population can be downloaded from the statistical division of the UNESCO [30] and UN Development Programme websites [465]. On those websites data is available for national adult/youth literacy rates, enrolment ratios and education index by international standard classification of education level (ISCED). This study focuses on adult literacy rate and education index. Due to the lack of data regarding literacy rate for many developed and developing countries, polynomial interpolation is used to have enough data for pair-by-pair comparison concerning technology penetration rates.

The data management process in this work is essentially based on the authoritative architecture of data warehouse systems [4]. Figure 1 shows the ETL process (*extract, transformation, load*), which is applied for the data management. The extraction component (1) has the function to procure data from the different data sources. Among other things, there are questions regarding the exchange of data, like formats to be considered. Furthermore, certain data subsets need to be extracted from the sources, why separation is of importance. A decisive factor here is also the question of the time of extraction. This is done as needed, whereas a periodic, event-based or immediate extraction is generally possible. After extraction, the needed data for analysis is stored in the work area. Step (2a) in *figure 1* is the so-called *transformation* component. The data obtained from different sources must be standardized in a certain way in order to make a valid processing possible. The unifying and processing of the data is carried out in this component. The *loading* up component in step (3) passes on the prepared data from the workspace to the corresponding database (Access DB). Furthermore, this component is responsible for the historicization of the data in a certain regard. This means old data is not simply deleted or overwritten but

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rather provided with a timestamp and stored. A change at a data set therefore has the consequence that two data sets exist with a different timestamp. In step (4a) the corresponding data are brought together for analysis purposes from different sources. For this use the *structured query language* (SQL) is used. Step 5 serves now to fetch the data for regression analysis. The corresponding data are exported from the database program. Afterwards the data are loaded in Step (6a) into the statistics program *SPSS* or in step (6b) into the numeric program *SciLab*. It comes in step (7a) or (7b) to the *correlation and regression analysis* by using the numeric program SciLab or SPSS, in which some queries (e.g. the categorization of the countries after economy performance) also take place in step (7c) directly at the Access DB.

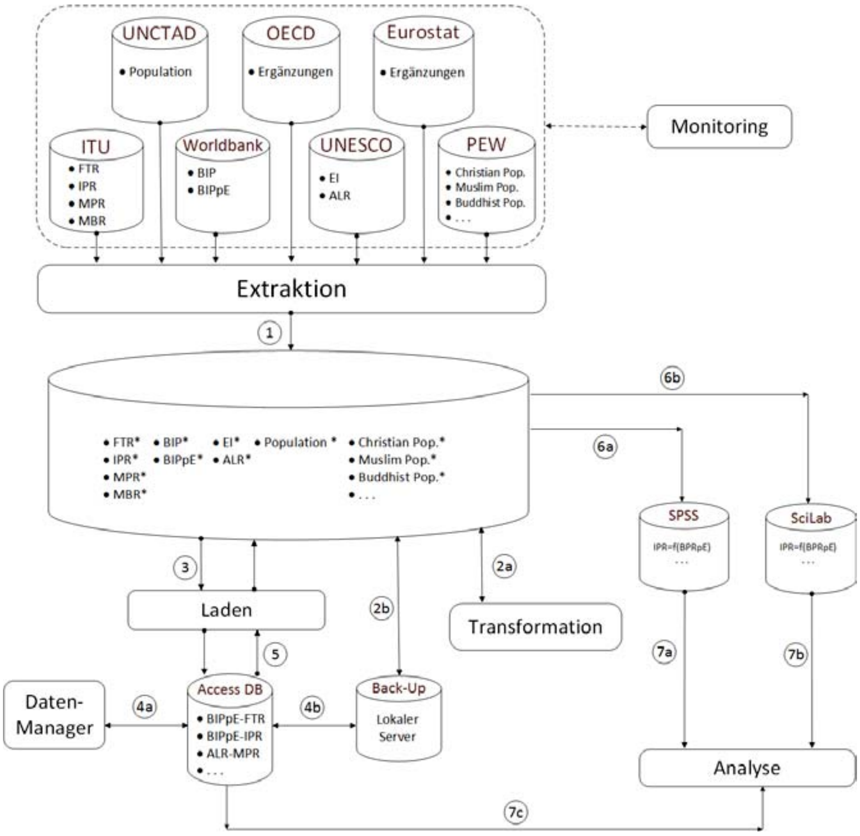

Figure 1. Adapted ETL-process.

Correlation quantifies the degree to which two variables are related, and this regards a linear form of mutual dependency [8] [23]. Regression finds the best line or function (method of least squares), which predict the dependent variable from the independent variable [117] [22]. The best fit function from the class of (test) functions is determined by using the least squares method. For this purpose, one minimizes the sum of the mean square of errors (*MSE*), wherein the coefficient of determination (*R2*) is a quality measure for the adaption of individual functions. The function which fits most to the data by means of method of least squares is then finally used for the relation between the dependent (e.g. mobile phone usage) and independent variable (e.g. literacy) in a certain year. A lot of known functions in the fields of economy, natural, physical and social science are used to identify the relation between technology penetration and different factors in a country. Interdisciplinary reasons for using some known functions are as follows:

1. Linear functions are easy and one of the first approach, if humans try to understand real-life phenomena with given data.
2. Exponential functions are often used to represent growth and decay, like population growth or depreciations

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3. Logarithmic functions are commonplace in scientific formulae, and in measurements of the complexity of algorithms and in many other different applications like in the measurement of earthquakes and sound
4. Logistic functions are used to model real-life quantities whose growth levels off because the rate of growth changes, from an increasing growth rate to a decreasing growth rate.
5. Planck's law describes originally the electromagnetic radiation emitted by a black body in thermal equilibrium at a definite temperature. Anyway, in general, it describes an initial increase of the dependent variable at higher levels of the independent variable, and then a decrease of the dependent variable at higher levels of the independent variable.

Function	**Formular**
1. Linear	$y_i = a + b \cdot x_i + \varepsilon_i$
2. Exponential	$y_i = a + b \cdot e^{(c \cdot x_i - d)} + \varepsilon_i$
3. Logarithmic	$y_i = a + b \cdot \log(x_i - c) + \varepsilon_i$
4. Logistic	$y_i = \dfrac{a}{b + c \cdot e^{(d \cdot x_i)}} + \varepsilon_i$
5. Planck´s Law	$y_i = \dfrac{a \cdot x_i^b}{c \cdot e^{(d \cdot x_i)} - 1} + \varepsilon_i$

Only bivariate correlations between two variables can be examined with a correlation coefficient and simple linear regression. If one would like to investigate on the relationship between several variables, there is the so-called multivariate and multiple regression analysis. There is a dependent variable Z (e.g. IPR) and two independent variables (e.g. GDPpC and Education Index). Furthermore, it is assumed that a simple regression analysis for the relationship between the internet user rate and the GDPpC provides a non-linear function *f(x)*. The function *g(y)* corresponds to the non-linear relationship between the IPR and the Education Index. The corresponding multiple regression model with the corresponding weights A and B is:

$$\boxed{Z = A \cdot f(x) + B \cdot g(y)}$$

The underlying functions *f(x)* and *g(y)* are of e.g. 3-parametric logarithmic type:

$$\begin{aligned} z.B: f(x) &= a + b \cdot \log(x - c) \\ g(y) &= d + e \cdot \log(y - h) \\ \Rightarrow Z &= A \cdot (a + b \cdot \log(x \cdot c)) + B \cdot (d + e \cdot \log(y - h)) \end{aligned}$$

Now, based on the method of least squares it is to minimize the function $\varphi(A, B)$:

$$\sum_{i=1}^{n} (z_i - A \cdot f(x_i) - B \cdot g(y_i))^2 = \varphi(A, B) \rightarrow min$$

For this we calculate the partial derivatives of $\varphi(A, B)$ below. These equations are set to zero to find the appropriate minimum.

