Linkages between level of educational attainment and technology diffusion in developing countries

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Abstract

Fast growth of Information and Communication Technology (ICT) has facilitated access to information as well as communication across the world. Although, penetration of ICT is not homogeneous in the developed and developing countries, resulted an increase in the information gap between these regions. There may be several reasons for asymmetrical diffusion but education plays an important role in the diffusion of a new product or technology. Therefore, our objective is to analyse growth of enrollment at different educational levels and linkages between levels of educational attainment and diffusion of ICT indicators. The paper is divided into two sections (i) to analyse enrollment trends at primary, secondary and tertiary level and (ii) to investigate relationship between levels of educational attainment and diffusion of ICT indicators; Internet user, Internet user and personal computers per 100 populations in Brazil, China, India and USA.

Results show that enrollment at primary level in Brazil, China and USA is expected to decline whereas in the case of India it may increase. Likewise enrollment at secondary and tertiary level in China, India and USA may increase in future. Analysis also indicates positive correlation between enrollment at primary level and penetration of Internet users personal computers in India whereas in the case of tertiary level it shows weak correlation. In the case of tertiary level except India there is a strong correlation

between penetration of Internet and personal computers. Further, it may be noticed that in the case of Brazil secondary education shows negative correlation in all cases.

Introduction

Education plays a critical role in the process of economic development and new product growth and diffusion. Therefore, better understating of educational growth is required which can be achieved by increasing enrollment at different levels of education. Due to several socio-economic factors enrollment varies at different levels of education across the countries. Generally education is divided into three levels (i) primary level (ii) secondary level (iii) higher/tertiary level. Primary education is given more importance across the world as it establishes and builds basic skills such as literacy, mathematics, logic, and analysis that provides essential skills to children for constant learning. Recently for many countries higher education has become more important. So, there is a need to expand primary level education to strengthen secondary and tertiary education. However, over the last few years most of the countries are affected by financial and economic decisions made by their governments. This in turn affects growth of enrollment at different levels of education. Despite that enrollment has grown at an unprecedented pace. Consequently, over the year stock of human capital is increasing which is a direct measure of expansion of education. This has led several applications of ICT in education sector by promoting the multiple uses of Internet and computers.

ICT is defined[1] as new information-processing and information-transmitting technologies that includes computer-related commodities and technologies such as broadcasting and wireless mobile telecommunications etc. Personal computer (PC) that connects Internet has become a vital tool for communication during the past few decades since its increase among the masses. It is observed that penetration of ICT is faster in developed nations rather than developing nations. So, the penetration of ICT can be linked to various socio-economic factors such as education, income and promotion of basic telecommunications infrastructure and market. Therefore, the objective of the paper is to analyse growth trends of enrollment at different levels of education and the relationship between level of education and diffusion of ICT; focuses on Internet and personal computers (PCs). The paper builds on empirical data pertaining to the

enrollment at primary, secondary and tertiary level and ICT in Brazil, China, India and USA.

Literature review

The growth of a new product or technology depends upon several attributes and is asymmetrical across the world. Several empirical methods have been applied to analyze the relationship between ICT penetration and its various determinants but the main problem has been the choice of dependent variable. Attainment of education levels may be one of the important factors that affect the diffusion of ICT through various means. However, several other factors also affect diffusion of a technology for example GDP, culture and openness of a society. Nelson and Phelps[2] (1966) explained that rate of technology diffusion depends upon educational attainment. In their view education affects the process of technology diffusion by speeding up the rate at which new inventions are adopted. They were also concerned with the level of tertiary and specialized schooling. Contrary, Lucas[3] (1988) advocated the improvement of basic skills, such as literacy and primary education. Similar other studies also illustrate a positive correlation between levels of educational attainment and diffusion of computer and Internet[4, 5]. They argued that in developing countries education has a significant impact on Internet access. Robinson et al[6] found positive correlation between education and Internet diffusion. Chinn and Fairlie[7] (2004) & Guillen and Suarez[8] (2005) also analysed the effect of education on diffusion of computers, Internet and digital divide. Recently, Wunnava and Leiter[9] (2007), also argues that education has a positive effect on Internet diffusion.

Many other related studies have focused on education and the spread of Internet use, Internet hosts per 1,000 inhabitants. Crenshaw and Robison[10] (2006), examine certain determinants including mass education, as drivers of Internet diffusion. They found that the most significant explanatory variables are development level, political freedom, and education. Moreover, Kiiski and Pohjolab[11] (2002), analyse data from 60 countries over the years 1995-2000, and concluded that GDP per capita and Internet access cost are important factors in OECD countries, but education is not. However, in developing countries education becomes significant factor to adopt ICT. Of late, Dewan,

Ganley and. Kraemer[12] (2005), also advocated that education has a positive impact on IT penetration. Quibria et al[13] (2003) have found that Internet use and tertiary education show significant statistical association.

