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Role of ICT Investment and Diffusion in the Economic Growth: A Threshold Approach for the Empirical Evidence from Pakistan

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Abstract: This study investigates the role of Information and Communication Technologies (ICT) investment and diffusion on Pakistan's economic growth by proposing the threshold level of ICT investment. At our proposed level, the ICT imports significantly enhance the intermediate inputs to capital goods, ultimately enhancing economic growth. For this empirical investigation, we use the maximum available data on technological innovation and investment, ranging from 2003 to 2018. Incorporating the structural breaks, the results of regression analysis reveal that Pakistan's economic growth is unaffected by ICT development. However, we observe the mixed shreds of evidence on the ICT investment. Following existing literature, we use ICT goods exports and imports as a proxy for ICT investment. Interestingly, the economic growth of Pakistan is again unaffected by the ICT goods exports. However, we observe that a one percent increase in ICT goods imports enhances economic growth by 1.73 percent. Then, we extend this analysis to the threshold approach, which reveals that ICT imports affect the overall economic growth when the ICT goods imports reach the level of 4.13 percent of the total imports. At this threshold, the ICT goods import significantly enhances the intermediate input to the capital goods, leading to higher economic growth. Therefore, the policymakers should ensure that the ICT goods import must be greater than the 4.13 percent of Pakistani imports.

Keywords: ICT; technological innovation; economic growth; threshold level

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1. Introduction

Technological innovations play a significant role in the economic development of any economy (Kuznets 1978); however, this role is not a smooth process (Field 2006). History reveals that the transmission, innovation, or the collapse of the latest technologies accelerates or decelerates the economic growth abruptly. In particular, Information and Communication Technologies (ICT) transforms the firm's production processes, which ultimately transmute the country's overall production process (Jalava and Pohjola 2008). Therefore, this nexus needs empirical investigation. Interestingly, the existing literature provides enough evidence from the developed economies (see Inklaar et al. 2008; Jorgenson et al. 2005; Van Ark et al. 2003). Nevertheless, this empirical investigation is hardly done on emerging economies like Pakistan (Erumban and Das 2016). To the best of our knowledge, there is no empirical evidence exploring the role of ICT investment and diffusion on Pakistan's economic growth. Further, we extend this empirical literature by proposing the threshold level for the ICT good imports. At our proposed level, the ICT imports significantly enhance the intermediate input to the capital goods, ultimately enhancing economic growth (Colecchia and Schreyer 2002). We contribute to the existing empirical

literature by providing the ICT variable specific threshold.

The existing empirical literature applies the growth accounting approach to analyse the impact of ICT on economic growth. The history of this topic goes back to the early 1980s. However, Solow (1987) made this topic attractive by linking ICT with the productivity statistics (also see Triplett 1999). Theoretically, this impact is channelized through three ways, including (1) production process, (2) labour efficiency and (3) multi-factor productivity growth. Looking at the first channel, information communication technology diffusion and development involve the production of innovative goods and services including computers, laptops, tablets, internet and its accessories (Jorgenson and Stiroh 1995; Brynjolfsson and Hitt 1995; Colecchia and Schreyer 2002; Blau et al. 1976). The second mechanism works through labour efficiency where information and communication technologies affect the factors of production. [See Brynjolfsson and Hitt (1995), for further details on the information technology as a production factor.] More directly, these technologies' investments enhance labour efficiency through different advanced mechanisms of the production process (O'Mahony and Vecchi 2005). This channel also works through automated manufacturing or production processes. [Even this mechanism works for crop production. See Chakane, Chaskar, Patil, Shelar and Godse (Chakane et al. 2017) for the further details on the nexus between automated information system and the crop management. Also see Rahman, Yousaf and Tabassum (Rahman et al. 2020) for the discussion on industrial production.] In this mechanism, the labour efficiency reduces the labour cost (Blanchard 2017), which is a critical component of the per-unit cost. Third, the continuous improvements in information communication and technologies enhance multi-factor production growth (Van Ark et al. 2003).

