Impact of Information Communication Technology on labor productivity: A panel and cross-sectional analysis

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ABSTRACT

This article examines the contribution of information and communications technologies (ICT) to labor productivity using panel data approach. The study covers the period of 2000-2015 for a complete dataset of 98 countries as well for three selected groups: low-income, middle-income, and high-income countries. The findings imply that telephone subscription and broadband subscription have a significant impact on overall labor productivity as well as labor productivity of service sector. The ICT affects the labor productivity, so investing in Information Communication Technology is necessary to increase the labor productivity.

Keywords: Information communication technology, labor productivity, panel data analysis, low-income, middle-income, high-income countries

1. Introduction

Information Communication Technology is changing the world around us. According to the World Bank report, ICT infrastructure has attracted investment, increased fiscal revenues and generated employment and opportunities for growth in developing countries. The number of mobile subscriptions worldwide has increased from 1 billion to 6 billion now, out of which nearly 5 billion are in developing countries. Internet users have grown twenty-fold and nearly 91% of the population have access to fixed or mobile telephone in developing countries. Information communication technologies are acting as a vehicle for growth in making system more accountable, cost-efficient and fast. The main challenge lies to extend the ICT network in developing and underdeveloped countries. The main contribution of this study is the investigation of the impact of Information Communication Technology on labor productivity on the aggregate level as well as the group of low-income, middle-income, and high-income countries. Analyzing the differential impact of variables on the group of low, middle and high-income countries allows us to provide a basis for relative comparison among variables. This comparison will help in making useful policy suggestions for the variables. The significant impact of

Information Communication Technology will motivate countries to invest in improving and strengthening ICT networks. These networks will help underdeveloped and developed countries to increase the pace of economic growth. According to the study by Ref. [**1**]; which argued that the role of the market service sector is important to improve productivity, we assume that taking into account the labor productivity of the service sector apart from overall labor productivity will make our results more sensitive to the changes in Information Communication Technology. Primary and Secondary sectors use Information Communication Technology as an intermediate in their production process but tertiary or service sector depends completely on Information and Communication Technology.

This paper is organized as follows. In **Section 2**, the literature review of previous work done in the field of ICT and productivity is provided. **Section 3** introduces the data and provides explanations about the variables used in the study. A brief description of the panel model and of the model used in our study is given in **Section 4**. In **Section 5**, interpretations of the results are presented, while **Section 6** and **7** have results and conclusions along with policy suggestions.

2. Literature review

Most of the studies concerning ICTs were done in reference to the United States in the late 1990s when some data was accessible. This paper analyzes the influence ICTs have had on productivity in recent times. The analysis covers most of the countries of the world according to the data availability and extends our study to a group of low, middle, and high-income countries. Studies done in the late 1990s had a very short data span to make inferences, now the availability of the data is greater, so we have analyzed the period of 2000-2015 which gives us the advantage to make our inferences more accurate. Some authors claimed the role of ICTs was significant and some authors claimed it to be insignificant [**2**]. in their paper investigated the basic premise of how much computing equipment has contributed to economic growth in the past two decades and concluded that the contribution of computer hardware was very small. It was computer hardware along with software that was responsible for growth. However, the share of computer software and hardware in the capital stock is particularly small, so they cannot account for significant growth unless the drastic rise in equipment takes place. [**3**]; in his paper, did an empirical analysis for US and Canada and found two factors to be important for diffusion and use of information technology. First, information and communication processing costs have fallen, and second, globalization that has increased competition. Cuberes (2010) claimed that the adoptions of information and communication technologies in general and the Internet in particular significantly contribute to economic growth and development. The same findings are obtained by Refs. [**4,5**]; with evidences at different levels of economic activity. [**6**]; in his paper, provides evidence for substitution of IT for other capital and labor inputs and finds the answer to the question: whether massive substitution to IT is accompanied by technical change? He finds that substitution is not accompanied by the technical change since there is no significant increase in total factor productivity in comparison to IT deployment [**7**]. conclude that information technology and production of computers software, hardware contribute about two-thirds to one percentage step up in the productivity growth. The study by Paul [**8**] assess the role of ICT as a capital good in contribution to output growth and concluded ICT capital goods have been important contributors to economic growth [**9**]. in their paper assessed the validity of the association of economic growth with information technology and after getting valid evidence authors further used the multi-sector growth model to analyze the steady-state properties and concluded productivity growth was sustainable. Numerous papers on ICT value at the country level have concluded that developed countries experience a significant positive impact on productivity as a result of ICT investment, but there has been no consensus with regards to the developing countries [**10,11**] [**8,12-14**] [**15**]. The latter have made

significant investments in their ICT infrastructure, necessitating a similar investigation into the payoff from ICT investments in developing countries [**16**]. [**16**] conducted research on this issue based on data from 45 countries, comparing the results of 1994-2007 to the figures of 1985-1993 [**12**]. They found investment in ICT over the more recent years has resulted in significantly increased productivity in upper-income developing countries. Additionally, it was concluded that human resources and other country factors moderate the ICT productivity effects. Using a non-parametric test [**17**], established the positive contribution of ICT technologies in terms of generating convergence clubs in the evolution of labor productivity [**18**]. found that major factors which negatively affect labor productivity are lack of experience, lack of labor surveillance, and, according to Ref. [**19**]; factors affecting productivity are lack of skill, lack of equipment. Information Technology and Productivity: Where Are We Now and Where Are We Going? [9] concluded that rapid growth in labor productivity after 1995 was due to using information technology capital goods and on analyzing stable state properties of multi-sector growth model they found that it was stable in the long-run [**20**]. investigated cross-country and cross-industry differences in labor productivity in association with ICT and concluded that ICT diffusion into Europe was at a much slower pace. Also, ICT producing sectors, computers, and other accessories showed similar productivity growth in all countries but there were differences in ICT producing services such as telecom services [**21**]. [**22**] concluded that the surge in US productivity in 1990 occurred not only in producers of software and high technology equipment but also in the retail and wholesale industries, thus ensuring that innovations added to economic growth as well. Basu (2008) concluded that one of the most important reasons for acceleration in productivity of factors of production is due to the use of ICT [**1**]. concluded that an increase in the volume of ICT and improvement in human capital has played a crucial role in increasing productivity of labor [**1**]. also showed that a slower emergence of knowledge about the use of Information Technology is attributable to slower improvement in productivity in European Economy. Vice versa, the more efforts are done to develop the knowledge, including ICT usage, the more rapid growth of productivity is achieved [**23**]. That is why development of knowledge regarding ICT becomes essential direction of education management [**24**] as well as for related areas for IT governance [**25**]. Various reasons for slower emergence were a small share of technology producing industries, slower multi-factor productivity growth. The author argued the key role of the market service sector to improve productivity growth. The studies have been done both at the country level and at firm or sectoral level to find the productivity of labor factor [**26,27**]. [26] found that the cyclical fluctuations and the growth path had the tendency to diminish the effects of technology-specific to ICT investment. The research findings confirmed that higher intensity of ICT investments combined with faster changes in ICT investment-specific technologies result in the more rapid growth of labor productivity [**28**]. did a study to find the influence ICT has on the MENA countries in terms of productivity of work factor. It was established that productivity of labor was improved due to the positive effects of human capital, ICT, education, and R&D. The difference in our study lies in increasing the data set to a large number of countries, using more recent period of time and comparing among groups of countries.