$$\frac{\partial\varphi}{\partial A} = 2 \cdot \sum_{i=1}^{n} (z_i - A \cdot f(x_i) - B \cdot g(y_i)) \cdot f(x_i) \stackrel{!}{=} 0$$

$$\Rightarrow \sum_{i=1}^{n} z_i \cdot f(x_i) = \left(\sum_{i=1}^{n} f^2(x_i), \sum_{i=1}^{n} g(y_i) \cdot f(x_i) \right) \cdot \begin{pmatrix} A \\ B \end{pmatrix}$$

$$\frac{\partial\varphi}{\partial B} \stackrel{!}{=} 0$$

$$\Rightarrow \sum_{i=1}^{n} z_i \cdot g(y_i) = \left(\sum_{i=1}^{n} g(y_i) \cdot f(x_i), \sum_{i=1}^{n} g^2(y_i) \right) \cdot \begin{pmatrix} A \\ B \end{pmatrix}$$

The result is a system of equations, which delivers the regression weights A and B after its resolution according to the following procedure.

$$\begin{pmatrix} \sum_{i=1}^{n} x_i^{*2} & \sum_{i=1}^{n} x_i^* y_i^* \\ \sum_{i=1}^{n} x_i^* y_i^* & \sum_{i=1}^{n} y_i^{*2} \end{pmatrix} \cdot \begin{pmatrix} A \\ B \end{pmatrix} = \underbrace{\begin{pmatrix} \sum f^2(x_i) & \sum f(x_i) g(y_i) \\ \sum f(x_i) g(y_i) & \sum g^2(y_i) \end{pmatrix}}_{=N} \cdot \begin{pmatrix} A \\ B \end{pmatrix}$$

$$= \underbrace{\begin{pmatrix} \sum z_i f(x_i) \\ \sum z_i g(y_i) \end{pmatrix}}_{=\beta} = \begin{pmatrix} \sum z_i x_i^* \\ \sum z_i y_i^* \end{pmatrix}$$

$$\boxed{\Rightarrow \begin{pmatrix} A \\ B \end{pmatrix} = \beta N^{-1}}$$

In doing so, we can find out the different importance (weight) of economic level and education standard for the deployment of the Internet in a country. Certainly there is also a relation between the economic power and the education level of a country. Based on the findings of this work and the different importance of economy and education for the deployment of ICT, in particular mobile phone usage and Internet penetration, it was able to suggest or advice important decision makers and international organisations, such as at the Internet Governance Forum in 2014 (Turkey) and 2015 (Brazil) or at UN/G20/OECD level.

3. Literature Overview and Distinction

In the 1990s, the term '*digital divide*' emerged to describe technology haves and have-nots. Current research regarding digital divide has a descriptive character. Those studies emphasize the digital divide by using demographical, economical or educational data, in general at an individual level of technology usage or digital skills of people in a country [2]. This study investigates the digital divide more from the perspective of '*digital inequality*'. There are mainly four successive kinds of access in the appropriation of digital technology [7]. These kinds of access are a) *motivation*, b) *physical* and *material access*, c) *digital skills* and d) *digital usage*. Here, the focus is on access types b) and c) by searching for functional relations between the economic power, education level and technology penetration rates of countries. It is assumed that the digital skills of a society are higher, if the education level of this society is higher. Physical and material access corresponds to mobile phone usage rate (MPR) and Internet penetration rate (IPR).

A number of empirical studies have been done on the topic of digital divide. A few of them highlighted that income level [1] [2], income distribution [9] [36], education level [5] [10] [21], size of population [28] and urbanization [3] have essential correlation with Internet penetration levels of countries. Andres et al. [2] stated that low-income countries have a steeper Internet diffusion curve than that of high-income countries. Although this result is rational, because low-income countries can '*leapfrog*' technological developments, it has to be mentioned, that the splitting to only two categories of income levels is questionable. Zhang [36] found out a positive contribution of GDP per capita (PPP, current int.$) to IPR and a negative influence of income distribution measured by the Gini-Index. Here it should be noted; a higher average income corresponds to a more equal income distribution in general [18] and that's not discussed anyway in the results of Zhang. Furthermore he did not explain the relation between GDP per capita and Internet penetration in form of a detailed function. Kiiski et. al. [21] showed that the average years of schooling is considerably a positive factor for the Internet hosts per capita in a country. Even so another study find out that the degree to which the difference in Internet rates depends upon education level is surprisingly small [6]. This is in contrast to our findings.

In the past, studies about using technology acceptance explain, how attitudes determine Internet penetration [3]. Such studies show, that some of the faster rates of growth in Internet use have been among individuals who are older, less educated, of minority status or with lower incomes. A similar research work to this study examines the relation of the Internet penetration rate with the human development level over the decade from 2000 through 2010 [25]. These results support the argument that a digital divide exists between developed and developing countries. The main outcomes of this study are that there is a positive correlation between human development level and Internet penetration rate and that the correlation has become slightly stronger from 2000 through 2010.

However, Internet Usage rates associated with these demographic groups are lower than that of the general population [24]. Another study points out, that more educated people use the Internet more actively and their use is more information oriented, whereas the less educated seem to be interested particularly in the entertainment functions of the Internet. If we look to the digital divide with respect to Internet penetration, there is still an inequality between developed and developing countries [25].

However, there seems to be no related scientific work analyzing the empirical relation between education index and Internet penetration, especially over the decade from 2000 through 2012. Therefore, this issue is tackled in this study. Furthermore, most of the related work describes the relation between economical development, education level and Internet penetration with linear regression functions and with logarithmic or exponential functions. In this study, more non-linear regression models like the logistic function or functions according to Planck's law are used to describe the relation between the different parameters in detail. Specifically the multivariate regression analysis for the relation between the ICT penetration rates as the dependent and education level and income situation as the different independent variables (described by non-linear regression functions), is a essential contribution to the scientific field related to digital divide or digital inequality.

4. Empirical Results and Functional Analysis

4.1 Relation between Economic Power and ICT usage

4.1.1 GDPpC and Mobile telephony (MPR)

Table 1 shows the number N of analyzed countries, the minimum (min), maximum (max), span (sp), mean (av), median (md) and standard deviation (sta) for the GDP per capita (GDPpC) and mobile penetration rate (MPR) in a worldwide perspective in the years 2000 and 2013.

Table 1. Descriptive statistics of mobile penetration rate (MPR) and GDP per capita (GDPpC)in year 2000 and 2013.

	2000 (N=177)						**2013 (N=178)**					
	sp	min	max	av	md	sta	sp	min	max	av	md	sta
GDPpc	90636	270	91011	10955	5702	14434	131154	603	131757	17898	11764	19760
MPR	79.68	0.01	79.69	15.89	4.46	22.63	233.07	5.61	238.68	101.48	106.09	38.77

If one describes the worldwide digital inequality in the context of *MPR* and the average *GDPpC* with the help of *sp* and *sta* as easy dispersion metrics, it turns out that the inequality in the use of mobile phones has increased between 2000 and 2013, whereas also the inequality regarding the *GDPpC* increased. Looking closer at the data for the year 2000 in *figure 1* one can recognize that states with a low *GDPpC* have low *MPR*. The greater the *GDPpC* values become, the greater also the *MPR* values become. Moving into the direction of higher *GDPpC* the *MPR* first reaches a maximum and afterwards drops again. In this initial situation the *Planck's function* (black) returns a very good adjustment (within the considered class of functions and according to the method of the squares) of the relationship between the *GDPpC* and the *MPR* in 2000.

