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Human Capital and the Adoption of Information and Communications Technologies: Evidence from Investment Climate Survey of Pakistan

Mazhar Mughal

Centre d'Analyse et Traitement Théorique des Données Economiques, Université de Pau et des Pays de l'Adour, France

Barassou Diawara

Graduate School of Economics, Kyushu University, Japan

Abstract This paper studies the impact of human capital on the adoption and diffusion of Information and Communications Technologies (ICT) in the Pakistani firms using the World Bank Enterprise Survey 2002-07. The paper considers various indicators of human capital and measures of ICT adoption and diffusion. On-the-job training, manager's level of qualification and production workers' level of education are found to positively determine the use of emails, website and other means of communication in a firm. The results are robust to the inclusion of geographical, sectoral and structural control variables. Firm size, sales and workers' compensation are also positively associated with the use of ICT. The findings show the importance of accumulation and development of human capital in the productivity growth in the era of skill-biased technical change. A concerted national effort for the enhancement of the workforce's computing skills is therefore a must if a developing economy such as Pakistan is to improve its competitiveness.

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Correspondence

Mazhar Mughal, mayher.yasinmughal@univ-pau.fr

Barassou Diawara, bassojawara@yahoo.co.jp

1. Introduction

Information and communications technologies (ICTs) have, during the last few decades, in so many ways reshaped the socioeconomic environment. Low-cost and convenient means of communication, information collection and dissemination and data processing have broken the barriers and rendered the world into a single grand economy. A large body of literature has focused on the positive association of adoption and use of ICT with productivity (see for example Brynjolfsson and Hitt, 1995; Colecchia and Schreyer, 2001; Greenan and Mairesse, 1996; Jorgenson and Stiroh, 2000; and Lichtenberg, 1995). Among various rank and epidemic effects considered to be dominant explanatory factors in ICT adoption and extent of use, human capital has a particularly important role [See Hollenstein (2004) for an excellent review of the literature on the factors determining ICT adoption and diffusion]. Obstacles in the adoption, implementation, maintenance and efficient use of the technologies due to shortage of skilled labour have prevented firms, particularly in the developing countries, from achieving their full productivity potential. [A detailed discussion of issues related to skill-biased technical change in the context of ICT can be found in Kaiser (2000) and Bresnahan *et al.* (2002) among others.] Caselli and Coleman (2001) examine the world-wide diffusion of computers and conclude that high levels of educational attainment are important determinants of computer-technology adoption. A one-percentage-point increase in the fraction of the labor force with education above the primary school level leads to an increase in computer investment per worker of roughly one percent. Other studies finding support for a strong and important role of education in ICT adoption include Kiiski and Pohjola (2002), Quibria *et al.* (2003) and Rogers (2003) among others.

Firm-level evidence for the positive association between the human capital and ICT adoption comes from Spain (Bayo-Morionesa and Lera-López, 2007), Italy (Giunta and Trivieri, 2007), Australia (Gretton, Gali and Parham, 2004) and Switzerland (Hollenstein, 2004). Few studies have so far examined the case of developing countries. Being poor in human capital, developing countries face greater impediments in ICTs adoption and implementation and such an analysis could shed light on the role of human capital in today's developing world firms. Analyzing a survey of 625 Senegalese firms, Diawara and Mughal (2010) determine that the level of education does not matter much in the firms' decision of whether or not to adopt ICTs. However, the quality of education has a strong role, whether in the form of on-the-job training, managers' education level or production workers' education level, in the probability of adopting new technologies by the firm.

This paper is also an attempt at studying the question in the context of a developing country. Using the World Bank Enterprise Surveys, we investigate the impact of the role of human capital endowment in the adoption and diffusion of ICT in the Pakistani firms. The timing of this survey is interesting, as the firms in the sample were first surveyed in 2002, just when the cost of ICT adoption in Pakistan (e.g internet bandwidth cost, taxes on computers etc) had begun to fall. As the companies were again surveyed five years later, the intervening period saw a precipitous decline in the cost of ICT adoption, and hence costs should no longer be a determining factor in a firm's decision to adopt the ICT. We can therefore better study the role of human capital at the firm's disposal in its adoption of the technology.

The paper looks for evidence for the following hypotheses:

H1. Education level of the top manager affects the firm's decision to adopt ICT. Here we suppose that the top manager's awareness of the importance and usefulness of the new technologies depends on his/her level of education. Therefore, it is expected that the higher his/her education level, the higher is the probability that the firms adopt new technologies.

H2. The impact of the workers' education level on the adoption of ICT might be ambiguous. Although the adoption of new technologies is dictated by the market conditions, we assume that it is not much related to the education level of the "normal" workers given that it is a decision taken by the top management of the company.

The use of ICT, however, is dependent on the education of the workers. A better trained and qualified workforce facilitates investment and implementation of ICT (Arvanitis, 2005; Hollenstein, 2004 and Bresnahan, Brynjolfsson, and Hitt, 2002). The education of firm employees should thus positively correlate with e-mail and internet use.

H3. Sales and exposure of the Pakistani firms to international quality standards motivate the enterprises to go for the new technologies. Higher revenues remove the capital constraints that hamper developing world firms from adopting new technologies which require considerable initial investment. Furthermore, increased sales create the need to better communicate with the clientele and to look for new markets, for which ICT can prove useful.