Existing literature provides the evidence on these transmission mechanisms where technological innovation improves the economic growth (see Erumban and Das 2016; Inklaar et al. 2008; Jorgenson et al. 2005; Lam and Shiu 2010; Van Ark et al. 2003). Based on this evidence, this strand of literature hypothesizes that information and communication technologies positively impact the economic growth of an economy. This literate reveal that the contribution of information and communication technologies reduces the transaction and information costs. In particular, this innovation reduces the industry's overall transaction costs through electronic commerce, electronic business and online financial transactions (Bester and Petrakis 1993). Another strand of literature focuses on the indirect impact of robust telecommunication infrastructure on the economic growth through (1) promoting trading activities (Dutta 2001); (2) enhancing the level of education (Cieslik and Kaniewska 2004); (3) improving the overall health level of the general public (Micevska 2005); (4) promoting the production level (Martin and Rogers 1995); and (5) improving the social services (Snieska and Simkunaite 2009). [For further details on the telecommunication and economic growth, see Chavula (2013), Datta and Agarwal (2004), Lee, Levendis and Gutierrez (Lee et al. 2012) and Narayana (2011).] Amongst these channels, the ICT imports are expected to affect the production level through improving the intermediate inputs. For Pakistan's case, we can observe this during the period from 2007 to 2012 when the telecom operators diversified their business activities (also see Inam 2006). Conversely, another strand of the literature reveals that the level of information and communication technologies matters in any economy's economic growth. In particular, the poor and low level of information technologies deteriorates economic growth (García-Muñiz and Vicente 2014; Nam and Pardo 2011; Van Ark and Piatkowski 2004).

On these lines, Baloch (2014) provides some interesting facts about the level of information and communication technologies in Pakistan. For instance, this study indicates that Pakistan is the least connecting country and placed at the 142nd rank. These results are based on the survey of total 162 economies. Looking at the overall level of information and communication in Pakistan, the level of connectivity from Baluchistan is substantially low. Resultantly, four out of five people are offline, and the innovative technologies are unavailable, especially in Pakistan's rural area. However, the connectivity level has substantially increased over the last two decades since the regulatory authorities offered substantial

incentives to the ICT investors (also see Hameed 2007). On these lines, we analyse the latest trends in ICT and economic growth. Figure 1 presents the emerging trends of ICT diffusion, developments and economic growth from 2003 to 2018. This is the maximum available data on these variables. A closer look at these emerging trends reveals that ICT goods imports (percent of total imports) are expected to affect economic growth. In particular, this behaviour is evident during the period of the Global Financial Crisis. Therefore, we suspect that ICT good imports (percent of total imports) are expected to impact economic growth significantly.

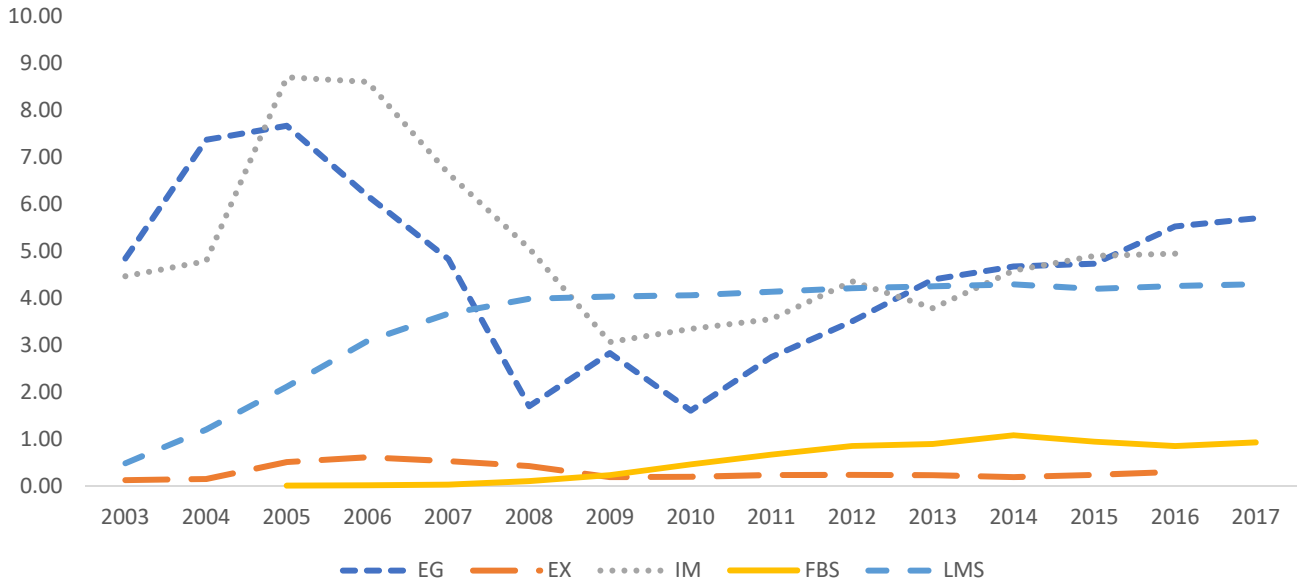

Figure 1. The Information and Communication Technologies (ICT) diffusion and economic growth. Note. EG, IM, EX, FBS and MS indicate the GDP growth (annual percent), ICT goods imports (percent of total goods imports), ICT goods exports (percent of total goods exports), fixed broadband subscriptions (per 100 people) and mobile cellular subscriptions (per 100 people), respectively.