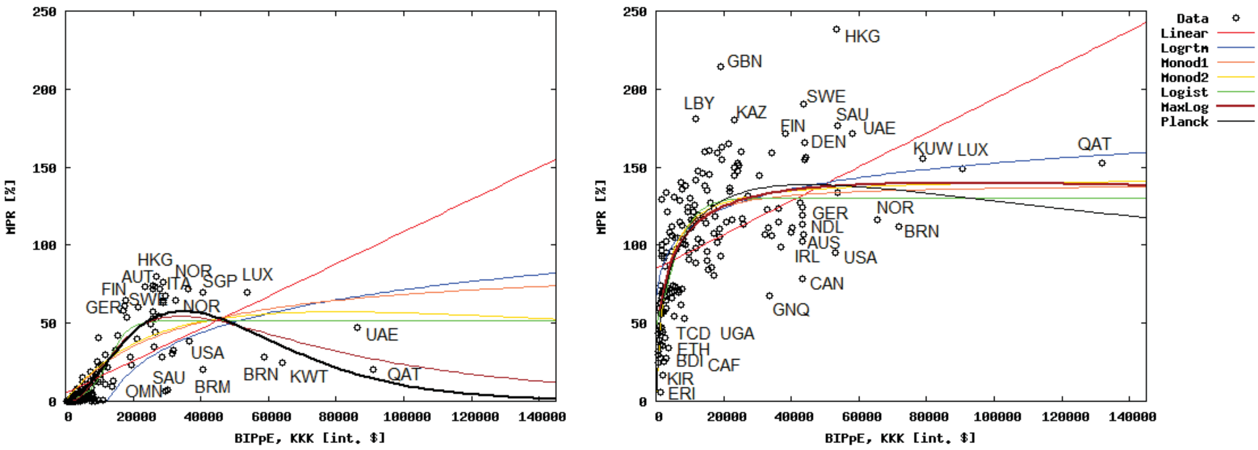

Figure 1. mobile phone penetration rate (MPR) as a function of GDP per Capita (GDPpC), year 2000 (left) und 2013 (right).

More than a decade later, a first observation is that the data concerning 2013 reach significantly higher values for MPR than the data in 2000. Furthermore the MPR is over 100% in many countries in 2013. This means that there is averaged more than one mobile device per person in a country. Overall, all states have increased their MPR, so that the catch-up in the mobile phone usage is very clear worldwide. In *figure 1* is also a list of selected functions such as *linear* (red), *logrtm* (blue), *monod1* (pink), *monod2* (gold), *logist* (green), *maxLog* (brown) und *Planck* (black). The 4-parameter function in equation 5 (see section 1.2) with the parameters a, b, c, and d (expression of the Planck function) delivers the best fit for 2000. After verification of the particular functions for each year between 2000 and 2013, it turns out that only in 2013 the *maxLog* function delivers a better adaptation than the *Planck* function. *Table 2* shows the different fitting functions and the associated values for the sum of squared errors (*MSE* or *MSE/N*) and the coefficient of determination (*R2*).

Table 2. Sum of mean square of errors (MSE) and coefficient of determination (R2) for regression MPR = f(BIPpK)

	2000 (N=177)			2013 (N=178)		
	MSE	MSE/N	R^2	MSE	MSE/N	R^2
Linear	48565	274.4	0.439	209077	1174.6	0.281
Logartm	32312	182.6	0.627	147529	828.8	0.439
Monod1	32674	184.6	0.622	148515	111.4	0.489
Monod2	30556	172.6	0.647	148515	105.3	0.489
Logist	21324	120.5	0.754	150714	102.8	0.482
MaxLog	21471	121.3	0.752	**148380**	**105.2**	**0.491**
Planck	**20788**	**117.4**	**0.760**	151586	101.2	0.479

In *figure 2* one can study the development of the best fit functions for the relationship between *GDPpC* and *MPR* from 2000 (blue) till 2013 (black). The result shows that the MPR has increased in all areas of *GDPpC* from year to year and has taken a similarly good development over all *GDPpC* ranges in more than a decade. This result is not only an artefact of the adaptation in the optimisation process; rather the investigation of the database laid for this optimisation delivers the same result. Based on *figure 2* one can recognise, that the *MPR* has raised over all *GDPpC* areas i.e. accordingly in all countries. This can be seen on the one hand in the higher course of the curve for 2013 (black) as the curve course for 2000 (blue). On the other hand, the data points for the year 2000 (blue) are not or barely overlaid with those data points for 2013. In relative terms, the shift of centre of data is stronger upwards (in the direction of *MPR*) than to the right (in the direction of *GDP*).

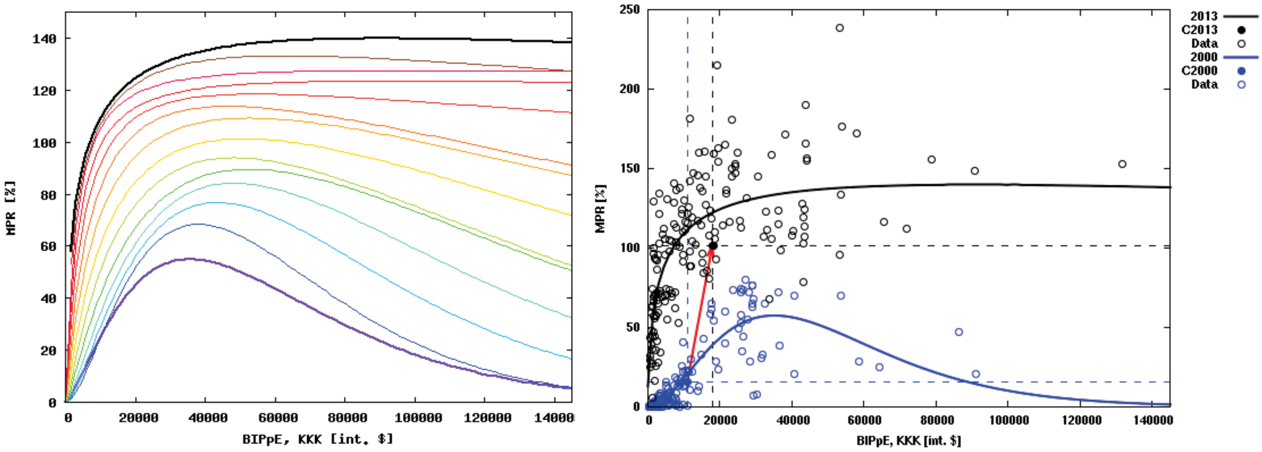

Figure 2. development of mobile phone penetration rate (MPR) as a function of GDP per Capita (GDPpC) between 2000 and 2013 (left); data points, best fit function, centre (right).

If one performs a growth analysis over the whole time from 2000 to 2013 for the *GDPpC* and the *MPR* in the suitable *GDPpC* categories A, B, C, D and E, where category A stands for the richest and category E for the poorest countries, one is able to examine, to what extent the *GDP* growth and the *MPR* growth are connected within and between these categories. The bar chart in figure 3 shows on the x-axis, the respective *GDPpC* category and on the y-axis the growth of *GDPpC* (blue) and *MPR* (burgundy). Hence the highest growth of *GDPpC* and MPR took place in category C (medium *GDPpC*). Both growth rates lie in category C with about 112 %. In the categoryA (highest *GDPpC*) and B (high *GDPpC*) is a similarly high *MPR* growth of approx. 94% and 94. 5%, whereby the *GDPpC* growth lies in category A with about 62 % and in category B with approx. 100 %. The *GDPpC* growth is in category D (low *BIPpE*) 109 % with a MPR-growth of 90 %. In category E (lowest *GDP*) was held the slightest *MPR* growth, namely by about 65 % with a *GDPpC* growth of nearly 77 %. The result indicates that the *GDP* and the *MPR* growth have a strong coherence (high correlation), especially if one does not consider the richest countries (category A). This does not surprise if one minds that the richest states can not show such a high performance as economically weaker states, because they start from a clearly higher level of *GDPpC*.

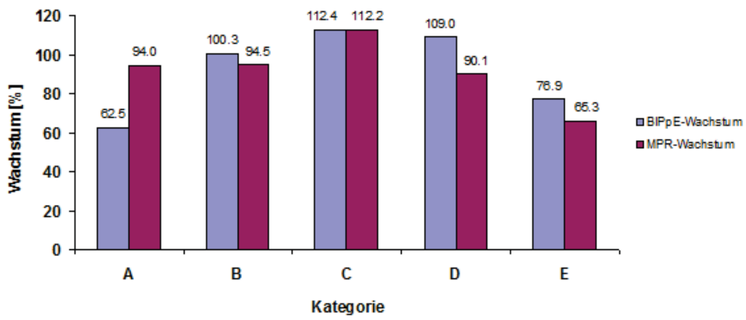

Figure 3. Growth rate (total) for GDPpC (blue) and MPR (burgundy) between 2000 and 2013.