To test the above hypotheses, we employ four measures of human capital: manager's qualification level, average education level of the workers, number of skilled workers in the firm and the existence of on-the-job training programs. Indicators of ICT adoption and diffusion used include email use by the employees, the firm having its own website, the percentage of the workforce using computers and the percentage of the production machinery that is computer controlled. Email and websites are important means of

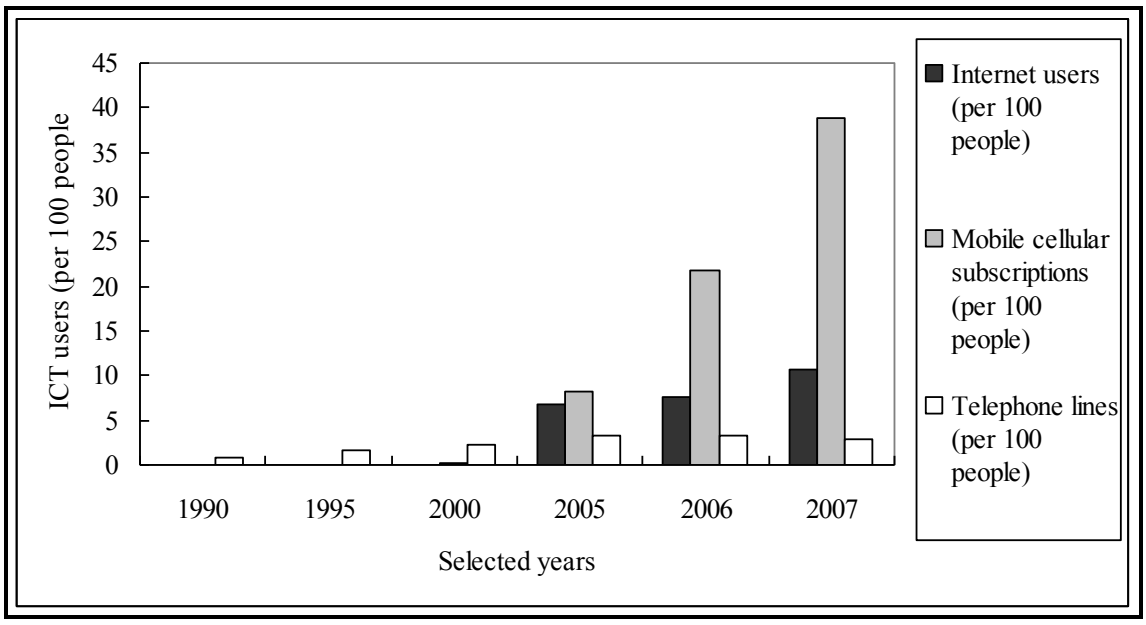
exchanging and disseminating information, and require the presence of an educated labour force. Given the nature of data and our dependent variables (both binary and continuous), we use the probit and simple random-effect panel models to assess the importance of education on the adoption of ICT in Pakistan.

The remainder of the paper is organized as follows. Section 2 gives some stylized facts related to the use of ICT and the human capital in Pakistan. Section 3 presents the empirical model, the choice of variables and the econometric techniques used. Results are given in Section 4 followed by the discussion of the main findings. Section 5 concludes the paper.

2. Adoption of ICT and human capital in Pakistan

Pakistan has been on the other side of the Digital divide throughout its history, being a lower income country. However, starting from the early 2000's, active government encouragement for the ICT adoption accompanied by a gradual deregulation of the hitherto public monopoly led to a rapid fall in costs and a sharp rise in technology use. Figure 1 depicts the evolution of selected ICT related indicators in Pakistan. For instance, the number of internet users grew from virtually nil in the 1990s to 11 percent in 2007. Similarly, the percentage of mobile cellular subscribers rose exponentially from almost zero percent in the 1990s to approximately 39 percent in 2007. On the other hand, the percentage of people using telephone lines has hardly budged from one percent in the 1990s to 3 percent in 2007.

Figure 1. Trend of selected ICT indicators in Pakistan



Source: World Bank (2010)

The increase in the ICT use probably has something to do with growth in economic activity (see the trend of per capital GDP in Table 1) and the human capital accumulation in the country. Table 1 presents some ICT and educational indicators together with the evolution of Pakistan's per capita GDP. The table shows that the rise in education attainment from a meagre base is also significant, though much less spectacular. Although the primary education gross enrolment rate has grown from 49 percent in 1990 to 92 percent, the percentage of population with secondary education at 33 percent still remains low. The level of economic activity in the country has also followed a pattern similar to the trend of internet use.

Table 1. Selected ICT and macroeconomic indicators

	1990	1995	2000	2005	2006	2007
ICT indicators						
Internet users (per 100 people)	0.00	0.00	-	6.74	7.55	10.77
Mobile cellular subscriptions (per 100 people)	0.00	0.03	0.22	8.20	21.70	38.75
Telephone lines (per 100 people)	0.78	1.74	2.21	3.36	3.30	2.96
Developmental and educational indicators						
GDP per capita (constant 2000 US$)	465.38	514.82	535.58	605.74	630.09	653.69
School enrollment, primary (% gross)	48.79	67.34	69.18	86.18	84.12	92.04
School enrollment, secondary (% gross)	21.65	-	-	28.58	30.01	32.54
School enrollment, tertiary (% gross)	-	-	-	4.47	4.52	5.12

Source: World Bank (2010)

The question that is yet unanswered, and which we try to address in this study, is whether the increase in education, and consequently the human capital available to the business sector, has helped in more intensive use and adoption of ICT in Pakistani firms, or has the flood of emails and web-surfing passed by the commercial sector of the country.