Furthermore, Moomal and Masrom (2015) analyse the recent ICT developments in Pakistan, evaluate their impact on the e-Business and human resource management strategies and compare these information technology innovations with the developed economies. They conclude that Pakistan is still lagging in the information and communication technologies compared to the developed economies. Arfeen and Khan (2009) provide similar empirical evidence from Pakistan's e-Government projects (Bhutto et al. 2012). [Bhutto, Rashdi and Abro (Bhutto et al. 2012) provide the indicators for Pakistan's science and technology policies. Khan and Qutab (2016) evaluate research students' behaviour in adopting technologies, including digital libraries in Pakistan.] These shreds of evidence indicate that the regulatory authorities should revise their policies towards the ICT diffusion and development in Pakistan. However, this evidence is from the last decades, and the ICT sector has performed well during this decade. To the best of our knowledge, empirical evidence could not provide any evidence on the impact of technological innovation on Pakistan's economic growth. This will be the first empirical investigation on the impact of ICT innovation on the economic growth in Pakistan to the best of our knowledge. This paper aims to analyse the impact of ICT investment and diffusion on the economic growth of Pakistan. We suspect that ICT good imports (percent of total imports) are expected to impact economic growth (see Figure 1) significantly. Therefore, this study's second objective is to provide a specific level of ICT goods imports, where it affects the intermediate input in the production process.

The remainder of this paper is organised as follows. Section 2 presents the relevant literature on the topic. Section 3 elaborates on the data, model and estimation strategy.

Section 4 of this paper presents the discussion of the estimated results. This paper is concluded in Section 5.

2. Synthesis of Literature

Since the late 1990s, the empirical investigation on the impact of ICT innovation on economic growth gained popularity due to the rapid diffusion of information technology during this period (Indjikian and Siegel 2005; Pohjola 2002). Even though economists assume a positive impact, the earlier empirical literature on this topic reveals the mixed evidence. [See Cette, Mairesse and Kocoglu (Cette et al. 2005) for further details on the USA's mixed evidence.] We categorise the existing empirical literature on the impact of ICT developments on economic growth into three categories. The first strand of literature opposes the basic assumption of the association between technological innovations and economic growth. This empirical evidence reveals that technological innovations have no impact on economic growth (Avgerou 1998; Wang 1999; Pohjola 2002). The second strand of the literature reveals that technological innovations have a positive impact on the economic growth of an economy (Gruber and Koutroumpis 2011; Lau and Tokutsu 1992; Kraemer and Dedrick 1994; Dewan and Kraemer 2000; Nour and Satti 2002; Choi and Yi 2009).

Intriguingly, the third strand of literature on the impact of ICT developments on economic growth reveals the negative and ambiguous and equivocal association between technological innovation and economic growth. [Few studies reveal the ambiguous and equivocal association between ICT development and economic growth. For further details, see Freeman and Soete (1997), Hassan (2005), Shahiduzzaman and Alam (2014) and Ishida (2015).] Turning now to the empirical evidence by the first strand of literature, Pohjola (2002) reveals that information and communication investment has no statistically significant economic growth impact. For this purpose, Pohjola (2002) conducts the panel data analysis using the data from 1985 to 1999 from 43 selected economies. Working on the determinants of economic growth in the developing economies, Avgerou (1998) could not include the information and communication technologies in this list. Likewise, Wang (1999) could not provide any evidence on the direct impact of technological innovation and development on Taiwan's economic growth. However, Wang (1999) reveals that technological developments can influence economic growth through different channels, including information infrastructure.

Most of the earlier studies report the positive impact of technological innovations on the economic growth in the developing (Baliamoune-Lutz 2003), emerging (Kraemer and Dedrick 1994) and developed economies (Lau and Tokutsu 1992). Working on similar lines, Dewan and Kraemer (2000) report a positive association between technological innovation and economic growth in the developed economies. Some researchers use a wide range of countries for this empirical investigation. For instance, Vu (2011) analyses the data from 102 economies and this empirical investigation reveal that information and communication diffusion has a statistically significant impact on economic growth. Later on, Vu (2013) investigates this empirical linkage in Singapore and reports that technological investment enhances an economy's economic growth. Some researchers explore this linkage from the investment perspective. For instance, Seo, Lee and Oh (Seo et al. 2009) report that investment in information and communication technologies is one of the significant economic growth drivers.