3. Data

Data for all the variables were taken from World Development Indicator online from World Bank Data. We used Panel data for the period from 2000 to 2015 for the set of 98 countries of the world. Our dataset is strongly balanced. Some missing values in the data are filled according to the trend of the series. Common rules used include i) average of last three observations, ii) fill with most recent value, iii) In case of increasing trend linearly extrapolated it.

3.1. Variables and their explanations

The rapid spread of mobile phones, the internet, and other applications of ICT has spurred sizable investments in ICT. The section describes the variables we use in the model to investigate the impact of Information Communication Technology on labor productivity. Labor productivity is defined as current GDP divided by labor force as well as labor productivity of service sector which is defined as GDP due to service sector divided by labor force. GDP of the service sector is calculated with help of a variable named services value added as a percentage of GDP. Other variables are gross capital formation as a percentage of GDP, foreign direct investment as a percentage of GDP, high technology export as a percentage of manufactured exports, various Information Communication Technology variables are Individuals using the internet as a percentage of the population, Fixed telephone subscriptions per 100 people, Fixed broadband subscription per 100 people, ICT goods exports as a percentage of total goods exports, ICT good import as a percentage of total goods imports, Mobile cellular subscription per 100 people. An important point to note is that we use the growth rate of all the variables in our study.

Variable services value added as a percentage of GDP includes value added in wholesale and retail trade, transport, government, financial, professional, and personal services such as education, healthcare, and real estate. GDP growth measures the increase or decrease of the final value of all goods and services produced in a country in a particular year. An increase in GDP growth suggests an increase in productivity per worker. Foreign direct investment helps to increase the fund available to the country thathelps in increasing production. The Gross capital formation measures the increase in fixed assets over the year. It includes investment in machines, vehicles, infrastructure. The greater will be fixed assets the more will be productivity. The impact of ICT will be measured with the help of the number of individuals using the internet measured as the percentage using the internet in the population, telephone, broadband and mobile subscription, ICT import, and export. These variables will exclusively calculate the impact of the use of ICTs on productivity.

Since we use a large number of variables in our model there might be chances of multicollinearity, particularly among ICT variables. We present correlation among variables in order to investigate multi-collinearity. According to the table, all values of correlation are less than 0.25. Thus, we incorporate all the variables in the model.

In **Table 1**, labor represents labor productivity growth of the service sector, tele represents telephone subscription, broad represents broadband subscription, tech represents high technology export, ictex represents ICT goods export, ictim represents ICT goods import, and mob represents mobile subscription.

4. Model

4.1. Panel model

According to the aim of the study, the dependent variable is the labor productivity of service sector for some model and the overall labor productivity for the rest. The variables are in terms of growth rates. After testing for the unit root in our variables using tests proposed by Refs. [**20,29**] we rejected the

null hypothesis of the unit root in our variables. We have static panel data for our analysis. In order to fit our model, we give a brief overview of static panel data techniques.

Panel model can be represented in form of the following equation:

$$y_{it} = x^{'}\beta_{it} + \varepsilon_{it} \qquad (1)$$

The main question is whether x;t and ;t are uncorrelated? If they are uncorrelated then this turns out as a Seemingly Unrelated Regression (SUR) type model with common coefficients. If they are correlated then we have a multiple equation system with common coefficients and endogenous regressors. Now the challenge is to estimate the model under the presence of endogeneity. Here comes the benefit of the panel data model where under certain assumptions, we can deal with endogeneity without using instruments. This estimation method is known as the fixed effects (FE) estimator.

Further error term it can be expressed as a sum of fixed effect component a_i and n_{it}. Fixed effect term captures unobserved heterogeneity across individuals that are constant over time. In our data fixed effect term constitutes country-specific term that does not vary over time. This can be for example motivation to use new technology among people, this is likely to be correlated with explanatory variables like internet usage, mobile phone subscription. Since people who are open to new technology will be able to adapt and use that technology efficiently.

$$\varepsilon_{it} = \alpha_i + \eta_{it} \qquad (2)$$

The basic difference between fixed effect and random effect models are as follows:

RE model: $E\ [\ X_{it}\ \alpha_i] = 0$, FE model: $E\ [X_{it}\ \alpha_i]\ 6 = 0$.

With the help of fixed effect regression, we can deal with endogeneity with the help of three equivalent approaches 1. Within-group estimator, 2. Least squares dummy variable estimator, 3. First difference estimator.

In case of the random effects model since no endogeneity therefore random effect framework is a Seemingly Unrelated Regression (SUR) model is just with modification in the covariance structure of the error term.