3. Empirical methodology

3.1. Econometric specifications

We measure the impact of education level in the firms and other characteristics on the adoption of ICTs using a general specification based on Bartoloni and Baussola (2001) and readapted in Diawara and Mughal (2010). The econometric specification has the following form:

$$Y_{it} = \beta_0 + \beta_1 EDUCATION + \sum_{j=2}^{k} \beta_j X_{ijt} + \varepsilon_{it}, \quad (1)$$

where Y_i is our dependent variables (dummy variable) showing whether firm *i* has adopted ICT or not as well as the percentage of ICT use by the workers. β_0 is a constant, β_1 and β_j are the coefficients of explanatory variables *EDUCATION* (education or human capital indicator) and X_{ij}, respectively, and ε_i is the error term. t refers to the years 2002 and 2007.

Dependent variables

Two types of dependent variables are used in this study, two binary and two continuous. The two binary variables are the use of email by workers and the surveyed firm having its website. The variable "use of email" is a dummy variable which takes the value of 1 if the firm uses email and 0 otherwise. Similarly, the variable "use of own website" is a dummy variable which takes the value of 1 if the firm has its website and 0 otherwise.
the email and website usage are standard variables in the ICT adoption and diffusion literature (see for example Bayo-Moriones and Lera-López, 2007; Hollenstein, 2004 etc), that represent the adoption of general-use information and communications technologies.
The above mentioned dependent variables are indicators obtained by asking the firms the question: "Does this establishment use any of the following (email/website) in its communications with clients and suppliers?" (World Bank, 2006).

The two other dependent variables are continuous and refer to the percentage of the workforce using computers and the percentage of the production machines that are computer-controlled. The first indicator (percentage of the workforce using computers) is obtained by asking the firm the following question: "What percent of your workforce regularly uses a computer in their jobs?" The variable "percentage of computer-controlled production machines" is obtained by the following question: "What percentage of your production machines is computer controlled?" (World Bank, 2006).

Independent variables

Our independent variables of interest are the education or human capital related variables namely the top manager's highest level of qualification, the average education level of the firms' typical worker, the number of skilled workers and the existence of on-the-job training programs.

(1) The top manager's highest qualification level refers to the highest level of education completed by the top manager. The levels considered are ranked from 1 to 8

and are respectively less than Secondary School, Secondary School, Higher Secondary School, Graduate degree (BA, BSC etc.), Masters of Business Administration (MBA) from a university in Pakistan, Masters of Business Administration (MBA) from a university in another country, Other post graduate degree (PhD, Masters) from a university in this country and Other post graduate degree (PhD, Masters) from a university in another country.

(2) The average education level of the firms' typical workers is the average educational attainment of a typical production worker employed and is ranked from 1 (for 0-3 years of education) to 4 (13 years and above of education), the other levels being 4-6 and 7-12 years of education.

(3) The number of skilled workers is a continuous variable and refers to the number of permanent, full-time skilled workers at the end of fiscal year 2005/2006.

(4) The on-the-job training is a dummy variable taking the value of 1 if the establishment runs formal training programs for its permanent, full-time employees and 0 otherwise.

Other independent variables are presented in Table 2 together with the summary statistics of the different variables used in the regression analysis. The other controls are the status of the firm which is a dummy variable showing whether the establishment is part of a larger firm or not. Whether the firm establishment has an internationally recognized quality certification or not is included as a dummy variable. The age, size, and sales of the surveyed firms and compensation of the production workers are also included as controls. Keeping in view the geographical scope of the study, dummies for the four provinces (Punjab, Sindh, NWFP and Balochistan) are inducted, as well as seven types of industries for sectoral considerations. Given the lack of a suitable measure of the cost of technology adoption in the Investment Climate survey and a substantial fall in the investments required for ICT adoption in the new century, we suppose that this factor affects all the firms in a minor but similar manner, and thus does not play a significant role in the equation.

3.2. Data issues

The data used in this study are taken from the Investment Climate Survey of Pakistan which is a joint effort of the World Bank Group and the Small and Medium Enterprise Development Authority (SMEDA) of the Government of Pakistan. The survey was conducted on more than 400 firms during the years 2002 and 2007 and is provided by the World Bank Enterprise Surveys (WBES). The WBES dataset is a stratified random sample of firms with a common questionnaire and sampling methodology for all participating countries. The Surveys use standardized survey instruments and a uniform

sampling methodology to minimize measurement errors and yield comparable data for the economies across the world.

Table 3. Variables considered: summary statistics

Variable	Description	Mean	Std. Dev.
Dependent variables			
Email	if firm uses email =1; otherwise=0	0.48	0.50
Website	if firm uses website =1; otherwise=0	0.29	0.45
Workers using computers	Percent of the workforce regularly using a computer	1.67	1.55
Computer-controlled production machines (%)	Percentage of the production machines computer controlled	0.24	0.47
Independent variables: education related			
Training	if firm conducts on-the-job training =1; otherwise=0	0.06	0.23
Highest education level of top manager	Highest level of education completed by the top manager	4.20	1.76
Average education of a production worker	Average educational attainment of a typical production worker	2.24	0.86
Skilled production workers	Number of permanent, full-time skilled workers	2.95	1.35
Independent variables: other controls			
Size (20 to 99 workers)	if firm employs 20-99 employees =1; otherwise=0	0.44	0.50
Size (more than 100 workers)	if firm employs100 workers and more =1; otherwise=0	0.22	0.42
Age of the firm	Age of the firm (in number of years)	3.22	1.26
Establishment part of a larger firm	if the establishment is part of a larger firm =1; otherwise=0	0.15	0.35
International quality certification	if firm has an int'l quality certification =1; otherwise=0	0.30	0.46
Compensation of production workers	Average monthly compensation, including benefits	8.26	0.77
Sales	Sales of the firm during the last fiscal year	16.86	2.10
Sindh	if the firm surveyed is in Sindh province =1; otherwise=0	0.24	0.43
North-West Frontier Province (NWFP)	if the firm surveyed is in NWFP =1; otherwise=0	0.08	0.28
Balochistan	if the firm surveyed is in Balochistan =1; otherwise=0	0.02	0.13
Islamabad	if the firm surveyed is in Islamabad =1; otherwise=0	0.01	0.07
Food	if firm is in the food industry =1; otherwise=0	0.16	0.37
Garments	if firm is in the garments industry =1; otherwise=0	0.16	0.36
Textiles	if firm is in the textiles industry =1; otherwise=0	0.27	0.44
Machinery and equipment	if firm is in the machinery and equipment =1; otherwise=0	0.02	0.15
Chemicals	if firm is in the chemicals industry =1; otherwise=0	0.08	0.28
Leather and leather products	if firm is in the leather industry =1; otherwise=0	0.05	0.22
Other manufacturing	if firm is in the other manufacturing industry =1; otherwise=0	0.16	0.37