These similar results were reported from different regions, including MENA. For instance, Nour and Satti (2002) analyse the data from MENA countries and report a positive economic growth impact. Comparatively recently, Sassi and Goaied (2013) reinvestigate two puzzling hypotheses and report that ICT directly impacts the economic growth of MENA countries. [These two puzzling hypotheses include: (1) financial development has a statistically significant impact on economic growth, and (2) ICT diffusion has a statistically significant economic growth impact.] Another cross-country analysis by Choi and Yi (2009) reports the positive association between internet usage and economic growth.

Some researchers focus on the development of telecommunication infrastructure (DTI) and its linkage with economic growth. For instance, Pradhan et al. (2014) uncover the linkage between DTI and economic growth. Applying panel VAR and Granger Causality on the data from 1991 to 2012, they report the bi-directional causality between the DTI and the economic growth in G20 economies.

Turning now towards the third strand of literature, few studies reveal the puzzling evidence on the association between technological innovation and economic growth. However, most of the studies report the negative impact of ICT development and diffusion on economic growth. For instance, Freeman and Soete (1997) report the negative impact of information technologies on economic growth-transmitted through labour and employment in the developed economies. This negative impact has a strong theoretical justification. For instance, Freeman and Soete (1997) reveal that technological innovations and development eliminate the unskilled and low workers from the market (O'Mahony et al. 2008; Ceccobelli et al. 2012), which is the critical reason of higher-income inequity in any economy. Ultimately, these economic situations lead to poverty in developing economies. This also affects labour productivity. For further details, see Ceccobelli, Gitto and Mancuso (Ceccobelli et al. 2012).

On these lines, Shahiduzzaman and Alam (2014) extend this strand of literature by reporting that technological capital enhances economic growth and productivity during the earlier period of technological innovations-the early 1990s. However, this impact deteriorates in the later decades. Hassan (2005) provides some mixed empirical shreds of evidence on these lines. For instance, he reports a positive impact on most of the selected economies. However, he could not provide such evidence for the case of MENA economies. Ishida (2015) further extends this strand of literature by incorporating energy consumption in this nexus. Applying autoregressive distributed lag bounds testing the approach on data from 1980 to 2010, Ishida (2015) reveals that ICT investment does not increase Japan's economic growth. However, this study further reports that ICT investment deteriorates energy consumption in Japan.

This literature review reveals that most of the empirical work is done on the developed economies including United Kingdom (Correa 2006; Oulton 2002), Japan (Jorgenson and Motohashi 2005), Spain (Martinez et al. 2008), Greece (Antonopoulos and Sakellaris 2009), Italy (Atzeni and Carboni 2006), Finland (Jalava and Pohjola 2002; Jalava and Pohjola 2007), USA (Jorgenson 2001; Martinez et al. 2010; Oliner and Sichel 2003; Stiroh 2002), Australia (Shahiduzzaman and Alam 2014) and Singapore (Vu 2013). However, the existing empirical literature did not talk about the threshold level. A closer look at the existing literature reveals that there is no empirical evidence exploring the impact of ICT diffusion and development on Pakistan's economic growth. This awaiting issue is the focus of this study to fill the existing gap in the empirical literature.

3. Data, Model and Empirical Strategy

This section explains the data extraction, model and the empirical strategy for this empirical investigation. We further categorize this section into (1) data and descriptive analysis, and (2) model and empirical strategy. Data and descriptive analysis elaborate on the data issues, data sources, the contractions of variables and their descriptive analysis. The model and estimation strategy presents the econometrical model and the estimation strategy used for this empirical investigation.

3.1. Data and Descriptive Statistics

We use annual data ranging from 2003 to 2018 to examine the impact of ICT investment and diffusion on Pakistan's economic growth. We extract the maximum available data from the world bank data (World Bank 2019). This was the maximum available data on these variables at the time of data collection. We collect the data for the ICT goods exports (percent of total goods exports), ICT goods imports (percent of total goods imports), Mobile Cellular subscriptions (per 100 people), Fixed broadband subscriptions (per 100 people) and GDP

growth (annual percent). [The world development indicator codes are IT.NET.BBND.P2, TM.VAL.ICTG.ZS.UN, IT.CEL.SETS.P2, IT.NET.BBND.P2 and NY.GDP.MKTP.KD.ZG.] First, two variables (ICT goods exports and imports) are used as a proxy for ICT investment. The next two variables (mobile cellular subscriptions and fixed broadband subscriptions) are used as a proxy for users' ICT diffusion. Furthermore, we apply GDP growth as a dependent variable, which is a proxy for economic growth. Table 1 shows descriptive statistics of the data, including minimum, maximum, mean, standard deviation, skewness, kurtosis and Jarque–Bera value. The descriptive analysis results reveal that ICT imports (M = 5.13; SD = 1.90) are almost five times greater than the ICT exports (M = 0.33; SD = 0.15).