The specification of the panel model used in the study is followed by:

$$Lab\ Prod\ Ser_{it} = \alpha_i + \beta_1(GdpGr)_{it} + \beta_2(GcfGr)_{it} + \beta_3(FdiGr)_{it} + \beta_4(InternetGr)_{it} + \beta_5(ICTexGr)_{it} + \beta_6(ICTimGr)_{it} + \beta_7(TelephGr)_{it} + \beta_8(BroadbandGr)_{it} + \beta_9(MobileGr)_{it} + \varepsilon_{it} \qquad (3)$$

After we have balanced stationary panel data the next thing is to investigate which model is appropriate for our data. We applied the Hausman test (1978) to full panel data set of 98 countries and the results indicate to reject the null hypothesis of no correlation between unobserved heterogeneity term and explanatory variable. Hence due to the presence of correlation between unobserved variables and independent variable fixed effect regression model become the correct choice to find the estimates.

5. Interpretations

In **Table 2**, we present results of the fixed effect regression model with labor productivity growth of the service sector as the dependent variable. The coefficient of gross capital formation growth is significant. It can be interpreted as follows - one percent increase in gross capital formation growth will imply 0.179% increase in labor productivity of the service sector. This result is consistent with the general notion that an increase in gross capital will increase the efficiency and productivity of labor. The coefficient of Lagged GDP growth is positive and significant, an increase in GDP growth implies a stronger economy and furthermore employment, which will lead to increase in labor productivity in the next period and other possible explanation being an increase in GDP growth will increase the supply in the market which will be followed by investment in capital and labor.

Table 1 Cross-correlation table.

Variables	Labour	FDI	GCF	Internet	Tele	broad	tech	ictex	ict im	mob
labour	1.000									
FDI	0.010	1.000								
GCF	0.211	0.007	1.000							
Internet	0.013	0.036	0.082	1.000						
tele	0.050	0.016	0.003	0.107	1.000					
broad	0.110	−0.004	0.024	0.042	−0.001	1.000				
tech	−0.013	−0.002	0.003	−0.008	−0.065	−0.004	1.000			
ictex	−0.010	−0.122	−0.019	0.018	−0.004	0.010	−0.001	1.000		
ictim	0.003	0.019	0.006	0.037	−0.003	−0.017	0.008	0.177	1.000	
mob	0.034	0.038	0.032	0.214	0.082	0.018	−0.006	−0.001	0.096	1.000

Table 2 Dependent Variable: Labor productivity Growth of service sector.

	(1)	(2)	(3)	(4)
FDIgrowth	0.000141	0.000137	0.000131	0.000145
	(0.425)	(0.439)	(0.461)	(0.413)
GCFgrowth	0.179***	0.179***	0.179***	0.171***
	(0.000)	(0.000)	(0.000)	(0.000)
L.gdp gr	0.924***	0.929***	0.929***	0.888***
	(0.000)	(0.000)	(0.000)	(0.000)
Internetgrowth	−0.00435	−0.00446	−0.00443	−0.00815
	(0.510)	(0.499)	(0.502)	(0.219)
Telegr	0.0417*	0.0421*	0.0421*	0.0355
	(0.028)	(0.026)	(0.027)	(0.060)
Broadgr	0.00244**	0.00247**	0.00247**	0.00236*
	(0.009)	(0.008)	(0.008)	(0.011)
Ictgoodimgr		0.00918	0.00960	0.00411
		(0.361)	(0.348)	(0.689)
Ictgoexgr			−0.0000989	−0.0000497
			(0.823)	(0.910)
Mobsubgr				0.0291*** (0.000)
Cons	3.372***	3.342***	3.347***	2.912***
	(0.000)	(0.000)	(0.000)	(0.000)
N	1469	1469	1469	1469

*p-values in parentheses (*p < 0.05, **p < 0.01, ***p < 0.001).*

This is the reason we took lagged value of GDP growth. The coefficient of Internet growth is negative and significant it can be justified, as individuals using the internet apart from their professional work is likely to decrease their productivity output. Telephone growth has a positive and significant coefficient, which implies that communication technology leads to sharing of information and services

thatleads to increase in labor productivity. Broadband subscription leads to more sharing of information and services which lead to increase in productivity of the service sector.

In **Table 3** when labor productivity growth is used as a dependent variable, the coefficient of gross capital formation and GDP growth reduces slightly. A possible explanation for this can be due to the service sector being relatively more sensitive to capital formation and GDP growth. Rest of the coefficients are mostly similar.

Table 3 Dependent Variable: Labor productivity Growth.

	(1)	(2)	(3)	(4)
FDIgrowth	0.000165	0.000164	0.000152	0.000165
	(0.339)	(0.343)	(0.382)	(0.341)
GCFgrowth	0.174***	0.174***	0.174***	0.167***
	(0.000)	(0.000)	(0.000)	(0.000)
L.gdp gr	0.854***	0.855***	0.855***	0.817***
	(0.000)	(0.000)	(0.000)	(0.000)
Internetgrowth	−0.00188	−0.00191	−0.00184	−0.00530
	(0.771)	(0.768)	(0.776)	(0.414)
Telegr	0.0456*	0.0457*	0.0456*	0.0396*
	(0.014)	(0.014)	(0.014)	(0.033)
Broadgr	0.00268**	0.00268**	0.00269**	0.00259**
	(0.003)	(0.003)	(0.003)	(0.004)
Ictgoodimgr		0.00228	0.00318	−0.00193
		(0.816)	(0.751)	(0.847)
Ictgoexgr			−0.000208	−0.000162
			(0.630)	(0.706)
Mobsubgr				0.0271*** (0.000)
Cons	3.008***	3.000***	3.012***	2.608***
	(0.000)	(0.000)	(0.000)	(0.000)
N	1469	1469	1469	1469

*p-values in parentheses (*p < 0.05, **p < 0.01, ***p < 0.001).*

Table 4 Low-Income Countries, Labor productivity of service sector.