The data taken into account in this study concern at best 431 enterprises in various sectors, namely food, textiles, garments, chemicals, machinery and equipment and leather. The dataset is accessible at www.enterprisesurveys.org; detailed information on the sampling methodology is also available on this website. The WBES database provides appropriate variables allowing the estimation of the existing relationship between the education and training of the workforce and the adoption of ICT's in Pakistan. Mean, standard deviation and the definition of the different variables used in the regressions are summarized in Table 3.

A cursory look at the data shows that the level of ICT use in Pakistani firms is still low, the technology used the most being e-mails. Less than 30 percent of the enterprises use their own websites when dealing with customers and suppliers while 48 percent use emails. Related to the educational variables, few enterprises have conducted job-related training programs while the average education level of the top manager is 4 corresponding to graduate degree (BA, BSC etc.). The volume of sales and compensation of the production workers may have high explanatory power given the high means associated with the respective variables. Moreover, Table 3 also shows that the age and size of the firms are quite diverse reflecting in the high value of their respective standard deviations.

3.3. Estimation methods

Two estimation methods are adopted in this study, namely the probit and simple ordinary least squares (OLS) models. First, we adopt a probit estimation approach to assess the impact of our educational variables on the adoption of ICT, namely email and website which are binary. Probit models transform a dichotomous dependent variable into a probability. The dependent variable is therefore categorical. Specifically, Y_i in equation (1) is a discrete random variable that assumes one of two possible values: 1 if the firm adopts ICT during the surveyed year and 0 if it does not. The independent variables may be either continuous or discrete, but they are assumed to be non-stochastic. On the other hand, simple OLS method is used when estimating the impact of human capital on the percentage of workers using computers and the percentage of production machines that are computer-controlled. Given the continuous nature of the variables, OLS can be an appropriate estimation technique.

It is worth noting that education of the workforce is clearly endogenous with respect to the firm's decision of whether or not to embrace a new technology. However, the limitation of the data with respect to the temporal dimension and number of variables

included does not allow the handling of probable endogeneity of the education variable. However, without attempting to undermine the probable presence of endogeneity, it can be noted that in the existing literature on the role of human capital on ICT adoption, few studies have taken into consideration the issue, and endogeneity has not been a major concern. For instance, studies such as Bartoloni and Baussola (2001), Bayo-Morionesa and Lera-López (2007) have not mentioned the possible endogeneity associated with the workforce education variable. Some other studies (for example, Hollenstein, 2004 and Battisti *et al.*, 2006) have, however, attempted to tackle the problem related to the endogeneity and have found that the robustness of the results are not affected[1].

4. Estimation results

4.1. Impact of education related variables

Parameters estimates from probit models of email and website use are presented in Table 3 and 6 while the regression results for the impact of education on the number of workers using email and the proportion of computer-controlled production machines are given in Table 5 and 7. It was not possible to use random effect models for the proportion of production machines that are computer-controlled due to the limited number of observations available for the variable.

The estimated impact of schooling on the probability of email and website use shows that the average number of years of the workforce education has a positive and significant impact on the email use while the top manager's qualification level has a positive and significant impact on the probability of website and email use. Same results are obtained by random effects estimations. The higher the education level of the top manager, the higher is the probability to use email and website in the firm's interaction with customers and suppliers. However, the education level of the workers is only reflected in the probability of email use.

Related to the workers' computer use and the proportion of the production that is computer-controlled, Tables 5 and 7 indicate that the workers education plays a primal role. In fact, workers' education level appears to be positively and significantly associated with the percentage of workers using computers. The managers' education level is, however, not significant in the use of computers by workers.

The number of skilled workers in the establishment has a positive relationship with

[1] We have also attempted to control the endogeneity of educational variables using variables such as "time inspected or met with tax official" without success. The variables do not appear to be good instruments. Besides, the instrumental variables remain below the Staiger-Stock (1997) threshold of 10 for strong instrument.

the percentage of workers using a computer and the proportion of computer-controlled production. However, the impact does not appear to be robust in the sense that the coefficient turns insignificant with the random effects model. The impact on the probability of email and website use is not significant either. With regards to the impact of on-the-job training, the results show that it has a positive effect on several dependent variables but its impact does not seem to be robust.

From the empirical findings, it can be said that our first hypothesis is partially verified. Managers' education clearly influences the probability of website and email use in the firm but not the percentage of workers using a computer and the proportion of computer-controlled production. This is in line with the findings of

Correa, Fernandes and Uregian (2010), who find that firms in East Europe and Central Asia run by managers with a college or postgraduate degree in 2002 are almost 23 percent more likely to use the web, all else held constant. Diawara and Mughal (2010) also find support for an important role of managerial education in the adoption and use of ICT in Senegal.