Table 1. Descriptive statistics.

	EG	IM	EX	FBS	MS
Mean	4.20	5.13	0.33	0.51	54.04
Median	4.54	4.74	0.24	0.57	60.33
Maximum	7.67	8.70	0.61	1.08	73.17
Minimum	1.61	3.07	0.19	0.01	8.30
Std. Dev.	1.81	1.90	0.15	0.42	20.62
Skewness	0.21	0.96	0.80	−0.06	−1.20
Kurtosis	2.36	2.66	2.05	1.35	3.20
Jarque-Bera	0.30	1.89	1.75	1.38	2.91
Probability	0.86	0.39	0.42	0.50	0.23
Sum	50.40	61.57	3.93	6.15	648.52
Sum Sq. Dev.	36.07	39.83	0.25	1.90	4678.75
Observations	16.00	16.00	16.00	16.00	16.00

Note. EG, IM, EX, FBS and MS indicate the GDP growth (annual percent), ICT goods imports (percent of total goods imports), ICT goods exports (percent of total goods exports), fixed broadband subscriptions (per 100 people) and mobile cellular subscriptions (per 100 people), respectively.

Similarly, the mobile cellular subscription per 100 people (M = 54.04; SD = 20.62) is much higher than the fixed broadband subscription per 100 people (M = 0.51; SD = 0.42). Further, the probability values of Jarque–Bera are less than the level of significance in all five cases. Therefore, we do not have enough shreds of evidence to reject the null hypothesis, which indicates that the data are normally distributed.

3.2. Model and Estimation Strategy

Following Ishida (2015), we consider the following specification to analyse the impact of ICT investment and diffusion on Pakistan's economic growth (also see Colecchia and Schreyer 2002; Toader et al. 2018).

$$EG_t = \gamma_o + \gamma_2 EX_t + \gamma_1 IM_t + \gamma_3 FBS_t + \gamma_4 LMS + \varepsilon_t \quad (1)$$

At period t, EG, EX, IM, FBS, LMS and ε denote the economic growth, the ICT goods exports, the ICT goods imports, internet users, mobile cellular subscriptions and the error term. For this empirical investigation, we use ICT goods exports and ICT goods imports as a proxy for ICT investment. We further use mobile cellular subscriptions and fixed broadband subscriptions as a proxy for ICT diffusion. We use GDP growth as a dependent variable. A closer investigation of Figure 1 reveals some breaks in the data, especially during the Global Finance Crisis (2007–2009). Therefore, we apply the breakpoint unit root tests along with the conventional unit root tests. [We apply Augmented Dickey-Fuller, Phillips–Perron and Kwiatkowski–Phillips–Schmidt–Shin as the conventional unit root tests.] On these lines, Martin et al. (2013) reveal a strong tendency that the test statistic falls in the non-rejection region for the unit root test by ignoring the structural breaks in the data. For the breakpoint unit root tests, we apply innovative outliers and the additive outliers and break types for all variables used in the study. We ensure that all the variables are either stationary or converted to stationarity before moving towards the ordinary least square estimates. We further make sure that none of the classical linear assumptions is violated.

For this purpose, we apply the Jarque–Bera normality test with the null hypothesis that the errors are normally distributed. We test all these null hypotheses at 5 percent level of significance. [For further discussion on the normality, homoscedasticity, and serial independence of regression residuals, see Jarque and Bera (1980).] We further ensure that errors are homoscedastic and serially independent. For this purpose, we apply the Breusch–Pagan–Godfrey Test and Breusch and pagan LM test, respectively (also see Breusch and Pagan 1980; Waldman 1983). We also apply the Ramsey reset test, CUSUM, and CUSUM of squares to ensure our model's stability (see Ramsey 1969).

In the end, we extend this analysis to the threshold regression, which provides us with a specific level of the significant variables. In particular, this form of regression introduces a threshold parameter in the equation, which provides an interpretable but straightforward and elegant way of modelling the non-linear relationship between the explanatory and explained variables. In Pakistan's case, such a relationship is possible during the first decade of the 21st century due to the structural changes in the telecom sector due to ICT investment. During the early stages of these structural changes, the businesses should be concerned about production-level quality (also see Martin and Rogers 1995). In these circumstances, the developing countries should rely on ICT imports to improve their production quality through intermediate inputs. Therefore, we expect that the parameters in Equation (1) vary according to the specific level of ICT investment and diffusion. Here the ICT goods imports are expected to enter the different regimes when these goods significantly enhance the intermediate inputs to the capital goods (Colecchia and Schreyer 2002). The ordinary least squares estimate of Equation (1) provides the results of all variables. We extract the significant variable (s) and use it as the threshold variable for the self-exciting model under the threshold variable specification. In this setting, the threshold regression specification will be as follows.