	(1)	(2)	(3)	(4)
FDIgrowth	0.000292	0.000273	−0.000121	0.0000202
	(0.414)	(0.449)	(0.838)	(0.972)
GCFgrowth	0.0809*	0.0811*	0.0803*	0.0696*
	(0.011)	(0.011)	(0.012)	(0.027)
L.gdp gr	−0.234	−0.233	−0.215	−0.178
	(0.390)	(0.394)	(0.434)	(0.506)
Internetgrowth	−0.00211	−0.00276	−0.00528	−0.0244
	(0.945)	(0.929)	(0.865)	(0.434)
Telegr	0.123*	0.122*	0.129*	0.106
	(0.041)	(0.043)	(0.035)	(0.078)
Broadgr	0.0109	0.0105	0.0101	0.00812
	(0.245)	(0.264)	(0.286)	(0.380)
Ictgoodimgr		0.0181	0.0235	0.0207
		(0.573)	(0.472)	(0.518)
Ictgoexgr			−0.00265	−0.00210
			(0.400)	(0.494)
Mobsubgr				0.0945** (0.004)
Cons	6.195**	6.139**	6.460**	3.221
	(0.003)	(0.003)	(0.002)	(0.172)
N	165	165	165	165

p-values in parentheses (*p < 0.05, **p < 0.01, ***p < 0.001).

Table 5 Middle-Income Countries, Labor productivity of service sector.

	(1)	(2)	(3)	(4)
FDIgrowth	−0.000159	−0.000160	−0.000160	−0.000145
	(0.870)	(0.869)	(0.869)	(0.881)
GCFgrowth	0.287***	0.287***	0.287***	0.277***
	(0.000)	(0.000)	(0.000)	(0.000)
L.gdp gr	1.166***	1.172***	1.172***	1.137***
	(0.000)	(0.000)	(0.000)	(0.000)
Internetgrowth	−0.0115	−0.0117	−0.0116	−0.0133
	(0.090)	(0.087)	(0.088)	(0.051)
Telegr	0.0274	0.0278	0.0278	0.0239
	(0.163)	(0.156)	(0.157)	(0.224)
Broadgr	0.00189*	0.00190*	0.00190*	0.00186*
	(0.038)	(0.036)	(0.036)	(0.041)
Ictgoodimgr		0.00939	0.00983	0.00578
		(0.381)	(0.369)	(0.601)
Ictgoexgr			−0.0000869	−0.0000493
			(0.836)	(0.906)
mobsubgr				0.0166* (0.024)
Cons	2.945 ***	2.895 ***	2.901 ***	2.622 ***
	(0.000)	(0.000)	(0.000)	(0.000)
	764	764	764	764

*p-values in parentheses (*p < 0.05, **p < 0.01, ***p < 0.001).*

5.1. Classification among low, middle and high-income countries

Results obtained from Panel data help us to know the overall impact of these variables but on an individual or group level. Thus, results need to be reinvestigated. Thus, we segregate our data into low-income, middle-income, and high-income countries and carry out the same analysis further. Applying Hausman's (1978) test to panel data of low, middle, and high-income countries. This time we fail to reject the null hypothesis of no autocorrelation among unobserved term and explanatory variables. A random effect model is used to find estimates of the parameters.

Comparing results of regression among low, middle, and high-income countries. In **Tables 4-6**, we present regression results of the random effect model with the dependent variable as Labor productivity of the service sector.

Comparing results of regression among low, middle, and high-income countries, in **Tables 7-9** we present regression results of random effect model with the dependent variable as overall labor productivity.

Table 4 Low-Income Countries, Labor productivity of service sector.

	(1)	(2)	(3)	(4)
FDIgrowth	0.000292	0.000273	−0.000121	0.0000202
	(0.414)	(0.449)	(0.838)	(0.972)
GCFgrowth	0.0809*	0.0811*	0.0803*	0.0696*
	(0.011)	(0.011)	(0.012)	(0.027)
L.gdp gr	−0.234	−0.233	−0.215	−0.178
	(0.390)	(0.394)	(0.434)	(0.506)
Internetgrowth	−0.00211	−0.00276	−0.00528	−0.0244
	(0.945)	(0.929)	(0.865)	(0.434)
Telegr	0.123*	0.122*	0.129*	0.106
	(0.041)	(0.043)	(0.035)	(0.078)
Broadgr	0.0109	0.0105	0.0101	0.00812
	(0.245)	(0.264)	(0.286)	(0.380)
Ictgoodimgr		0.0181	0.0235	0.0207
		(0.573)	(0.472)	(0.518)
Ictgoexgr			−0.00265	−0.00210
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Mobsubgr				0.0945** (0.004)
Cons	6.195**	6.139**	6.460**	3.221
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	(1)	(2)	(3)	(4)
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	(0.870)	(0.869)	(0.869)	(0.881)
GCFgrowth	0.287***	0.287***	0.287***	0.277***
	(0.000)	(0.000)	(0.000)	(0.000)
L.gdp gr	1.166***	1.172***	1.172***	1.137***
	(0.000)	(0.000)	(0.000)	(0.000)
Internetgrowth	−0.0115	−0.0117	−0.0116	−0.0133
	(0.090)	(0.087)	(0.088)	(0.051)
Telegr	0.0274	0.0278	0.0278	0.0239
	(0.163)	(0.156)	(0.157)	(0.224)
Broadgr	0.00189*	0.00190*	0.00190*	0.00186*
	(0.038)	(0.036)	(0.036)	(0.041)
Ictgoodimgr		0.00939	0.00983	0.00578
		(0.381)	(0.369)	(0.601)
Ictgoexgr			−0.0000869	−0.0000493
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	(0.000)	(0.000)	(0.000)	(0.000)
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reject the null hypothesis of no autocorrelation among unobserved term and explanatory variables. A random effect model is used to find estimates of the parameters.

Comparing results of regression among low, middle, and high-income countries. In **Tables 4-6**, we present regression results of the random effect model with the dependent variable as Labor productivity of the service sector.

Comparing results of regression among low, middle, and high-income countries, in **Tables 7-9** we present regression results of random effect model with the dependent variable as overall labor productivity.

Table 6 High-Income Countries, Labor productivity of service sector.