This study confirms to some extent the assumption or hypothesis, that the catching up generally in the use of ICT and in particular in the mobile phone usage runs faster worldwide than catching up with respect to prosperity in general. The size and/or the growth/shrinking of the population have no significant influence on the *MPR*. A hypothesis represented in this work is that we will experience a convergence in the ICT use. This thesis is confirmed so far for the mobile phone usage, as that in 2013 the worldwide average *MPR* has reached about 100 % and that the *MPR* growth between 2000 and 2013 over all *GDPpC* areas took place at a similarly high level, also due to the fact that in many countries there is more than one mobile phone connection and that the availability of prepaid systems has favoured the mobile phone usage in the poorer regions of the world ('mobile miracle'). In this context today one can describe the situation in the following way: The world population calls up mobile and has carried out the jump of the local-engaged communication (fixed network) to the person engaged communication (mobile phone).

4.1.2 GDPpC and Internet Usage (IPR)

Aberrantly to the considerations in the previous section, the question gets answered, how big the amount of a country is in the world gross domestic product (world GDP) and which amount a country has in the worldwide Internet users (world IPR). The population size is factored out in the considerations of the economic achievement and the Internet usage. *Figure 4* shows on x-axis the economic achievement of a country as a portion in the world *GDP* and on the y- axis the Internet usage extent of a country as a portion in the world IPR in the year 2000 (left) and 2013 (right).

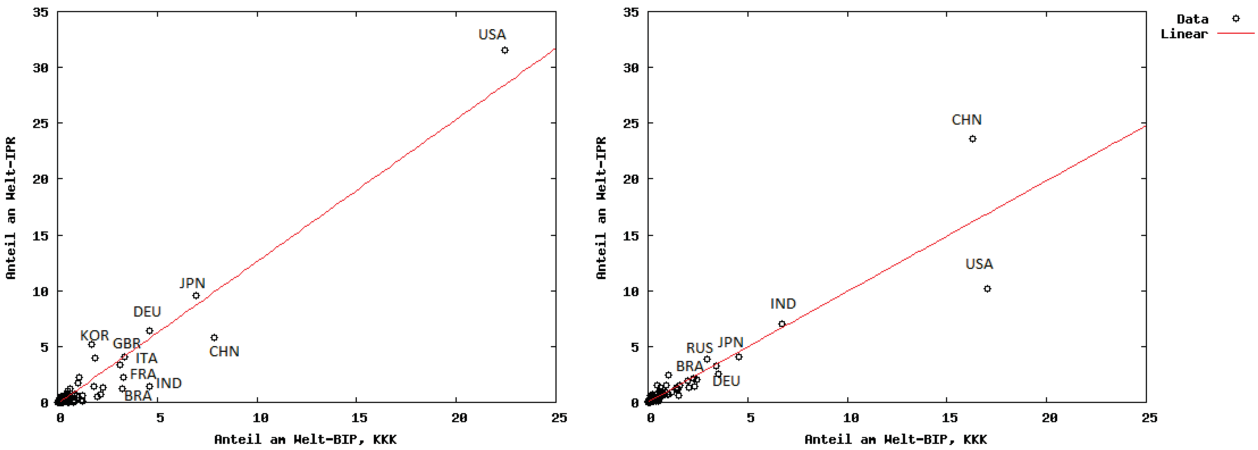

Figure 4. Proportion of world IPR as a function of the proportion of world GDP, 2000 (left) and 2013 (right).

The United States has accounted for about 23 % of world economic output and about 30 % of Internet users (worldwide). If one divides the states into one group above and one below the regression line, the USA, Japan, Britain and Korea are located above and states like China, India, Brazil, Russia and the so-called BRIC states, but also France and Italy below the line. As *figure 4* shows, there is a high correlation in the year 2000. Furthermore, it is in such a way, that the relations after 13-year development in 2013 still can be described well by a linear model, i.e. that still a high correlation is given. This easy analysis points to a narrow respect between the economic power of a country and the Internet use in this country. This is also valid, if one ignores the population number with regard to the economic power. In a per capita consideration the differences between the richer and poorer countries are still much greater. This is also due to the large population of countries such as China and India. It is interesting in this context that in 2013 all the BRIC countries are above the linear regression model and the USA, Japan and Germany lie under it. This development is a consequence of that the BRIC states, which have a relatively large population, increased their IPR between 2000 and 2013 significantly. Since the alignment of communication is still faster than the economic performance, the size of population of BRIC states leads to a correspondingly large Internet population.

Table 3 shows for the *GDPpC* and the *IPR* the values of the descriptive statistics. The *IPR* has in 2000 a maximum of 52% (Norway) and this value increases till 2013 to approximately 96.5% (Iceland). The *IPR* minimum value of 0.01% (Dem. Rep. of Congo) in 2000 increases slightly and is almost 1% (Eritrea) in 2013. There are again the African countries, as in the *MPR*, which have the lowest values for the *IPR*. The average increases over the same period from nearly 8% to about 41.6%. It is interesting, that the median of 39.2% in 2013 is nearly at the same level as the average value, although the median of nearly

2% in 2000 is on a four times lower level as the average. This is a consequence of the significantly higher balance of the proportions till 2013, as further noted in another context above.

Table 3. Descriptive statistics of Internet penetration rate (IPR) and GDP per capita (GDPpC)in year 2000 and 2013.

	2000 (N=177)						2013 (N=181)					
	sp	min	max	av	md	sta	sp	min	max	av	md	sta
GDPpC	90741	270	91011	10919	5732	14351	141961	603	142564	18484	11653	21728
IPR	51.99	0.01	52.00	7.97	1.98	12.91	95.65	0.90	96.54	41.57	39.20	29.02

We consider further in detail the empirical relationship between *GDPpC* and *IPR* per country. Here are significantly greater differences to be expected, as above in considering the economic output (*GDP*) of each state. The relationship is no longer linear. In *figure 4.12* (left), it is evident that states with a lower *GDPpC* have a lower *IPR*. The greater the value of the *GDPpC* becomes, the greater also becomes the IPR, indeed, for quite big values of the *GDPpC* it falls again. This is not surprising in this respect, as nearly every Internet access in year 2000 occurred via a fixed network connection by dial-up (modem). The mobile Internet access hardly existed worldwide. So the fixed network was a necessary condition for the Internet connection, which was (only) developed in richer countries. The Scandinavian countries Denmark, Sweden, Norway and Finland have worldwide one of the highest IPR in 2000. But also Australia, Germany, Great Britain, Japan, Canada, Korea, Switzerland, Singapore and the USA have high values for the *IPR*. There are countries such as Bahrain, Brunei, Kuwait, Oman, Saudi Arabia, and the United Arab Emirates, but also surprisingly Luxembourg, which have a high *GDPpC* and in relation to this huge *GDPpC* value a relatively low *IPR* value compared to the remaining rich states. These are primarily the oil states that enforce a form of Planck's function for the relationship between *GDPpC* and *IPR*. Reason is found in the in parts of nature ‘borrowed’ prosperity, mainly resulting from the sale of oil and gas, not from an internationally competitive, diversified productive economy, which itself would require massive dissemination of technology, Internet usage and innovation in this area.