Thus, there is a basic reason for assuming an association between levels of educational attainment and Internet and computers diffusion. Therefore, in this article an attempt is made to analyse cross-country growth of enrollment and association between the levels of education and ICT indicators.

Methodology and Data Analysis

The theoretical structure and analysis of the paper is based on the previous studies and literature. It is assumed that personal computers (PCs) and Internet usage are affected by level of educational attainment in a given society. Therefore, education is included as an independent variable and PCs and Internet penetration as dependent variables in the empirical model presented below. Hypothetically countries with higher educational levels and literacy rate are more likely to have higher penetration rate of PCs and Internet. The first reason is that the World Wide Web and email are completely text based which needs education at least primary level in order to be able to use the Internet. Secondly, academic institutions and universities play an important role in adopting new technology based on computers and Internet. Moreover, other important aspects of education like research and on line access of textbooks and reading material depend on the use of computers, which help in penetrating Internet. Therefore, it can be presumed that education promotes the adoption of the computers and Internet along with other factors such as GDP, high telecom infrastructure, urban population and openness of the society. Taking education, as independent variable is advantageous as data pertaining to enrollment is available easily.

For analyzing growth of enrollment at different levels in Brazil, China, India and USA data for the period 1999-2005 is used which is listed in Tables 1a-1c. Similarly data for personal computers per 100 population and Internet per 100 populations and Internet users is used for different years as given in Tables 2a-2c.

Table 1a: Total no. of enrolment in primary level (public & private)

Year	India	China	Brazil	USA
1999	110,985,877	*138,556,000	20,939,076	24,937,931
2000	113,612,541	*134,321,000	20,211,506	24,973,176
2001	113,826,978	130,132,548	19,727,684	25,297,600
2002	115,194,579	125,756,891	19,380,387	24,855,480
2003	125,568,597	121,662,360	18,919,122	24,848,518
2004	(**) 136,193,772	*117,380,000	18,979,209	24,559,494
2005	142,364,593	*113,145,000	*18,290,500	24,454,602

Source: http://stats.uis.unesco.org/unesco/TableViewer/tableView.aspx
** Indicates computed; ** UIS estimates*

Table 1b: Total no. of enrolment in Secondary level (public & private)

Year	India	China	Brazil	USA
1999	67,089,892	77,436,268	24,982,899	22,444,832
2000	71,030,515	77,436,268	26,096,870	22,593,562
2001	72,392,727	86,516,712	26,441,248	23,087,042
2002	76,215,685	90,722,795	26,789,210	23,196,310
2003	81,050,129	95,624,760	24,592,569	23,854,458
2004	84,569,081	*100,446,000	25,155,104	24,185,786
2005	*87,519,100	*105,413,000	*25,345,900	24,431,934

Source: http://stats.uis.unesco.org/unesco/TableViewer/tableView.aspx
** Indicates computed*

Table 1c: Total no. of enrolment in Tertiary level (public & private)

Year	India	China	Brazil	USA
1999	*9,171,986	6,365,625	2,456,961	13,769,362
2000	9,404,460	7,364,111	2,781,328	13,202,880
2001	9,834,046	9,398,581	3,125,745	13,595,580
2002	10,576,653	12,143,723	3,582,105	15,927,987
2003	11,295,041	15,186,217	3,994,422	16,611,711
2004	10,009,137	*16,817,900	4,275,027	16,900,471
2005	11,777,296	*19,060,000	*4,687,862	17,272,044

Source: http://stats.uis.unesco.org/unesco/TableViewer/tableView.aspx
** Indicates computed*;

Table 2a: Density of Internet users per 100 population

Year	India	China	Brazil	USA
1991			0.00	1.19
1992	0.00		0.01	1.77
1993	0.00	0.00	0.03	2.32
1994	0.00	0.00	0.04	4.98
1995	0.03	0.00	0.11	9.39
1996	0.05	0.01	0.45	16.70
1997	0.07	0.03	0.79	22.01
1998	0.14	0.17	1.48	30.66
1999	0.28	0.70	2.04	36.55
2000	0.54	1.77	2.88	44.06
2001	0.67	2.63	4.54	50.10
2002	1.57	4.57	7.99	55.21
2003	1.73	6.12	9.92	55.58
2004	3.22	7.19	11.96	63.00
2005	5.44	8.44	17.24	66.33
2006	---	10.35	---	69.10