	(1)	(2)	(3)	(4)
FDIgrowth	0.000133	0.000127	0.000124	0.000130
	(0.484)	(0.504)	(0.512)	(0.493)
GCFgrowth	0.310***	0.312***	0.321***	0.317***
	(0.000)	(0.000)	(0.000)	(0.000)
L.gdp gr	1.005***	0.986***	1.016***	0.990***
	(0.000)	(0.000)	(0.000)	(0.000)
Internetgrowth	0.0488*	0.0490*	0.0475*	0.0351
	(0.024)	(0.024)	(0.028)	(0.154)
Telegr	−0.0352	−0.0306	−0.0312	−0.0341
	(0.682)	(0.722)	(0.715)	(0.690)
Broadgr	0.00922*	0.00907*	0.00931*	0.00808
	(0.024)	(0.027)	(0.022)	(0.057)
Ictgoodimgr		−0.0406	−0.00728	−0.0116
		(0.264)	(0.851)	(0.766)
Ictgoexgr			−0.0343*	−0.0348*
			(0.016)	(0.015)
Mobsubgr				0.0406 (0.292)
Cons	2.007**	2.007**	2.038**	1.944**
	(0.001)	(0.001)	(0.001)	(0.002)
N	540	540	540	540

*p-values in parentheses (*p < 0.05, **p < 0.01, ***p < 0.001).*

Table 7 Low income countries, labour productivity growth.

	(1)	(2)	(3)	(4)
FDIgrowth	0.000307	0.000298	−0.0000842	0.0000330
	(0.355)	(0.372)	(0.878)	(0.951)
GCFgrowth	0.0638*	0.0639*	0.0632*	0.0543
	(0.030)	(0.031)	(0.033)	(0.064)
L.gdp gr	−0.154	−0.153	−0.135	−0.105
	(0.543)	(0.546)	(0.594)	(0.674)
Internetgrowth	0.0149	0.0146	0.0121	−0.00375
	(0.604)	(0.612)	(0.675)	(0.897)
Telegr	0.111*	0.111*	0.117*	0.0977
	(0.048)	(0.049)	(0.039)	(0.081)
Broadgr	0.00507	0.00490	0.00447	0.00284
	(0.560)	(0.575)	(0.610)	(0.741)
Ictgoodimgr		0.00761	0.0129	0.0106
		(0.798)	(0.670)	(0.723)
Ictgoexgr			−0.00257	−0.00212
			(0.377)	(0.459)
Mobsubgr				0.0786** (0.008)
Cons	5.194**	5.170**	5.482**	2.788
	(0.007)	(0.008)	(0.005)	(0.204)
N	165	165	165	165

p-values in parentheses (*p < 0.05, **p < 0.01, ***p < 0.001).

5.2. Gross capital formation growth

The coefficient of Gross capital formation growth is 0.089 for low-income countries, 0.287 for middle-income countries, and 0.310 for high-income countries. These results are completely in accordance with the relative results we expect among these groups. In low-income countries industries are mostly labor-intensive. Therefore, growth in GCF will have the least effect on low-income countries and a greater effect on high-income countries.

5.3. Lagged GDP growth

Lagged GDP growth has an insignificant impact on low-income countries, GDP growth has a higher impact on middle-income countries as compared to high-income countries. This can be explained as high-income countries are already developed and have less scope to improve productivity as compared to middle-income countries.

Table 8 Middle-Income Countries, Labor productivity Growth.

	(1)	(2)	(3)	(4)
FDIgrowth	0.0000915	0.0000913	0.0000920	0.000108
	(0.926)	(0.926)	(0.925)	(0.912)
GCFgrowth	0.286***	0.286***	0.285***	0.276***
	(0.000)	(0.000)	(0.000)	(0.000)
L.gdp gr	1.070***	1.071***	1.072***	1.040***
	(0.000)	(0.000)	(0.000)	(0.000)
Internetgrowth	−0.00850	−0.00853	−0.00847	−0.0101
	(0.215)	(0.214)	(0.218)	(0.145)
Telegr	0.0304	0.0305	0.0304	0.0267
	(0.124)	(0.123)	(0.125)	(0.178)
Broadgr	0.00219*	0.00220*	0.00220*	0.00216*
	(0.017)	(0.017)	(0.016)	(0.019)
Ictgoodimgr		0.00222	0.00305	−0.000789
		(0.838)	(0.782)	(0.944)
Ictgoexgr			−0.000164	−0.000130
			(0.697)	(0.757)
Mobsubgr				0.0156* (0.000)
Cons	2.464***	2.452***	2.463***	2.198**
	(0.000)	(0.000)	(0.000)	(0.002)
N	764	764	764	764

*p-values in parentheses (*p < 0.05, **p < 0.01, ***p < 0.001).*

Table 9 High Income Countries, Labor productivity.

	(1)	(2)	(3)	(4)
FDIgrowth	0.000122	0.000116	0.000114	0.000123
	(0.491)	(0.510)	(0.516)	(0.485)
GCFgrowth	0.356***	0.358***	0.364***	0.359***
	(0.000)	(0.000)	(0.000)	(0.000)
L.gdp gr	0.906***	0.890***	0.910***	0.873***
	(0.000)	(0.000)	(0.000)	(0.000)
Internetgrowth	0.0450*	0.0452*	0.0442*	0.0261
	(0.026)	(0.025)	(0.028)	(0.254)
Telegr	0.0168	0.0208	0.0204	0.0162
	(0.834)	(0.795)	(0.798)	(0.839)
Broadgr	0.00814*	0.00801*	0.00817*	0.00639
	(0.033)	(0.036)	(0.032)	(0.106)
Ictgoodimgr		−0.0360	−0.0133	−0.0195
		(0.287)	(0.714)	(0.590)
Ictgoexgr			−0.0235	−0.0241
			(0.079)	(0.071)
Mobsubgr				0.0589 (0.101)
Cons	2.240***	2.240***	2.261***	2.123***
	(0.000)	(0.000)	(0.000)	(0.000)
N	540	540	540	540

*p-values in parentheses (*p < 0.05, **p < 0.01, ***p < 0.001).*

5.4. Internet growth

Internet growth has an insignificant effect in case of low-income countries whereas it has a negative and significant impact in case of middle-income countries and a positive and significant impact on high-income countries. A possible reason can be in middle-income countries: they have not reached the break-even point when ICTs start yielding an increase in productivity whereas in high-income countries it has started yielding positive effect.

5.5. Telephone subscription growth

Telephone subscription has a significant and positive impact on low-income countries whereas Broadband subscription has a positive and significant impact in case of middle and high-income countries and coefficient of broadband subscription clearly indicate high-income countries are making more use of Information Communication Technology as compared to middle-income countries.