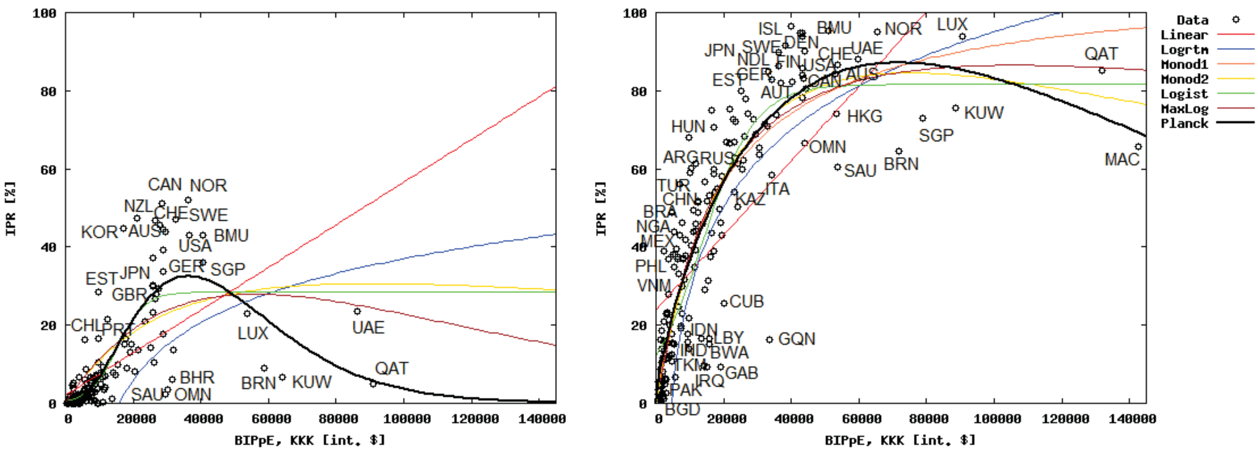

Figure 5. Internet penetration rate (IPR) as a function of GDP per Capita (GDPpC), year 2000 (left) und 2013 (right).

The values for the *IPR* have in 2013 increased significantly compared to 2000. The statement from 2000 that states with low *GDPpC* have a rather low *IPR* is also valid for 2013, in spite of occurred catching-up processes. Furthermore the obvious correlation is valid that higher *GDPpC* values cause higher *IPR* values. Table 4.12 lists the results of the regression analysis with the values for the sum of squared errors (*MSE* or *MSE/N*) and the coefficient of determination (R2) for all functions tested for the years 2000 and 2013. As already mentioned, the *Planck* function fits best, followed by the functions *maxlog* and *logist* with a similarly good adjustment in 2000. In 2013, the *Planck* function again has the best fit, but also the rest of the tested functions, except for the linear, describe the relationship similarly

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well. This points to the fact that the functions with an inhibition lose relatively in strength and functions with saturation win relatively in strength for this relationship.

Table 4. Sum of mean square of errors (MSE) and coefficient of determination (R2) for regression MPR = f(BIPpK).

	2000 (N=177)			2013 (N=178)		
	MSE	MSE/N	R^2	MSE	MSE/N	R^2
Linear	18440	104.2	0.372	74357	410.8	0.509
Logartm	14177	80.10	0.517	35274	194.9	0.767
Monod1	14292	80.75	0.513	33760	186.5	0.777
Monod2	13690	77.34	0.534	32466	179.4	0.786
Logist	10946	61.84	0.627	35212	194.5	0.768
MaxLog	10261	57.97	0.651	33032	182.5	0.782
Planck	**9760**	**55.14**	**0.668**	**32011**	**176.9**	**0.789**

Figure 6 shows the development of the best fit function for 2000 (blue) to 2013 (black). For all years between 2000 and 2013 the Planck function achieves the best fit. The results for the fit functions show that the *IPR* has expanded similar for all *GDPpC* areas between 2000 and 2007. The (Planck) fitting functions for the years 2008 and 2009 run in this respect slightly differently, because states with the biggest *GDPpC* have lower *IPR* values, than during the years before. However, this is not appropriate as the data show. So this is an artefact of the regression optimization. This results from the fact that the countries in the medium *GDPpC* area between 2008 and 2009 tend to have a larger (relative) increase in their *IPR* than the countries in the top *GDPpC* area. The reasons for this are to be found in the beginning of the mobile Internet usage in countries with a medium *GDPpC*. One can observe the same phenomenon in 2013.

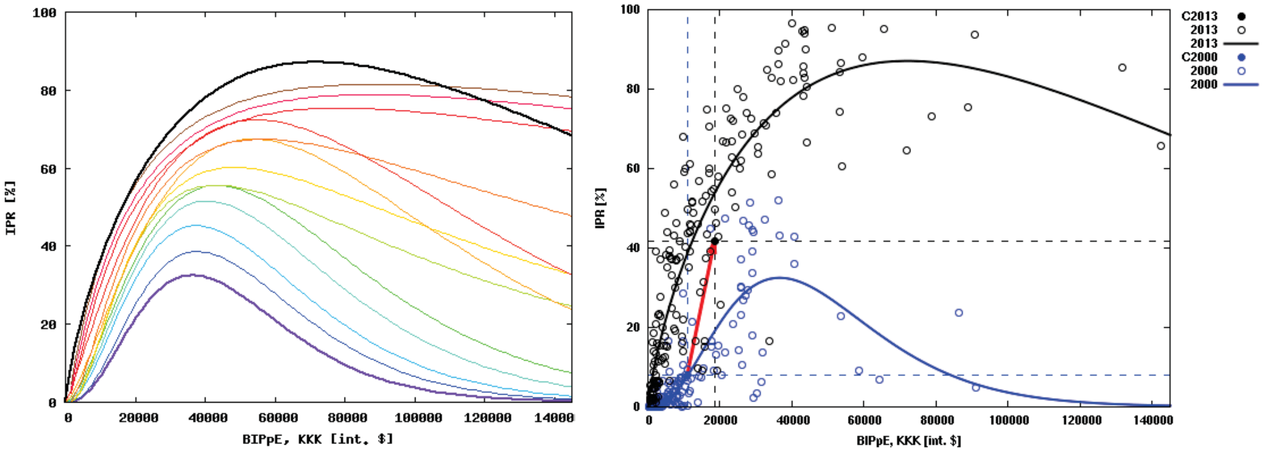

Figure 6. Development of Internet penetration rate (IPR) as a function of GDP per Capita (GDPpC) between 2000 and 2013 (left); data points, best fit function, centre (right)

In *figure 6* is to be recognised once more that the *IPR* increased over all *GDPpC* areas in all countries. The curve for 2000 (blue) runs clearly below the curve for 2013 (black) and there is no intersection of the curves. Furthermore, there is hardly a superposition of the two point clouds. The shift of focus is more upwards (towards *IPR*) than to the right (towards *GDPpC*) relatively regarded.

If one carries out a growth analysis from 2000 to 2013 for the *GDP* and the *IPR* in the corresponding *GDPpC* categories A, B, C, D and E (division, see appendix A.1) the relationship between *GDP* growth and *IPR* growth can be specified. Figure 4.15 shows on the x-axis the respective *GDPpC* category and on the y-axis the growth rates for the *GDPpC* (blue) and the *IPR* (red). The respective number refers to the overall growth between 2000 and 2013. Here category A stands for the richest and category E for the poorest countries.

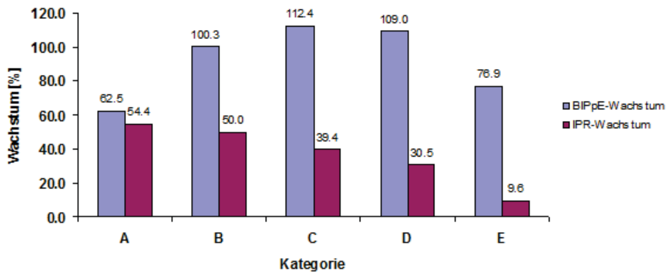

Figure 7. Growth rate (total) for GDPpC (blue) and IPR (burgundy) between 2000 and 2013.

The highest average IPR growth of 54.4% took place in the highest GDPpC category A, but in this category also the slightest GDPpC growth of 62.5% is given what, nevertheless, absolutely means a high growth, because the richest countries have a higher starting level than poorer countries. This finding is interesting that the average (absolute) IPR growth is lower, the poorer the group of states is. This means that in category B, the second strongest IPR growth takes place with 50%, followed by the category C with 39.4%, category D with 30.5% and category E with 9.6%. On the one hand the thesis that the catching-up in the usage of Internet gets confirmed generally. But on the other hand this finding shows that regarding to the global spread of Internet access, especially in the developing countries still much is to be done. In summary, the empirical relationship between the GDP and the IPR both in 2000 and in 2013 is positive. The Planck function modelled this context (within the considered class of functions) best for all years from 2000 to 2013. The course of the Planck function in 2000 is similar to the the one of the relationship between the GDPpC and FTR, suggesting also the then existing physical connection of Internet and Fixed Telephony (see section 4.4.2). Up to 2013 almost all states have increased their IPR and on average the richest states show the highest rise and the poorest states the lowest. With the relative increase it is exactly the reverse. This observation underlines the thesis that the catching-up in Internet usage around the world runs (clearly) faster than catching up with regard to prosperity in general.