There is also some support for the second hypothesis. Workers' education is found to be positively and significantly associated with the percentage of workers using computers and the proportion of computer-controlled production whereas its impact on the proportion of website and email use is not significant.

4.2. Impact of other variables

Other variables taken into account represent the firm's structural characteristics, such as firm size and age. The financial status of the firm is also considered through variables such as the sales and compensation of production workers. Moreover, to control for the possibility that the firm be part of a larger group and that it has an international quality certification, respective dummies are added. We also control for the geographical location and the existence of branches of the surveyed firms through a set of dummy variables.

The results show that large firms have a higher probability of adopting the new technologies. This is true for the use of email and website and the percentage of workers using a computer but not for the proportion of computer-controlled production machines. This result indicates that larger firms, which are often more capital-intensive and with a more educated workforce, are better at making use of the ICT, an effect termed as Shumpeterian. Small firms, even if well-aware of the importance and potential gains from the ICT, often lack the financial muscles to bear the initial cost of new technology adoption. Firm size is likewise found to be important in ICT adoption in studies such as Giunta and Trivieri (2007) and Correa, Fernandes and Uregian (2010).

Age and the establishment being part of a larger firm are not significant factors in the adoption of ICTs. The ambiguity of a firm's age in terms of ICT adoption and use can be explained by considering the strengths of older and younger firms. Older firms often possess the resources to acquire a new technology, whereas the younger firms are keener to undergo the necessary structural changes for technology adoption.

With respect to geographical distribution, it is in the firms located in Sindh where workers are the most likely to use computers while the other provincial dummies are statistically non-significant. This is probably due to Sindh's largest city Karachi's prominence in the Pakistani economy. Karachi, being the largest and the principal port city of Pakistan, is the country's major financial, industrial and trade center, which naturally requires strong communication links with the interior of the country as well as abroad.

The findings also show that firms in the food, leather and textile industries are less likely to use email and website but have fewer workers using computers, the impact being robust for email and website use. This finding holds importance for the country given that textiles form the backbone of the Pakistani economy, being the country's largest industry. Textiles, along with leather, make up over two-thirds of the country's exports. A low level of ICT adoption in these sectors points to the low value-added nature of their products, a weakness that has kept Pakistani manufacturing industry stuck in tough competition in the international market for low-end simple manufactured items, away from the more sophisticated but lucrative high-value-added products

Workers' compensation is also positively and significantly associated with the probability of email and website use. However, its impact on the workers' computer use is not significant. This is also borne out by the fact that technologically less-sophisticated industries, such as textiles and leather, also rank lower in the sectoral wage hierarchy (Irfan, 2008)

Sales are positively and significantly associated with the probability of email and website use. Their impact on the proportion of workers using computers is, however, not significant. This suggests that the higher the financial capability of the firm, the higher will be the probability that it uses websites and emails in its interactions with suppliers and customers. This result is similar to the one obtained by Correa, Fernandes and Uregian (2010), who find that East European and Central Asian firms with smaller market shares are significantly less likely to use the web.

Whether the firm has an international quality certification or not is also an important determining factor in its decision to use the new technologies. In fact, our findings show

that companies with international quality certification are more likely to use email and websites. However, the impact on the proportion of workers using computers is not statistically significant.

Subsequently, we can state that our third hypothesis is also partially verified. Sales and the possession of international quality certification is important in the probability of website and email use but not on the proportion of workers using computers.