5.6. Labor productivity and service sector productivity

Comparing results between labor productivity and labor productivity of service sector in case of low, middle, and high-income countries we find a significant difference between coefficients in all three cases.

5.7. Telephone subscription growth

Telephone subscription shows a higher impact on labor productivity in the service sector as compared to labor productivity overall in case of low-income countries. It is consistent with the hypothesis that

the service sector would use more percentage of Information Communication Technology as compared to the overall sector.

5.8. Broadband subscription growth

Similar results can be seen for broadband subscription in case of middle-income countries and high-income countries. Broadband subscription has a greater impact on the productivity of the service sector as compared to overall labor productivity.

6. Results

The growth rate of Gross Capital Formation, Lagged GDP growth rate, telephone subscription growth rate, and broadband subscription growth rate have a significant impact on overall labor productivity as well as labor productivity of the service sector. Thus, investing in capital formation, Information Communication Technology is necessary to increase labor productivity.

In case of low-income countries variable gross capital formation growth and telephone, subscription play a significant role in affecting labor productivity overall and labor productivity of the service sector.

In case of middle-income countries, gross capital formation growth, lagged GDP growth and broadband subscription are significant variables in affecting both labor productivities. Internet growth rate variable is significant only in case of labor productivity of the service sector.

In case of high-income countries gross capital formation growth, lagged GDP growth, internet growth, and broadband subscription are significant in affecting labor productivity in both cases.

7. Conclusion

The obtained results can help to design and implement better policies regarding Information Communication Technology in the future. Some policy suggestions we make are as follows: The world organizations should provide aid to low and middle-income countries to expand their ICT network and to increase investment in capital formation at a very reasonable rate of interest and more adaptive conditions. Since conditions often imposed on borrower countries are imposed according to consensus developed by high-income countries. Low-income and middle-income countries have to focus on the improvement of the ICT networks and also seek assistance from developed countries in getting affordable technology. Another important way to improve labor productivity is to make the labor force more skilled. Increasing competition and growing technology are taking place of labor and thus, labor needs to be more skilled in order to exist on the market. This can be achieved by opening centers to skill young people. Policies have to be designed by governments in a way that there remains an incentive to work. Providing unemployment allowances and other benefits, especially in case of developed countries, actually makes the people less motivated to work. The government has to improve policies in a regular manner so that only individual in need gets the assistance. The real test of policies is after they are implemented. The main work of policymakers should not end after making policies and implementing them but again and again, it should be time-tested to reduce loopholes present in them. The use of ICT should be diverted to make people educated, reduce poverty. Then ICTs will prove to be a boon in the real sense generating positive externality and taking a step forward in making the world a better place.

Nevertheless, the conducted study has limitations. The level of schooling in the labor force was not taken into account in our study though it can be expected that the higher the schooling level, the higher is the productivity of IT investment. The future research in this area will be covering the level of schooling in the labor force and its impacts.

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Appendix

Countries used in our study are as follows: Albania, Argentina, Armenia, Australia, Austria, Azerbaijan, Burundi, Benin, Burkina Faso, Bangladesh, Bulgaria, Belarus, Bolivia, Brazil, Barbados, Botswana, Switzerland, Chile, China, Cameroon, Colombia, Cyprus, Czech Republic, Germany, Denmark, Dominican Republic, Algeria, Ecuador, Egypt, Spain, Estonia, Finland, Fiji, France, United Kingdom, Georgia, Greece, Honduras, Croatia, Hungary, India, Ireland, Iceland, Italy, Jamaica, Jordan, Japan, Kazakhstan, Kyrgyz Republic, Cambodia, Korea Rep, Sri Lanka, Lithuania, Latvia, Morocco, Moldova, Madagascar, Mexico, Macedonia, Malta, Mozambique, Mauritius, Malawi, Malaysia, Namibia, Nicaragua, Netherlands, Norway, New Zealand, Pakistan, Panama, Peru, Philippines, Poland, Portugal, Paraguay, Romania, Russian Federation, Saudi Arabia, Senegal, Singapore, El Salvador, Slovak Republic, Slovenia, Sweden, Togo, Thailand, Tunisia, Turkey, Tanzania, Uganda, Ukraine, Uruguay, United States, St. Vincent and the Grenadines, Venezuela RB, South Africa, Zimbabwe.

Low-income countries are as follows: Burundi Benin, Burkina Faso, Madagascar, Mozambique, Malawi, Senegal, Togo, Tanzania, Uganda, Zimbabwe.

Middle-income countries are as follows: Albania, Argentina, Armenia, Azerbaijan, Bangladesh, Bulgaria, Belarus, Bolivia, Brazil, Botswana, China, Cameroon, Colombia, Dominican Republic, Algeria, Ecuador, Egypt, Arab Rep. Fiji, Georgia, Honduras, Croatia, India, Jamaica, Jordan, Kazakhstan, Kyrgyz Republic, Cambodia, Sri Lanka, Morocco, Moldova, Mexico, Macedonia, FYR, Mauritius, Malaysia, Namibia, Nicaragua, Pakistan, Panama, Peru, Philippines, Paraguay, Romania, Russian Federation, El Salvador, Thailand, Tunisia, Turkey, Ukraine, St. Vincent, and the Grenadines, Venezuela RB, South Africa.

High-Income countries are as follows: Australia, Austria, Barbados, Switzerland, Chile, Cyprus, Czech Republic, Germany, Denmark, Spain, Estonia, Finland, France, United Kingdom, Greece, Hungary, Ireland, Iceland, Italy, Japan, Korea, Rep. Lithuania, Latvia, Malta, Netherlands, Norway, New Zealand, Poland, Portugal, Saudi Arabia, Singapore, Slovak Republic, Slovenia, Sweden, Uruguay, United States.

Hausman test for complete data to check whether to use FE or RE.