Source: http://mdgs.un.org/unsd/mdg/SeriesDetail.aspx?srid=605

Table 2b:Total number of Internet users

Year	India	China	Brazil	USA
1990				2000000
1991			5000	3000000
1992	1000		20000	4500000
1993	2000	2000	40000	6000000
1994	10000	14000	60000	13000000
1995	250000	60000	170000	25000000
1996	450000	160000	740000	45000000
1997	700000	400000	1310000	60000000
1998	1400000	2100000	2500000	84587000
1999	2800000	8900000	3500000	102000000
2000	5500000	22500000	5000000	124000000
2001	7000000	33700000	8000000	142823008
2002	16580000	59100000	14300000	159000000
2003	18481044	79500000	18000000	161632400
2004	35000000	94000000	22000000	185000000

Source: http://mdgs.un.org/unsd/mdg/SeriesDetail.aspx?srid=608

Table 2c:Number of personal computers per 100 population

Year	India	China	Brazil	USA
1990	0.03	0.04	0.31	21.79
1991	0.04	0.07	0.44	23.43
1992	0.05	0.09	0.64	25.30
1993	0.06	0.12	0.86	27.20
1994	0.09	0.17	1.17	29.68
1995	0.13	0.23	1.73	32.41
1996	0.16	0.36	2.15	35.86
1997	0.21	0.60	2.63	39.98
1998	0.27	0.89	3.01	44.95
1999	0.33	1.22	3.63	50.53
2000	0.45	1.59	5.01	57.21
2001	0.58	1.90	6.29	62.44
2002	0.72	2.76	7.48	67.67*
2003	0.89	3.90	8.87	72.45*
2004	1.21	4.08	10.71	76.22

Source: http://mdgs.un.org/unsd/mdg/SeriesDetail.aspx?srid=607
** Indicates computed*

To analyse enrollment trends linear growth model; $y = a + bx$ is applied. Logistic function is also used to study growth pattern but in this case empirical data exhibits linear trend. For establishing correlation between levels of educational attainment and diffusion of Internet and computers Pearson correlation and t-test technique are applied, which are mathematically represented below:

$$r = \frac{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)\left(Y_i - \bar{Y}\right)}{(n-1)S_X S_Y}$$

Similarly, t-test is used to test the hypothesis and t-values are calculated by using following formula:

$$t = \frac{r}{\sqrt{\left(\frac{1-r^2}{n-2}\right)}}$$

where symbols have their usual meanings. For parameter estimation and regression analysis SYSTAT[14] package is used. Parameter estimates and projections of enrollment at different levels are listed in Tables 3a-3c. Similarly, the correlation and t-test analysis matrix is given in Tables 4a-4c.

Table 3a: Projections for enrollment at primary level

Year	India	China	Brazil	USA
2008	1.58E+08	1.03E+08	1.72E+07	2.43E+07
2009	1.65E+08	9.92E+07	1.69E+07	2.42E+07
2010	1.72E+08	9.59E+07	1.65E+07	2.41E+07
2011	1.80E+08	9.27E+07	1.62E+07	2.40E+07
2012	1.88E+08	8.96E+07	1.59E+07	2.39E+07
2013	1.96E+08	8.66E+07	1.55E+07	2.38E+07
2014	2.05E+08	8.38E+07	1.52E+07	2.37E+07
2015	2.14E+08	8.10E+07	1.49E+07	2.36E+07
a	18.447	18.783	16.867	17.044
b	0.043	-0.034	-0.020	-0.004
MSE	1213.443	1217.177	986.043	1014.857

Table 3b: Projections for enrollment at secondary level

Year	India	China	Brazil	USA
2008	1.01E+08	1.25E+08	2.51E+07	2.56E+07
2009	1.05E+08	1.32E+08	2.50E+07	2.60E+07
2010	1.10E+08	1.40E+08	2.49E+07	2.64E+07
2011	1.15E+08	1.48E+08	2.48E+07	2.68E+07
2012	1.20E+08	1.56E+08	2.47E+07	2.72E+07
2013	1.26E+08	1.65E+08	2.46E+07	2.76E+07
2014	1.32E+08	1.74E+08	2.45E+07	2.80E+07
2015	1.38E+08	1.84E+08	2.44E+07	2.85E+07
a	17.997	18.094	17.073	16.907
b	0.045	0.055	-0.004	0.015
MSE	1153.876	1174.054	1018.510	1007.668

Table 3c: Projections for enrollment at tertiary level

Year	India	China	Brazil	USA
2008	1.27E+07	3.66E+07	6671391.326	2.05E+07
2009	1.32E+07	4.45E+07	7437321.148	2.15E+07