Table 4. Probit estimates of the email and website use

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Email				Website			
Workers' average education	0.33***	-	-	-	0.07	-	-	-
	(0.11)				(0.10)			
Skilled production workers	-	0.00	-	-	-	-0.00	-	-
		(0.00)				(0.00)		
On-the-job training	-	-	0.71	-	-	-	0.29	-
			(0.65)				(0.42)	
Managers' education	-	-		0.14**	-	-	-	0.14**
				(0.06)				(0.06)
Size (20 to 99 workers)	0.70***	0.72***	0.59**	0.69***	0.30	0.28	0.25	0.31
	(0.23)	(0.23)	(0.24)	(0.23)	(0.24)	(0.24)	(0.26)	(0.24)
Size (more than 100 workers)	1.30***	1.27***	1.26***	1.22***	0.75***	0.74***	0.71**	0.70**
	(0.31)	(0.31)	(0.33)	(0.31)	(0.29)	(0.29)	(0.32)	(0.29)
Age	-0.07	-0.01	0.12	-0.03	-0.02	-0.01	0.17	-0.03
	(0.07)	(0.07)	(0.14)	(0.07)	(0.08)	(0.08)	(0.15)	(0.08)
Establishment part of a larger firm	-0.08	0.10	0.10	-0.03	-0.08	-0.03	0.28	-0.17
	(0.22)	(0.21)	(0.29)	(0.21)	(0.20)	(0.20)	(0.27)	(0.20)
International quality certification	1.05***	1.10***	1.22***	1.06***	1.17***	1.20***	1.33***	1.15***
	(0.20)	(0.21)	(0.23)	(0.20)	(0.18)	(0.18)	(0.20)	(0.18)
Workers' compensation	0.35**	0.34**	0.39**	0.34**	0.32**	0.31**	0.22	0.34**
	(0.14)	(0.14)	(0.17)	(0.14)	(0.13)	(0.13)	(0.16)	(0.13)
Sales	0.17***	0.17***	0.17***	0.17***	0.20***	0.22***	0.22***	0.19***
	(0.05)	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)	(0.06)	(0.05)
Balochistan	-0.13	-0.15	-0.38	-0.16	-0.23	-0.25	-0.62	-0.22
	(0.69)	(0.67)	(0.70)	(0.67)	(0.72)	(0.73)	(0.77)	(0.72)
NWFP	-0.55	-0.39	-0.43	-0.34	-0.24	-0.18	0.01	-0.16
	(0.37)	(0.35)	(0.38)	(0.34)	(0.40)	(0.40)	(0.42)	(0.40)
Sindh	0.01	0.09	0.19	0.04	-0.03	-0.02	0.05	-0.04
	(0.21)	(0.21)	(0.24)	(0.21)	(0.20)	(0.20)	(0.24)	(0.20)
Food	-1.47***	-1.46***	-1.33***	-1.51***	-1.08***	-1.12***	-1.20***	-1.15***
	(0.34)	(0.33)	(0.37)	(0.33)	(0.33)	(0.33)	(0.37)	(0.33)
Garments	-0.53*	-0.54**	-0.65**	-0.52*	-0.21	-0.21	-0.29	-0.23
	(0.28)	(0.27)	(0.30)	(0.28)	(0.26)	(0.26)	(0.30)	(0.27)
Textiles	-1.02***	-1.07***	-0.94***	-1.06***	-0.88***	-0.89***	-0.76***	-0.92***
	(0.27)	(0.27)	(0.29)	(0.27)	(0.26)	(0.26)	(0.29)	(0.26)
Machinery and equipment	-0.91	-0.96*	-0.96	-0.90	-	-	-	-
	(0.58)	(0.57)	(0.59)	(0.60)				
Chemicals	-0.44	-0.44	-0.12	-0.53	-0.74**	-0.76**	-0.50	-0.89**
	(0.37)	(0.37)	(0.43)	(0.37)	(0.37)	(0.37)	(0.43)	(0.38)
Leather	-1.39***	-1.43***	-0.78	-1.56***	-1.21**	-1.24**	-0.98*	-1.41***
	(0.45)	(0.46)	(0.54)	(0.47)	(0.52)	(0.52)	(0.58)	(0.54)
Other manufacturing	0.19	0.15	0.38	0.25	0.18	0.14	0.54	0.29
	(0.43)	(0.43)	(0.46)	(0.43)	(0.39)	(0.39)	(0.45)	(0.40)
Constant	-6.17***	-5.89***	-6.66***	-6.25***	-6.83***	-6.98***	-6.83***	-7.14***
	(1.35)	(1.35)	(1.69)	(1.37)	(1.36)	(1.38)	(1.71)	(1.39)
Observations	428	429	353	431	415	416	340	418
R^2	0.448	0.435	0.463	0.446	0.418	0.420	0.471	0.430

Notes: Standard errors in parentheses; ***, ** and * means significant at 1%, 5% and 10% levels, respectively

Table 5. OLS estimates of the impact of education on computer use and computer-controlled production

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Workers using computers				Computer-controlled production			
Average education of worker	0.29***	-	-	-	0.08**	-	-	-
	(0.10)				(0.03)			
Skilled production workers	-	0.00*	-	-	-	0.00***	-	-
		(0.00)				(0.00)		
On-the-job training	-	-	0.44	-	-	-	0.23**	-
			(0.34)				(0.10)	
Managers' education	-	-	-	0.06	-	-	-	-0.01
				(0.06)				(0.02)
Size (20 to 99 workers)	0.57**	0.68**	0.58**	0.64**	-0.02	-0.00	-0.02	-0.02
	(0.26)	(0.27)	(0.28)	(0.27)	(0.06)	(0.06)	(0.06)	(0.06)
Size (more than 100 workers)	1.11***	1.15***	1.38***	1.12***	0.10	0.10	0.09	0.12
	(0.29)	(0.30)	(0.32)	(0.30)	(0.08)	(0.08)	(0.08)	(0.08)
Age	-0.13*	-0.08	-0.33**	-0.10	-0.01	-0.02	-0.01	-0.02
	(0.07)	(0.07)	(0.13)	(0.07)	(0.03)	(0.03)	(0.03)	(0.03)
Establishment part of a larger firm	-0.19	-0.08	-0.23	-0.10	0.19***	0.18***	0.19***	0.21***
	(0.19)	(0.19)	(0.23)	(0.20)	(0.07)	(0.07)	(0.07)	(0.07)
International quality certification	0.32	0.34*	0.43*	0.36*	0.10*	0.09	0.10*	0.12**
	(0.19)	(0.20)	(0.22)	(0.20)	(0.06)	(0.06)	(0.06)	(0.06)
Workers' compensation	0.14	0.13	0.24	0.14	-0.07	-0.05	-0.05	-0.05
	(0.14)	(0.14)	(0.18)	(0.14)	(0.04)	(0.04)	(0.04)	(0.04)
Sales	0.08	0.07	0.08	0.08	0.04***	0.04***	0.05***	0.05***
	(0.05)	(0.05)	(0.06)	(0.05)	(0.01)	(0.01)	(0.01)	(0.01)
Balochistan	0.54	0.58	0.60	0.54	0.10	0.12	0.08	0.11
	(0.79)	(0.80)	(0.81)	(0.80)	(0.18)	(0.18)	(0.18)	(0.18)
NWFP	-0.76*	-0.76*	-0.84*	-0.69	-0.02	-0.01	0.02	0.01
	(0.45)	(0.45)	(0.49)	(0.46)	(0.10)	(0.09)	(0.10)	(0.10)
Sindh	0.69***	0.72***	0.62***	0.70***	0.06	0.09	0.08	0.07
	(0.19)	(0.20)	(0.22)	(0.20)	(0.06)	(0.06)	(0.06)	(0.06)
Food	-0.58*	-0.62*	-0.73**	-0.65*	-0.14	-0.14	-0.16*	-0.16*
	(0.33)	(0.33)	(0.36)	(0.33)	(0.09)	(0.09)	(0.09)	(0.09)
Garments	-0.52**	-0.65**	-0.72**	-0.60**	0.06	0.03	0.04	0.05
	(0.26)	(0.26)	(0.29)	(0.26)	(0.07)	(0.07)	(0.07)	(0.07)
Textiles	-0.70***	-0.87***	-1.05***	-0.81***	-0.04	-0.10	-0.06	-0.06
	(0.25)	(0.26)	(0.28)	(0.26)	(0.07)	(0.07)	(0.07)	(0.07)
Machinery and equipment	-1.30	-1.37	-1.00	-1.39	0.01	-0.02	-0.00	-0.00
	(1.35)	(1.38)	(1.37)	(1.38)	(0.13)	(0.13)	(0.13)	(0.13)
Chemicals	0.62*	0.51	0.54	0.49	0.01	0.01	0.02	0.02
	(0.37)	(0.38)	(0.43)	(0.38)	(0.11)	(0.11)	(0.11)	(0.11)
Leather	0.33	0.14	0.03	0.09	-0.07	-0.08	-0.08	-0.08
	(0.57)	(0.58)	(0.70)	(0.58)	(0.15)	(0.14)	(0.15)	(0.15)
Other manufacturing	-0.39	-0.60	-0.56	-0.56	-0.16	-0.19*	-0.18*	-0.20*
	(0.38)	(0.38)	(0.38)	(0.38)	(0.10)	(0.10)	(0.10)	(0.10)
Constant	-1.83	-1.14	-1.62	-1.67	-0.07	0.01	-0.17	-0.12
	(1.41)	(1.44)	(1.80)	(1.44)	(0.40)	(0.40)	(0.41)	(0.40)
Observations	279	279	225	280	358	357	352	359
R^2	0.31	0.29	0.35	0.29	0.25	0.27	0.25	0.24