$$EG_t = \begin{cases} \gamma_5 V_t' + \alpha_1 SV_t + \varepsilon_{1t}, \text{ if } SV_t \leq RG_1 \\ \gamma_6 V_t' + \alpha_2 SV_t + \varepsilon_{2t}, \text{ if } RG_1 < SV_t \leq RG_2 \\ \gamma_7 V_t' + \alpha_3 SV_t + \varepsilon_{3t}, \text{ if } RG_2 < SV_t \leq RG_3 \\ \quad . \\ \quad . \\ \quad . \\ \gamma_n V_t' + \alpha_n SV_t + \varepsilon_{nt}, \text{ if } RG_{n-1} < SV_t \leq r_n \end{cases} \tag{2}$$

Here, SV_t denotes the significant variable, which is based on the estimation results of Equation (1). V_t indicates the rest of the ICT investment and diffusion variables from Equation (1). In particular, these are the insignificant variables if the threshold type allows. The threshold RG1 to RGm are the parameters for the non-linear structure. For the case of ICT imports, we are interested in the second regime, where ICT imports affect the intermediate inputs. Therefore, we use the sequential procedure that gives a maximum of two regimes (Strikholm and Terasvirta 2006; Rahman et al. 2018). Resultantly, our threshold Equation is as follows.

$$EG_t = \gamma_8 V_t' + \alpha_1 SV_t + \varepsilon_{1t} \; if \; SV_t < RG_1 \tag{3}$$

$$EG_t = \gamma_9 V_t' + \alpha_2 SV_t + \varepsilon_{2t} \; if \; SV_t < RG_2 \tag{4}$$

We use a smooth threshold specification with the threshold normal where this model determines the threshold values by grid search with concentrated coefficients. We use the ordinary covariance method with the information matrix of the outer product of the gradient (OPG). For the estimation algorithm, we apply Broyden, Fletcher, Goldfarb and Shanno (BFGS) and Marquardt as the optimization and step methods, respectively. This model achieves the convergence after 17 iterations. The optimum number of regimes are two in this case where the expected parameters are expected to be different. For the case of no threshold, the model collapsed down to the original model. The next section presents the discusses the results of our empirical investigation.

4. Results and Interpretation

Following our empirical strategy, this section presents and discusses the results of Equation (1). The conventional unit root tests reveal stationarity in economic growth (EG), ICT goods exports, ICT goods imports, fixed broadband subscribers and mobile cellular subscriptions (See Table 2). In the presence of structural breaks, Martin et al. (2013) reveal a strong tendency that the test statistic falls in the non-rejection region for the unit root test by ignoring the structural breaks in the data. Therefore, we decide based on the breakpoint unit root test results (Table 2). Even though some variables are non-stationary according to the conventional unit root tests, we follow Martin et al. (2013) guidelines and decide based on the results of breakpoint unit root tests. Therefore, all variables are used at the level in the regression analysis.

Table 2. Unit root tests.

	EG	EX	IM	FBS	MS
Level					
ADF	−3.75 **	−4.98 **	−0.39	0.21	0.12
PPS	−0.37	−0.44	−0.40	0.55	0.88
KPSS	0.16	0.17	0.21	0.11	0.15 *
Break Point innovative Outliers	−6.10 ***	−13.70 ***	−6.83 ***	−5.83 ***	−5.48 ***
Break Point -additive Outliers	−5.23 **	−5.99 ***	−5.01 ***	−5.39 ***	−5.04 **
First Difference					
ADF			−2.63 **	−1.63 *	−1.37
PPS	−3.62 ***	−2.34 **	−2.63 **	−1.63 *	−1.37
KPSS				0.10	0.08
Break Point—innovative Outliers					
Break Point—additive Outliers					
Decision	Level	Level	Level	Level	Level

Note: EG, EX, IM, FBS and MS denote economic growth, ICT goods exports, ICT goods imports, fixed broadband subscribers and mobile cellular subscriptions. Null hypothesis: Series is non-stationary except for the case of KPSS. For this case, the Null hypothesis: series is stationary. *** p-value < 0.01. ** p-value < 0.05. * p-value < 0.10. Decision indicates the integration level of variables used in the regression analysis. ADF, PPS and KPSS indicates the Augmented Dickey–Fuller, Phillips–Perron and Kwiatkowski–Phillips–Schmidt–Shin tests, respectively.