	---- Coefficients ----			
	(b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
FDIgrowth	.0000877	.0000507	.000037	.0000342
GCFgrowth	.1641188	.1671065	-.0029877	.0032173
Internetgr~h	-.0122644	-.0046159	-.0076485	.0015682
telegr	.0295781	.0367709	-.0071928	.0051179
broadgr	.0031664	.0038493	-.0006828	.0001952
ictgoodimgr	.0003562	.0010333	-.0006771	.0020449
ictgoexgr	-.0000513	-.0000977	.0000464	.0001492
mobsubgr	.0029566	.0039514	-.0009948	.001094

b = consistent under Ho and Ha; obtained from xtreg B = inconsistent under Ha, efficient under Ho; obtained from xtreg

```
Test:  Ho:  difference in coefficients not systematic

             chi2(8) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                     =       37.45
           Prob>chi2 =      0.0000
```

Fixed effect Regression results (dependent variable: Lab prod_ser).

```
Fixed-effects (within) regression               Number of obs      =      1469
Group variable: country                         Number of groups   =        98

R-sq:  within  = 0.1310                         Obs per group: min =        14
       between = 0.4243                                        avg =      15.0
       overall = 0.1541                                        max =        15

                                                F(9,1362)          =     22.82
corr(u_i, Xb)  = 0.0026                         Prob > F           =    0.0000
```

lab_ser_gr	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
FDIgrowth	.000145	.0001773	0.82	0.413	-.0002027	.0004928
GCFgrowth	.1712686	.0198977	8.61	0.000	.1322351	.2103021
gdp_gr						
L1.	.8876692	.0936791	9.48	0.000	.7038982	1.07144
Internetgrowth	-.0081473	.0066296	-1.23	0.219	-.0211527	.0048581
telegr	.0355273	.0188981	1.88	0.060	-.0015452	.0725997
broadgr	.0023616	.0009229	2.56	0.011	.0005512	.004172
ictgoodimgr	.0041052	.0102681	0.40	0.689	-.0160379	.0242483
ictgoexgr	-.0000497	.0004396	-0.11	0.910	-.0009121	.0008127
mobsubgr	.0290868	.0072097	4.03	0.000	.0149436	.0432301
_cons	2.912407	.5137734	5.67	0.000	1.904534	3.92028
sigma_u	2.8251252					
sigma_e	12.270245					
rho	.05034263	(fraction of variance due to u_i)				

```
F test that all u_i=0:     F(97, 1362) =     0.79            Prob > F = 0.9351
```

Fixed effect Regression results (dependent variable: Lab prod).

```
Fixed-effects (within) regression               Number of obs      =      1469
Group variable: country                         Number of groups   =        98

R-sq:  within  = 0.1258                         Obs per group: min =        14
       between = 0.4425                                        avg =      15.0
       overall = 0.1463                                        max =        15

                                                F(9,1362)          =     21.79
corr(u_i, Xb)  = -0.0196                        Prob > F           =    0.0000
```

LabProdGrowth	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
FDIgrowth	.0001652	.0001735	0.95	0.341	-.0001751	.0005055
GCFgrowth	.1667531	.0194709	8.56	0.000	.1285569	.2049493
gdp_gr						
L1.	.8166851	.0916697	8.91	0.000	.636856	.9965142
Internetgrowth	-.0053009	.0064874	-0.82	0.414	-.0180274	.0074255
telegr	.0395572	.0184927	2.14	0.033	.00328	.0758345
broadgr	.0025913	.0009031	2.87	0.004	.0008197	.0043628
ictgoodimgr	-.0019335	.0100479	-0.19	0.847	-.0216445	.0177775
ictgoexgr	-.0001623	.0004302	-0.38	0.706	-.0010062	.0006816
mobsubgr	.0270624	.007055	3.84	0.000	.0132225	.0409022
_cons	2.607784	.5027529	5.19	0.000	1.62153	3.594038
sigma_u	2.4406518					
sigma_e	12.007045					
rho	.03967856	(fraction of variance due to u_i)				

```
F test that all u_i=0:     F(97, 1362) =     0.61            Prob > F = 0.9988
```

Random Effect Regression for Low-Income Countries (Lab prod_ser).

```
Random-effects GLS regression                   Number of obs      =       165
Group variable: country                         Number of groups   =        11

R-sq:  within  = 0.1420                         Obs per group: min =        15
       between = 0.0059                                        avg =      15.0
       overall = 0.1368                                        max =        15

                                                Wald chi2(9)       =     24.57
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0035
```

lab_ser_gr	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FDIgrowth	.0000202	.0005786	0.03	0.972	-.0011137	.0011542
GCFgrowth	.0696246	.0314146	2.22	0.027	.0080532	.1311961
gdp_gr						
L1.	-.1783405	.2680666	-0.67	0.506	-.7037414	.3470604
Internetgrowth	-.0243813	.0311324	-0.78	0.434	-.0853996	.036637
telegr	.1059729	.06005	1.76	0.078	-.0117229	.2236687
broadgr	.0081202	.0092493	0.88	0.380	-.0100081	.0262485
ictgoodimgr	.0206855	.0319736	0.65	0.518	-.0419815	.0833525
ictgoexgr	-.0021039	.0030741	-0.68	0.494	-.0081291	.0039213
mobsubgr	.0945452	.0324081	2.92	0.004	.0310265	.1580639
_cons	3.220797	2.356589	1.37	0.172	-1.398033	7.839627
sigma_u	0					
sigma_e	15.355191					
rho	0	(fraction of variance due to u_i)				

Random Effect Regression for Low-Income Countries (Lab prod).

```
Random-effects GLS regression                   Number of obs      =       165
Group variable: country                         Number of groups   =        11

R-sq:  within  = 0.1152                         Obs per group: min =        15
       between = 0.0246                                        avg =      15.0
       overall = 0.1108                                        max =        15

                                                Wald chi2(9)       =     19.31
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0227
```

LabProdGrowth	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FDIgrowth	.000033	.0005394	0.06	0.951	-.0010241	.0010901
GCFgrowth	.0542854	.0292851	1.85	0.064	-.0031123	.1116831
gdp_gr						
L1.	-.1052335	.2498952	-0.42	0.674	-.5950191	.3845522
Internetgrowth	-.0037548	.029022	-0.13	0.897	-.0606368	.0531273
telegr	.0976969	.0559794	1.75	0.081	-.0120207	.2074145
broadgr	.0028445	.0086223	0.33	0.741	-.0140549	.0197439
ictgoodimgr	.0105663	.0298062	0.35	0.723	-.0478527	.0689853
ictgoexgr	-.0021216	.0028657	-0.74	0.459	-.0077384	.0034951
mobsubgr	.0786445	.0302112	2.60	0.009	.0194316	.1378575
_cons	2.787528	2.196844	1.27	0.204	-1.518206	7.093263
sigma_u	0					
sigma_e	14.314991					
rho	0	(fraction of variance due to u_i)				

Random Effect Regression for Middle-Income Countries (Lab prod_ser).