Notes: Standard errors in parentheses; ***, ** and * means significant at 1%, 5% and 10% levels, respectively

Table 6. Random effects probit models: estimates of email and website use

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Email				Website			
Workers' average education	0.33***	-	-	-	0.07	-	-	-
	(0.11)				(0.10)			
Skilled production workers	-	0.00	-	-	-	-0.00	-	-
		(0.00)				(0.00)		
On-the-job training	-	-	0.71	-	-	-	0.30	-
			(0.65)				(5.08)	
Managers' education	-	-	-	0.14**	-	-	-	0.14**
				(0.06)				(0.06)
Size (20 to 99 workers)	0.70***	0.72***	0.59**	0.69***	0.30	0.29	0.26	0.32
	(0.23)	(0.23)	(0.24)	(0.23)	(0.24)	(0.24)	(4.37)	(0.24)
Size (more than 100 workers)	1.30***	1.27***	1.26***	1.22***	0.77***	0.76***	0.75	0.72**
	(0.31)	(0.31)	(0.33)	(0.31)	(0.29)	(0.30)	(12.60)	(0.30)
Age	-0.07	-0.01	0.12	-0.03	-0.02	-0.01	0.18	-0.03
	(0.07)	(0.07)	(0.14)	(0.07)	(0.08)	(0.08)	(2.95)	(0.08)
Establishment part of a larger firm	-0.08	0.10	0.10	-0.03	-0.08	-0.04	0.29	-0.18
	(0.22)	(0.21)	(0.29)	(0.21)	(0.21)	(0.20)	(4.93)	(0.21)
International quality certification	1.05***	1.10***	1.22***	1.06***	1.20***	1.22***	1.40	1.18***
	(0.20)	(0.21)	(0.23)	(0.20)	(0.18)	(0.18)	(23.54)	(0.18)
Workers' compensation	0.35**	0.34**	0.39**	0.34**	0.32**	0.32**	0.23	0.34**
	(0.14)	(0.14)	(0.17)	(0.14)	(0.14)	(0.14)	(3.87)	(0.14)
Sales	0.17***	0.17***	0.17***	0.17***	0.21***	0.22***	0.23	0.19***
	(0.05)	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)	(3.89)	(0.05)
Balochistan	-0.13	-0.15	-0.38	-0.16	-0.24	-0.25	-0.65	-0.23
	(0.69)	(0.67)	(0.70)	(0.67)	(0.74)	(0.75)	(10.96)	(0.73)
NWFP	-0.55	-0.39	-0.43	-0.34	-0.24	-0.18	0.01	-0.16
	(0.37)	(0.35)	(0.38)	(0.34)	(0.41)	(0.41)	(0.45)	(0.41)
Sindh	0.01	0.09	0.19	0.04	-0.03	-0.02	0.06	-0.04
	(0.21)	(0.21)	(0.24)	(0.21)	(0.21)	(0.21)	(1.00)	(0.21)
Food	-1.47***	-1.46***	-1.33***	-1.51***	-1.11***	-1.15***	-1.26	-1.18***
	(0.34)	(0.33)	(0.37)	(0.33)	(0.34)	(0.34)	(21.21)	(0.34)
Garments	-0.53*	-0.54**	-0.65**	-0.52*	-0.22	-0.22	-0.31	-0.23
	(0.28)	(0.27)	(0.30)	(0.28)	(0.27)	(0.27)	(5.16)	(0.27)
Textiles	-1.02***	-1.07***	-0.94***	-1.06***	-0.90***	-0.91***	-0.80	-0.94***
	(0.27)	(0.27)	(0.29)	(0.27)	(0.27)	(0.27)	(13.54)	(0.27)
Machinery and equipment	-0.91	-0.96*	-0.96	-0.90	-5.70	-5.72	-6.50	-5.86
	(0.58)	(0.57)	(0.59)	(0.60)	(11,487.74)	(11,499.16)	(82,330.67)	(18,240.66)
Chemicals	-0.44	-0.44	-0.12	-0.53	-0.76**	-0.77**	-0.53	-0.91**
	(0.37)	(0.37)	(0.43)	(0.37)	(0.38)	(0.38)	(8.94)	(0.39)
Leather	-1.39***	-1.43***	-0.78	-1.56***	-1.24**	-1.27**	-1.03	-1.44***
	(0.45)	(0.46)	(0.54)	(0.47)	(0.53)	(0.54)	(17.44)	(0.55)
Other manufacturing	0.19	0.15	0.38	0.25	0.19	0.15	0.57	0.30
	(0.43)	(0.43)	(0.46)	(0.43)	(0.40)	(0.40)	(9.55)	(0.41)
Constant	-6.17***	-5.89***	-6.66***	-6.25***	-6.96***	-7.11***	-7.18	-7.27***
	(1.35)	(1.35)	(1.69)	(1.37)	(1.40)	(1.42)	(121.01)	(1.42)
Observations	428	429	353	431	428	429	353	431