Table 3 presents the estimated results of Equation (1). These results indicate that Pakistan's economic growth appears to be unaffected by ICT development ($\gamma_3 = 0.71$; $p > 0.05$; $\gamma_4 = 0.02$; $p > 0.05$). These results are consistent with one strand of literature, which we categorise as the third strand of literature (See Avgerou 1998; Wang 1999; and Pohjola 2002). One of the possible reasons for this fact is that technological innovations and developments eliminate the unskilled and poor workers from the market, which is the crucial reason for higher-income inequity in any economy (See Freeman and Soete 1997). [See O'Mahony, Robinson and Vecchi (O'Mahony et al. 2008), Ceccobelli, Gitto and Mancuso (Ceccobelli et al. 2012) and Ishida (2015) for further discussion on similar results.] However, we observe that the ICT investment lead by the imports has a statistically significant impact on Pakistan's economic growth ($\gamma_2 = 1.73$; $p < 0.05$) when ICT imports (percentage of total imports) reaches the threshold level of 4.13 entering into the different regime. This threshold level is logical since Table 1 above indicates that the average ICT imports (percentage of total imports) are 5.13. These log-log model results indicate that one percent change in the ICT goods imports (beyond the threshold level of 4.13) increases Pakistan's economic growth by 1.73 percent, ceteris paribus. Looking at the telecommunication growth over the last two decades, especially when the Pakistan Telecommunication Company Limited (PTCL) was privatised, it is expected that ICT imports are an integral part of the intermediate inputs. [See Siddiqi, Nouman and Ahmad (Siddiqi et al. 2012) and Mangi and Siddiqui (2013) for further details on Pakistan Telecommunication Company Limited's privatisation.] The memorandum between PTCL and ZTE Corporation also accelerates intermediate inputs' role (See Kumar 2007). Therefore, the information and communication technologies enhance the intermediate inputs to the capital goods (Colecchia and Schreyer 2002).

Table 3. Regression analysis.

	EX	IM	FBS	MS	AR (1)
CE	−9.24	1.73 **	0.71	0.02	−0.83 **
(se)	*(6.69)*	*(0.61)*	*(1.87)*	*(0.04)*	*(0.30)*
Threshold		4.13			
DW	2.73				
R^2	0.89				
Adj-R^2	0.78				
Ramsey Reset Test					
F-Statistics	0.81				
p-value	0.42				

Note. *** *p*-value < 0.01. ** *p*-value < 0.05. * *p*-value < 0.10. The dependent variable is EG.

Another possible reason is that the intermediate inputs might reduce the overall transaction costs in the industry through electronic commerce, electronic business and online financial transactions (see Bester and Petrakis 1993). Further, this indirect impact is also possible through other indirect channels identified in the existing literature including (1) promoting trading activities; (2) enhancing the level of education; (3) improving the overall health level of the general public; (4) promoting the production level; and (5) improving the social services (See Dutta 2001; Cieslik and Kaniewska 2004; Micevska 2005; Martin and Rogers 1995; Snieska and Simkunaite 2009). Therefore, ICT imports enhance the overall economic growth of Pakistan.

Turning now to the stability analysis, the CUSUM and CUSUM of squares tests reveal the model's stability (see Figures 2 and 3). Both figures indicate that our model is stable at 5 percent level—the parameters are strongly stable. Furthermore, we also apply the Ramsey test (Ramsey 1969) to confirm the parameters' stability. [The null hypothesis is that our model is adequate.] The test value of the Ramsey reset test (F = 0.18, $p > 0.05$) reveals that the test statistic falls in the non-rejection region (see Table 4). We do not have enough evidence to reject the rejected hypothesis of an adequate model. This ensures the stability of our model. Overall, the analysis results disclose that ICT diffusion has no significant impact on the economic growth of Pakistan. ICT investment has a statistically significant impact on the economic growth of Pakistan. However, we observe that only ICT imports help in enhancing the economic growth in Pakistan. Looking at the second component of ICT investment, ICT exports reveal an insignificant negative effect on economic growth ($\gamma_1 = -9.24$; $p > 0.05$) that is an unhealthy sign for an economy. Perhaps, one of the possible reasons for this is that the ICT sector in Pakistan is passing through in the growth phase, and ICT exports cannot meet the required international standards. The policymakers should set some quality standards for ICT exports to meet the requirements of the international market.