Random-effects GLS regression — Number of obs = 764
Group variable: country — Number of groups = 51

R-sq: within = 0.1795 — Obs per group: min = 14
between = 0.4253 — avg = 15.0
overall = 0.2020 — max = 15

Wald chi2(9) = 187.98
corr(u_i, X) = 0 (assumed) — Prob > chi2 = 0.0000

lab_ser_gr	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FDIgrowth	-.0001452	.0009695	-0.15	0.881	-.0020454	.001755
GCFgrowth	.2772539	.0371591	7.46	0.000	.2044234	.3500844
gdp_gr						
L1.	1.137029	.1123875	10.12	0.000	.9167536	1.357305
Internetgrowth	-.0133218	.0068285	-1.95	0.051	-.0267055	.0000619
telegr	.0239089	.0196593	1.22	0.224	-.0146226	.0624404
broadgr	.0018571	.0009068	2.05	0.041	.0000798	.0036343
ictgoodimgr	.0057838	.0110539	0.52	0.601	-.0158814	.027449
ictgoexgr	-.0000493	.0004185	-0.12	0.906	-.0008696	.000771
mobsubgr	.0166237	.007226	2.30	0.021	.002461	.0307865
_cons	2.622094	.7281154	3.60	0.000	1.195014	4.049174
sigma_u	1.141706					
sigma_e	12.03579					
rho	.00891803	(fraction of variance due to u_i)				

Random Effect Regression for Middle-Income Countries (Lab prod).

Random-effects GLS regression — Number of obs = 764
Group variable: country — Number of groups = 51

R-sq: within = 0.1622 — Obs per group: min = 14
between = 0.4661 — avg = 15.0
overall = 0.1844 — max = 15

Wald chi2(9) = 170.48
corr(u_i, X) = 0 (assumed) — Prob > chi2 = 0.0000

LabProdGrowth	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FDIgrowth	.0001082	.0009792	0.11	0.912	-.0018111	.0020275
GCFgrowth	.2758092	.0375974	7.34	0.000	.2021195	.3494988
gdp_gr L1.	1.039942	.1123438	9.26	0.000	.8197523	1.260132
Internetgrowth	-.0100565	.0068927	-1.46	0.145	-.023566	.0034531
telegr	.0267139	.0198247	1.35	0.178	-.0121417	.0655696
broadgr	.0021562	.000916	2.35	0.019	.000361	.0039514
ictgoodimgr	-.0007887	.0111636	-0.07	0.944	-.022669	.0210916
ictgoexgr	-.0001303	.0004208	-0.31	0.757	-.0009551	.0006944
mobsubgr	.0155853	.0072864	2.14	0.032	.0013041	.0298664
_cons	2.198028	.7135511	3.08	0.002	.7994937	3.596563
sigma_u	0					
sigma_e	12.267686					
rho	0	(fraction of variance due to u_i)				

Random Effect Regression for High-Income Countries (Lab prod_serv).

```
Random-effects GLS regression                   Number of obs      =       540
Group variable: country                         Number of groups   =        36

R-sq:  within  = 0.2058                         Obs per group: min =        15
       between = 0.4375                                        avg =      15.0
       overall = 0.2176                                        max =        15

                                                Wald chi2(9)       =    147.44
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
```

lab_ser_gr	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FDIgrowth	.0001298	.0001891	0.69	0.493	-.0002408	.0005003
GCFgrowth	.3171388	.0473899	6.69	0.000	.2242563	.4100212
gdp_gr						
L1.	.9904784	.1372177	7.22	0.000	.7215367	1.25942
Internetgrowth	.0350843	.0245894	1.43	0.154	-.01311	.0832786
telegr	-.0340934	.085547	-0.40	0.690	-.2017625	.1335757
broadgr	.0080823	.0042423	1.91	0.057	-.0002325	.0163972
ictgoodimgr	-.0115942	.0389667	-0.30	0.766	-.0879676	.0647792
ictgoexgr	-.0347842	.0143049	-2.43	0.015	-.0628214	-.006747
mobsubgr	.0406072	.038538	1.05	0.292	-.0349259	.1161403
_cons	1.943554	.6319822	3.08	0.002	.7048918	3.182216
sigma_u	0					
sigma_e	10.712165					
rho	0	(fraction of variance due to u_i)				

Random Effect Regression for High-Income Countries (Lab prod).

```
Random-effects GLS regression                   Number of obs      =       540
Group variable: country                         Number of groups   =        36

R-sq:  within  = 0.2283                         Obs per group: min =        15
       between = 0.4643                                        avg =      15.0
       overall = 0.2382                                        max =        15

                                                Wald chi2(9)       =    165.70
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
```

LabProdGrowth	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FDIgrowth	.0001229	.0001762	0.70	0.485	-.0002224	.0004681
GCFgrowth	.358739	.0441522	8.13	0.000	.2722023	.4452758
gdp_gr L1.	.8731658	.127843	6.83	0.000	.6225981	1.123733
Internetgrowth	.0261189	.0229094	1.14	0.254	-.0187828	.0710206
telegr	.0162018	.0797024	0.20	0.839	-.1400121	.1724157
broadgr	.0063899	.0039525	1.62	0.106	-.0013569	.0141366
ictgoodimgr	-.0195381	.0363045	-0.54	0.590	-.0906937	.0516174
ictgoexgr	-.0240965	.0133276	-1.81	0.071	-.0502181	.0020252
mobsubgr	.0589221	.0359051	1.64	0.101	-.0114506	.1292948
_cons	2.123484	.5888052	3.61	0.000	.9694474	3.277522
sigma_u	0					
sigma_e	10.01744					
rho	0	(fraction of variance due to u_i)				

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