Notes: Standard errors in parentheses; ***, ** and * means significant at 1%, 5% and 10% levels, respectively

Table 7. Impact of education on computer use, the random effects model

	(1)	(2)	(3)	(4)
Workers' average education	0.29***			
	(0.10)			
Skilled production workers		0.00		
		(0.00)		
On-the-job training			0.00	
			(0.00)	
Managers' education				0.07
				(0.06)
Size (20 to 99 workers)	0.57**	0.68**	0.00	0.63**
	(0.26)	(0.27)	(0.00)	(0.27)
Size (more than 100 workers)	1.10***	1.14***	0.00	1.10***
	(0.29)	(0.30)	(0.00)	(0.30)
Age	-0.13*	-0.08	0.00	-0.10
	(0.07)	(0.07)	(0.00)	(0.07)
Establishment part of a larger firm	-0.19	-0.07	0.00	-0.10
	(0.19)	(0.19)	(0.00)	(0.20)
International quality certification	0.32	0.35*	0.00	0.37*
	(0.19)	(0.20)	(0.00)	(0.20)
Workers' compensation	0.14	0.12	0.00	0.14
	(0.14)	(0.14)	(0.00)	(0.14)
Sales	0.08	0.07	0.00	0.08
	(0.05)	(0.05)	(0.00)	(0.05)
Balochistan	0.54	0.57	0.00	0.54
	(0.79)	(0.80)	(0.00)	(0.80)
NWFP	-0.78*	-0.81*	0.00	-0.74
	(0.45)	(0.46)	(0.00)	(0.46)
Sindh	0.69***	0.72***	0.00	0.70***
	(0.20)	(0.20)	(0.00)	(0.20)
Food	-0.57*	-0.61*	0.00	-0.63*
	(0.33)	(0.34)	(0.00)	(0.34)
Garments	-0.51*	-0.63**	0.00	-0.58**
	(0.26)	(0.27)	(0.00)	(0.27)
Textiles	-0.71***	-0.88***	0.00	-0.82***
	(0.26)	(0.26)	(0.00)	(0.26)
Machinery and equipment	-1.30	-1.38	0.00	-1.40
	(1.35)	(1.38)	(0.00)	(1.38)
Chemicals	0.62*	0.48	0.00	0.46
	(0.37)	(0.38)	(0.00)	(0.38)
Leather	0.33	0.14	0.00	0.07
	(0.57)	(0.58)	(0.00)	(0.58)
Other manufacturing	-0.39	-0.61	0.00	-0.56
	(0.38)	(0.38)	(0.00)	(0.38)
Constant	-1.82	-1.15	1.58***	-1.69
	(1.41)	(1.44)	(0.00)	(1.44)
Observations	279	279	225	280

Notes: Standard errors in parentheses; ***, ** and * means significant at 1%, 5% and 10% levels, respectively

5. Concluding remarks

This study of the impact of human capital on the adoption and use of ICT represents one of the few efforts to date to analyze the determinants of the adoption of new technologies in developing countries. Estimates from the probit and simple OLS and random effects models provide some new insights on the firm-level evolution of a developing economy. The analysis shows that the higher the education attainment of the top manager, the higher is the probability of the firm possessing a website and using

email for interaction with customers and suppliers. The education level of the workforce is also found to be a determinant of computer use in a firm. Thus, our first and second hypotheses stated in the introduction are partially verified. Consequently, we can infer that education levels are a key determinant in the adoption of ICTs in developing countries, and that firms in the developing countries with higher human capital enjoy greater competitivity.

Our third hypothesis is also partly accepted. In fact, sales are found to be positively and significantly associated with the probability of website and email use but have a non significant impact on the proportion of workers using computers.

The findings show the importance of accumulation and development of human capital in the productivity growth in the era of skill-biased technical change. A concerted national effort for the enhancement of the workforce's computing skills is therefore a must if a developing economy such as Pakistan is to improve its competitivity.

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