4.2 Relation between Education Level and ICT usage

In a society and culture that is dependent on the written language in addition to oral communication, the literacy of people is a distinct advantage compared to illiteracy. The use of the Internet for example is restricted significantly for illiterate people, because it works on a text-based nature until today mainly. As a comparison, the use of fixed or mobile phones requires (almost) no literacy skills.

4.2.1 Literacy and Mobile Telephony

To use the mobile phone, you have to be able to identify at least the digits 0 to 9. This requires no skills for reading and writing of letters or words. The identification of numbers and corresponding basic operations such as adding numbers is part of skills are indicated in the adult literacy rate (*ALR*). It is expected that the empirical relationship between the *ALR* and the mobile phone rate (MPR) is low, but should be lower in 2012 or functionally run significantly different than in 2000. The reason for this is the rapid spread of mobile telephony in this period across all countries in the world, also within illiterate people. Table 5 shows the descriptive statistics for the intersection of the data for ALR and MPR for the years 2000 and 2012.

Table 5. Descriptive statistics of adult literacy rate (ALR) and mobile phone penetration rate, year 2000 and 2013.

	2000 (N=148)						2012 (N=153)					
	sp	min	max	av	md	sta	sp	min	max	av	md	sta
ALR	90.3	9.54	99.79	81.99	89.79	20.87	68.48	31.37	99.85	86.05	93.80	16.91
MPR	76.39	0.02	76.41	17.52	5.64	23.37	182.43	4.98	187.41	102.55	106.17	40.46

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In 2000, the global average *ALR* is about 81.2%, while this rate increased to about 86.2% in 2012, although in the same period, the world population has increased by almost 16% from 6 to 7 billion people. Worldwide development programs relating to the MDGs and similar campaigns contribute to this progress. The *sp* of the *ALR* has decreased worldwide from about 90% to almost 70%, which is also a positive signal in the direction of improving global levels of education. The data confirms that most countries with a low *ALR* are located on the African continent. In Africa, the high population growth is a major challenge when it comes to increase the *ALR* in total. The Baltic countries belong to the countries with the highest *ALR*. These high values for the *ALR* are also consequences of the culturally high importance of education in the old Soviet Union. In both years the median value is with 89.1% in 2000 and 93.8% in 2012 slightly higher than the average. Most times it is the other way round, for example, at income distributions, i.e. the average is (often significantly) higher than the median.

What is it the reasoning? In many distribution situations there are great outliers upwards as very high incomes that amount a multiple of the average income. In the present education data it is different. Almost all states are with regard to the *ALR* anyway at a level greater than 50%, many greater than 80%. An *ALR* = 100% is the upper limit. There are no outliers upwards, only those down. The median is about 90% in 2000. The mean value is therefore determined by smaller ALR close to 50% and lower. This drives the mean value downwards in the direction of about 80%, what is less than the median. In 2000 the data points are strewn along the ALR and MPR axis, which is why the exponential model and the power function describe the relation well, which means that only for high values of the ALR also accordingly high values of the MPR are reached. It is probably the case that in 2000 the mobile telephony was closely linked for financial reasons with the fixed telephony, although the respective physical infrastructure was decoupled.

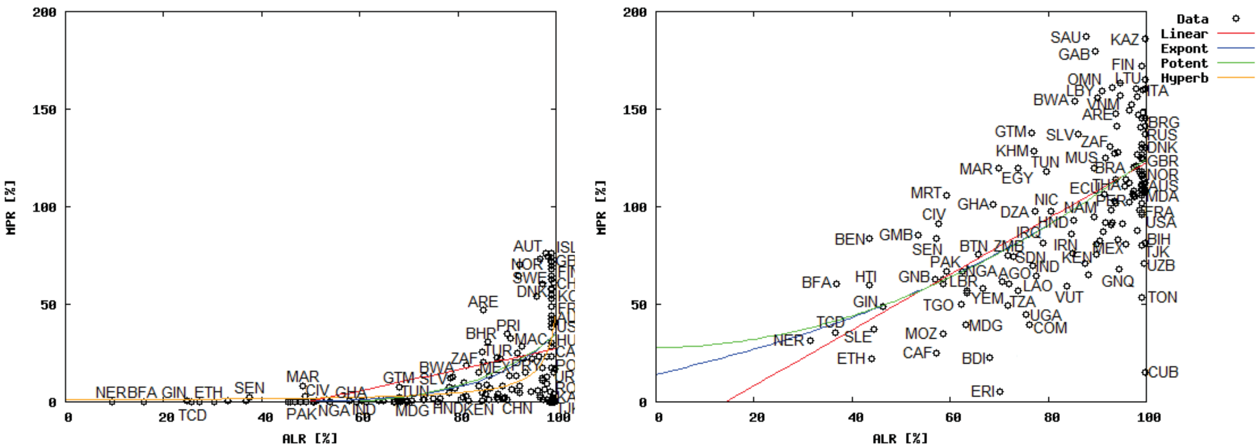

Figure 8. Mobile phone penetration rate (MPR) as a function of GDP per capita (GDPpC), year 2000 (left) and 2013 (right).

The relationship between the ALR and MPR changes up to 2012 so far that also for relatively low values of the ALR high values of the MPR exists. This change is clearly visible in the functional modelling of the relationship between ALR and MPR, because in 2012 the linear, exponential and power function have almost identical values for the sum of squared errors (MSE or MSE / n) and the coefficient of determination (R2).

Table 6. Sum of mean square of errors (MSE) and coefficient of determination (R2) for regression MPR = f(ALR).

	2000 (N=148)			2012 (N=153)		
	MSE	MSE/N	R^2	MSE	MSE/N	R^2
Linear	61603	416.2	0.232	160139	1046.6	0.357
Expont	54214	366.3	0.324	159100	1039.8	0.361
Power	54311	366.9	0.323	158923	1038.7	0.361

Catching up in the mobile telephony use in the developing and emerging countries in which worldwide most illiterates live, decisively contributes to this positive development. The 100% mark of the MPR is achieved from an ALR of about 60%.

4.2.1 Education Index and Internet Usage

The use of the Internet still requires at least the ability to read and to write. But what is the functional relationship between the Internet penetration rate (*IPR*) and the level of education as measured by the Education Index (*EI*)? A basic thesis is as follows: The higher the *EI* of countries is, the higher the *IPR* should be. Another theory, which is described on the basic thesis with the importance of the educational level of countries for the *IPR* decreases continuously between 2000 and 2012 and will most likely decrease in the future. Table 4.31 shows the descriptive statistics for the intersection of the data for *EI* and *IPR* for the years 2000 and 2012.

Table 7. Descriptive statistics of Internet penetration rate (IPR) and Education Index (EI), year 2000 and 2012.

	2000 (N=161)						2012 (N=174)					
	sp	min	max	av	md	sta	sp	min	max	av	md	sta
EI	0.863	0.111	0.974	0.579	0.605	0.213	0.812	0.177	0.989	0.6487	0.685	0.202
IPR	51.98	0.02	52.00	8.14	1.98	13.12	95.41	0.8	96.21	39.02	36.38	28.42

A first sight at the point cloud in figure xx shows that in both years a positive correlation exists between the EI and the IPR. If one looks at the previous section 4.2.5 about the relationship between the educational standard, measured by the Alphabetization Rate (ALR), and the IPR, the _rst di_erence is to be observed here. While indeed a high ALR is a necessary but not a su_cient condition for a high IPR, you have at the top of EI also correspondingly high, but no low values for the IPR in 2000. One can see this also in the fact that many data points are spread along the EI axis up to a value of about 0.6 and up from this EI value the IPR increases. A compression of the data along the IPR axis is here, as opposed to the correlation between ALR and IPR, in 2012 not available. One also notes this di_erence with the comparison of the single regression models. The hyperbolic function (yellow green) delivers the worst adaptation for the connection between EI and IPR.22 The relationship between EI and the IPR is modelled with the help of a power function (green) best of all, followed by the exponential function (blue) which is almost as good as the power function. The linear regression model delivers (red) only partly a good adaptation (see table 8).