2010	1.37E+07	5.40E+07	8291185.924	2.26E+07
2011	1.42E+07	6.55E+07	9243081.301	2.37E+07
2012	1.47E+07	7.95E+07	1.03E+07	2.49E+07
2013	1.53E+07	9.65E+07	1.15E+07	2.61E+07
2014	1.58E+07	1.17E+08	1.28E+07	2.75E+07
2015	1.64E+07	1.42E+08	1.43E+07	2.88E+07
a	15.999	15.480	14.622	16.343
b	0.036	0.194	0.109	0.049
MSE	912.162	925.295	794.109	957.465

Table 4a: Values for *r* and *t* for educational attainment V/S Internet users

Education Level	India		China		Brazil		USA	
	r	t	r	t	r	t	r	t
Primary	0.950	6.09**	-0.994	-17.46**	-0.925	-4.88**	-0.544	-1.3
Secondary	0.950	6.08**	0.979	9.51**	-0.280	-0.58	0.945	5.76**
Tertiary	0.490	1.12	0.998	29.44**	0.992	16.02**	0.854	3.29*

Note: *1. t- table; 5% ,4 = 2.776, 1%, 4 =4.604 2. ** - Indicates significant at both 5% and 1% level of significance, 3. * - Indicates significant at only 5% level of significance*

Table 4b: Values for *r* and *t* for educational attainment V/S Internet user /100 population

Education Level	India		China		Brazil		USA	
	r	t	r	t	r	t	r	t
Primary	0.955	5.95**	-0.996	-17.88**	-0.943	-5.02**	-0.693	-1.24
Secondary	0.920	6.19**	0.986	9.49**	-0.293	-0.56	0.957	5.31**
Tertiary	0.766	1.15	0.998	28.23**	0.981	16.94**	0.883	3.13*

Note: *1. t- table; 5% ,4 = 2.776, 1%, 4 =4.604 2. ** - Indicates significant at both 5% and 1% level of significance, 3. * - Indicates significant at only 5% level of significance.*

Table 4c: Values for *r* and *t* for educational attainment V/S PCs per 100 population

Education Level	India		China		Brazil		USA	
	r	t	r	t	r	t	r	t
Primary	0.958	6.66**	-0.976	-8.93**	-0.943	-5.83**	-0.559	-1.35

Secondary	0.985	11.58**	0.964	7.25**	-0.216	-0.44	0.970	7.91**
Tertiary	0.591	1.46	0.994	17.88**	0.993	16.58**	0.891	3.93*

Note: *1. t- table; 5% ,4 = 2.776, 1%, 4 =4.604 2. ** - Indicates significant at both 5% and 1% level of significance, 3. * - Indicates significant at only 5% level of significance*

Results and Discussion

Brazil, India and China are the emerging economies, which constitute a larger share of the world population. Structure of enrollment in these countries is a crucial indicator of expansion of education and these countries may be good source of human capital stock in the future. Therefore, the comparative estimations of enrollment with USA at different levels will be a significant to cope with future expansion and challenges in education sectors. Analysis shows that enrollment at primary level is showing declining trends except India. The major reason behind this is likely the decline in the population of the age group 5-10 years in countries like China and Brazil[15] while in the case of India it is increasing. However, enrollment at secondary is expected to increase except in the case of Brazil. It is noticeable that enrollment at tertiary level in India, China, Brazil and USA is increasing equally. It may be concluded that the growth in enrollment provides supports the growth of higher and tertiary education. However, growth of enrollment at all levels is not identical among Brazil, India, China and USA. For example enrollment at primary reflects increasing trends due to government policy of free education to all children upto primary and upper primary levels under *Serva Shiksha Abhiyan* (SSA). Though Brazil, China, India and USA are promoting tertiary education to have sufficient higher qualified human capital for encouraging research. Growth in enrollment at tertiary level in these countries indicates

Analysis indicates strong positive correlation between all levels of educational attainment and Internet users and PCs users. However, at tertiary level there is a weak correlation between enrollment and Internet users. Conversely, China shows significant negative correlation between Primary enrollment and Internet users but shows significant positive correlation between Secondary enrollment and tertiary level for Internet users and PCs as well. The same results follows in the case of USA. However, In the case of Brazil There is a negative correlation between primary and secondary level enrollment and Internet users and PCs whereas at tertiary level the association is positive. Evidently

negative correlation is due to decline of enrollment at primary level at in the case of China and USA and at primary and secondary level in the case of Brazil. This supports the view that education is the most significant variables for Internet penetration[12]. Thus level of educational attainment influences the adoption and penetration ICT indicators such as Internet users and PCs. Though degree of significance may vary among the countries. This also confirms past findings that education enrollment have a significant impact on penetration rate and usage of computers and Internet.

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