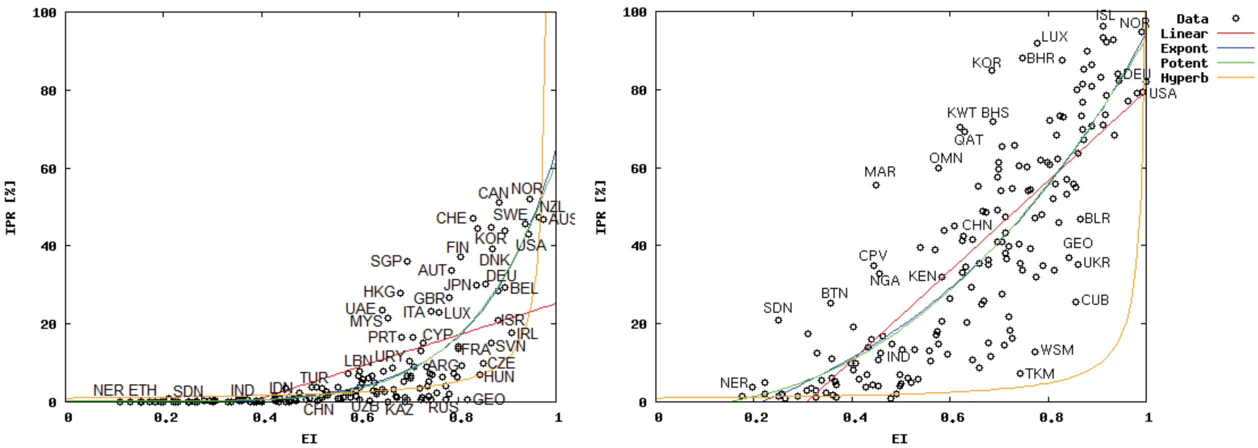

Figure 9. Internet penetration rate (IPR) as a Education Index (EI), year 2000 (left) and 2012 (right).

Table 8. Sum of mean square of errors (MSE) and coefficient of determination (R2) for regression IPR = f(EI)

	2000 (N=161)			2012 (N=174)		
	MSE	MSE/N	R^2	MSE	MSE/N	R^2
Linear	15623	97.04	0.433	46135	265.14	0.670
Expont	8859	55.02	0.678	42011	241.44	0.699
Potent	**8818**	**54.77**	**0.680**	**41817**	**240.33**	**0.701**
Hyperb	19429	120.68	0.294	312670	1796.95	-0.168

Up to 2012 the dispersion of the point cloud changes what is to be seen good optically. The power function gives in 2012, as well as in 2000, the best fit within the considered class of functions. The exponential function delivers the second-best adapting. The linear model approximates the data in 2012 significantly better than in 2000. Basically all three functions deliver a similarly good modelling of the connection between the EI and the IPR. A high EI delivers a high value of the IPR and, however, already a middle EI level is sufficient to reach rather high values of the IPR. Countries with a low EI also tend to have a low IPR, although there are also countries that, despite a relatively low EI have rather high values for their IPR. Catching up in Internet use has progressed worldwide for all countries faster than the development in the area of education. This fact suggests that global convergence processes in Internet use run significantly faster than the convergence in the context of education. Interesting is the negative value of the coefficient of determination (R2), which is obtained for the hyperbolic function in 2012 (see *table 8*) and occurs in this work for the first time in this form. This is first contra intuitive, because one would think the R2 to be a squared size, because it's symbolic description. This would then always have values greater than or equal to zero. However, this is not the case here. It does not concern a size in the square, but from the definition follows that in the case in which the adaptation of a function to the data is worse than a horizontal line at the level of the average value, the size R2 is negative. In this example one can interpret this as follows: The negative value of the R2 says that the carried out modelling of the data with certain (here as hyperbolic assumed) function is worse than the modelling of the data with a steady function which runs at the level of the average of the IPR.

4.3 Multivariate Regression

By univariate regression (only) relationships between two variables can be examined. If one uses instead multiple variables for predicting a size, one goes to the field of multivariate and multiple regression analysis (see section xx). When considering several independent variables in general, the question arises, which of them affects the dependent variable at most or at least. The effect of each explanatory variable on the dependent variable is measured (indirectly via the associated estimators) by the respective regression coefficient. If the independent variables own different units, the dimensions of the regression coefficients cannot be compared (directly). Standardised regression coefficients compensate the effect of different scales. Thus all variables of the regression model receive a statistically uniform unit. The contact with the negative weights which can appear in the optimisation process just like that is interesting also. Comparing the dimension of the influence of the respective independent variables one has to use the absolute value and compare them with each other. In this work the regression coefficients (A, B, C and D) are used as weight variables that specify which importance the respective predictor enters the forecast.

4.3.1 Combination of the factors MPR, GDPpC, EI, ALR

Looking at the mobile phone rate (MPR) as the dependent variable and the GDP per capita (GDPpC), the Education Index (EI) and the adult literacy rate (ALR) as the (three) independent variables, the question is to which extent the individual independent variables affect the MPR. Besides, the interaction between three explanatory variables is to be considered once more implicitly with. The approach is the following:

$$MPR = A \cdot f_1(GDPpC) + B \cdot f_2(EI) + C \cdot f_3(ALR) + D$$

Based on the results in previous sections the presumption is that the MPR is related to the GDPpC most, the EI second most and the ALR lowest. The relationship between the GDPpC and the MPR was modelled in 2000 using a Planck function, which will be used now as class of underlying transformation functions f1 for the GDPpC data. In 2012, the transformation function f1 is a MaxLog function. The relationship between MPR and EI has been described both in 2000 and 2012 using a power function, which is now used as a transformation function f2 for the EI data. Furthermore, the relationship between MPR and ALR in 2000 and 2012, was modelled by an exponential function f3. For 2000, the following regression weights A, B, C and D result:

$$A = 0.737, B = 0.485, C = 0.291, D = -3.563$$

The result shows that the MPR is related most strongly in 2000 to the GDPpC. It further shows that the EI affects the MPR the second strongest. Besides, the MPR is determined differently strongly by GDPpC and EI. In comparison to these both explanatory variables the ALR has a lower influence on the MPR. Considering the proportional influence of all independent variables, the following relationship is found: The GDPpC affects the MPR to 48.7%, the EI to 32.1% and the ALR to 19.2%. How can this result be interpreted?

In 2000, the mobile phone has been used almost exclusively in the more richer states. Thus, the GDPpC was the determining factor for the MPR worldwide. In these countries, furthermore, the ALR is consistently very high, i.e. in this group of states the ALR has no great importance for the height of the MPR for the purposes of a di_erentiation characteristic. The lower meaning of the EI concerning the MPR is determined above all by states like Greece, Hong Kong, Italy, Korea, Portugal, Singapore, Spain etc., that have a relatively high MPR, but a low EI have in comparison to states like Belgium, Denmark, Germany, Finland, the Netherlands, Norway or Sweden. It can be assumed that the ALR in 2012 will have an even lower impact on the MPR, because firstly, the ALR has increased worldwide and on the other, the mobile phone is now used almost all over the world by many people. Moreover, in this context is to be expected that the GDPpC and the EI will determine the MPR again similarly strongly.
For 2012, the following regression weights A, B, C, D result:

$$A = 0.206, B = 0.184, C = -0.085, D = -2.412$$

The MPR is still influenced strongest by the GDPpC, followed by the EI, indeed, with the difference that now both explanatory variables exert an according to portion similarly strong influence on the MPR. This result corresponds to the expectations. The GDPpC has the strongest influence on the MPR in 2000 and 2012, but decreases proportionally in this period. The EI increases it's proportionally influence during the considered period, while the connection with the ALR sinks a little bit. But what could be the reasons for this?

Worldwide, the MPR has massively increased between 2000 and 2012, so that almost the entire world population nowadays uses the mobile phone. One could logically conclude from this that there might be no more recognizable connection between the MPR and the independent variables, because the mobile phone is used by everybody no matter whether somebody is rich or poor, educated or uneducated, able to and write or not. In spite of this fact the analyses deliver a differentiated relationship between MPR, GDPpC, EI and ALR. This is due to the fact that the MPR is not limited upwards. There are many countries with a MPR significantly over 100%, because one person can have and has more than one mobile phone access. A MPR value over 100% is recognizable over all GDPpC areas. So this is in fact not only in rich states the case. Furthermore one can not observe any compensatory effects by the growth of the population in a country or in the whole world with regard to the increase of the MPR. Another reason could lie in the fact that the MPR shows a saturation effect in 2012 worldwide indeed, but, however, there are still some countries in Africa with a low prosperity level and educational standard (Ethiopia, Burundi, Eritrea, Kiribati, Congo, Mozambique, Niger, Rwanda, Sierra Leone, Togo, Chad, Uganda, Central Africa etc.) in which still less than half of the population has a mobile phone.

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4.3.2 Combination of the factors IPR, GDPpC, EI, ALR

If one looks at the Internet penetration rate (IPR) as the dependent variable and the GDP per capita (GDPpC), the Education index (EI) and the adult literacy rate (ALR) as the independent variables, is the question again with which weight the single independent variables in_uence the IPR. Here are implicitly the interactions between the three explanatory variables to consider with. It is placed the following approach:

$$IPR = A \cdot f_1(GDPpC) + B \cdot f_2(EI) + C \cdot f_3(ALR) + D$$

For 2000 the following regression weights A, B, C and D result:

$$A = 0.671, B = 0.584, C = -0.239, D = -0.222$$

The result shows that the IPR is most related to the GDPpC, second most to the EI and lowest to the ALR. Here the GDPpC and the EI have a similar influence on the IPR. This indicates once more to a (possible) high correlation of economic power and education level of a country. Compared to GDP and EI the ALR has (significantly) less impact on the IPR. A negative regression weight, as it is the case for C, is an 'artefact' of the optimization. Concerning the contents the negative regression coefficient C concerning the ALR means that with rising ALR values there is a smaller probability for the MPR to accept high values. In comparison to that positive regression coefficients, as it is the case for the GDPpC and the EI, with rising values for the GDPpC and the EI lead to rising probabilities for high MPR values. Considering the proportional influence of all independent variables, one finds the following relationship: The GDPpC affects the IPR to 44.9%, the EI to 39.1% and the ALR to 16.0%.

Though the reading and writing ability is one of the basic competence of people to be able to use the Internet, indeed, the access to the Internet is first a question of cost. A wide literacy of the population is further a necessary condition for a correspondingly high level of prosperity in a country, but not a sufficient condition. A high level of prosperity in turn allows more likely to be able to afford Internet access. In 2000 an Internet connection is to be found almost only in rich countries and in these countries nearly the whole population is alphabetised. From this results the low correlation between IPR and ALR. Within this group of rich countries there are differences regarding the education level in form of the EI, what explains the strong meaning of the EI.

What is the situation after 12 years of development in 2012? The following regression proportions A, B, C and D result:

$$A = 0.624, B = 0.441, C = -0.023, D = -3.762$$

It becomes clear first of all that all the regression coefficients have reduced (according to amount). This is related to the used transformation functions. It also turns out that the IPR is still most related to the GDPpC followed by the EI. The IPR is influenced by the GDPpC to 57.3%, by the EI to 40.5% and the ALR to 2.2%.

The IPR has risen between 2000 and 2012 worldwide on just 40%. In this time frame the biggest (absolute) growth concerning the IPR has taken place in the rich states, what explains the increase of the meaning of the GDPpC as explanatory variable. In comparison with that the slightest IPR growth took place in the poorest states. Within the group of rich states an accordingly high EI is given. Furthermore, these countries already have an ALR very close to the 100% limit, that consequently has almost no significance for the explanation of IPR level. Now the IPR has increased worldwide, also as a result of access to the mobile Internet. How is it to be explained then that the weight of the ALR is so low in 2012? The reason could lie in the fact that within the countries in which the Internet is widespread, i.e. a high IPR, there are (clearly) higher differences with regard to the EI than with regard to the ALR, because most countries have a very similar ALR. The result is clear, because the ALR within the states, which use the Internet, is either already very high before 2000 or have risen until 2012 on a very high level. By technological means, as already described on top, the narrow coupling of the Internet access with the fixed network infrastructure is responsible for this in 2000, while up to 2012 the Internet access has partially decoupled from the fixed network infrastructure, namely by the success of the mobile Internet.

5. Conclusion

The investigations concerning the empiric or functional relationship between the GDP per capita (GDPpC) of a country and the different access rates of technology, e.g. Internet and mobile penetration rate, show a positive correlation in the years 2000 and 2012/2013, as well as also for all years in between. The relationship between the GDP per capita and the mobile phone access rate (MPR) is best modelled in 2000 with the Planck function and in 2013 with a maxLog function. For all GDPpC categories a nearly similar MPR growth is to be observed. In 2013 many countries have a MPR of 100%, what leads also to a worldwide MPR of about 100%. Thus, one can say that most people have a mobile phone access now. It is convincingly represented that the catching up in mobile phone usage runs much faster than the convergence in prosperity. The result for the relation between the absolute GDP produced and the Internet penetration rate (IPR) shows first that a strong linearly positive correlation exists between the portion of a country in the world GDP and its portion in the worldwide Internet users. Concerning this a few rich states were represented very over-proportional in the Internet world. Reason for this is the largely physical coupling of an Internet access to the fixed network in the year 2000. However, between 2000 and 2013 the IPR growth was greatest in the richest and richer countries and smallest in the poorer and poorest countries. The hopes in this area are based on the mobile Internet access on the basis of technological convergence of mobile telephony and Internet. Indeed, up to 2013, it came to better balanced relations and in fact the mobile Internet usage increased significantly during the previous years.

A (very) high ALR is generally a necessary condition on a high technology penetration in a country, but by far still no sufficient one. There is no country which shows a relatively high deployment of ICT with a low ALR. This statement is valid in a weaker form for the EI as a stronger measure of the educational standard. There are isolated states which show moderately high values of the respective access rate with a relatively low EI. This situation is different a little bit for the mobile telephony in this respect, as that also for relatively low values of the ALR and the EI high values of the MPR are given, because the mobile phone is used by everybody, no matter whether educated or uneducated.

The presented multivariate approach to determine the importance of the factors considered covers regressions as form of a linear combination. It becomes clear that a correlation between the level of wealth and the educational level of a country exists, both in 2000 and in 2012, and the fact that it is difficult to achieve sustainable progress in these two areas. The multiple regression analysis have confirmed that the access rates to ICT are most influenced by the GDPpC, the second most by the EI and the lowest by the ALR. Here, the GDPpC and EI have a similarly strong impact on the respective access rates. This also points to the implicitly existing (high) interaction between economic performance and level of education in a country. In comparison, the ALR has a significantly lower impact on the economic level. Overall, the studies conclude that the convergence regarding ICT usage proceeds worldwide faster than the convergence in terms of wealth and education in general, so the initial formulated thesis is confirmed. Based on this research, the digital divide is declining over the decade between 2000 and 2013, since more people worldwide use mobile phones and the Internet. But a high digital inequality explained to a significant extent by the functional relation between technology penetration rates, education level and average income still exists. Furthermore it supports the actions of countries at UN/G20/OECD level for providing ICT access to all people for a more balanced world in context of sustainable development by postulating that policymakers need to promote comprehensive education worldwide by means of using ICT.

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