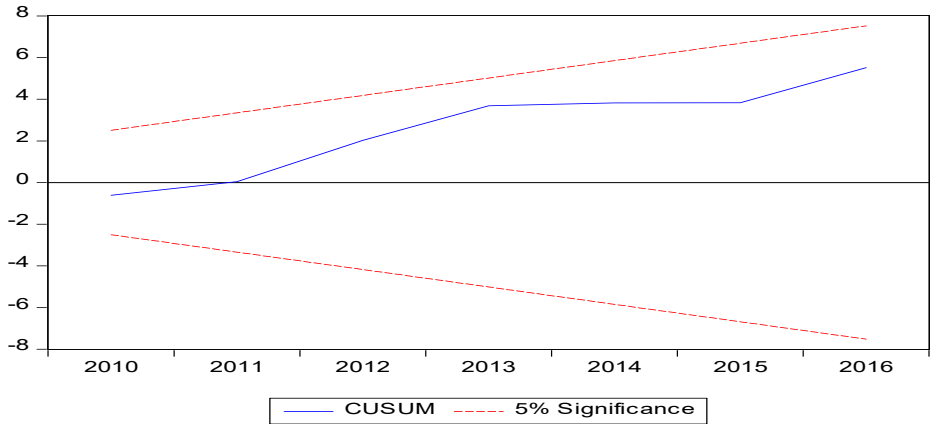

Figure 2. CUSUM Test—Recursive Estimation.

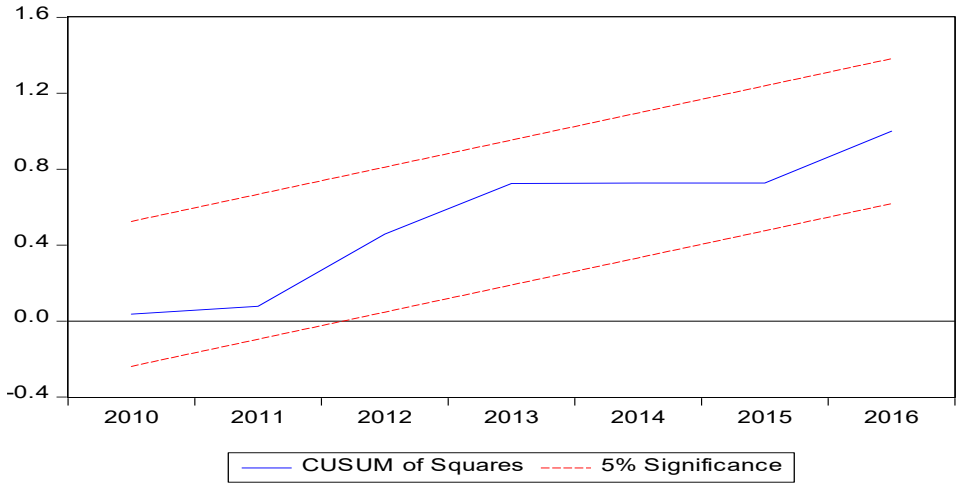

Figure 3. CUSUM of Squares Test—Recursive Estimation.

Table 4. Residual tests.

Normality Test			Serial Correlation			Heteroskedasticity Test		
Jarque-Bera Test	**Test Value**	**Prob.**	**Breusch-Godfrey LM Test**	**Test Value**	**Prob.**	**Breusch-Pagan-Godfrey Test**	**Test Value**	**Prob.**
	1.06	0.59		6.82	0.08		0.78	0.58

Note. The null hypotheses for these tests are as follows. A normality test: the errors are normally distributed. Serial Correlation: The errors are independent of each other. Heteroskedasticity test: The errors are homoscedastic.

Limited availability of the data is one of the limitations of this study since we use the maximum available data from 2003 to 2018 on these variables. Although we have checked and reported the residual diagnostics and the model's stability, the results of this study should be used carefully. Considering this limitation, we recommend that future research should be conducted to look for the ICT proxies where the longer time series are available.

5. Conclusions

This study first investigates the role of ICT investment and diffusion on Pakistan's economic growth. Second, this study provides the specific level of ICT goods imports where it affects the intermediate input in the production process. Using the data from 2003 to 2018, the regression analysis revealed that ICT diffusion does not affect Pakistan's economic development. Looking at the ICT investment—proxied by the ICT goods exports and imports—we observed mixed evidence. Grippingly, the economic growth of Pakistan is again unaffected by the ICT goods exports. However, we observed that a one percent increase in the ICT goods imports enhances the economic growth by 1.73 percent when ICT imports (percentage of total imports) reaches the threshold level of 4.13 entering into the different regime. These pieces of evidence reveal that ICT goods import significantly enhance the quality of intermediate input to the capital goods, leading to higher economic growth. The other indirect channels are discussed in detail in Section 4 (Results and Interpretations). Based on the results of this empirical investigation, we emphasize that the policymakers should prioritize the ICT infrastructural development by encouraging the ICT investment to enhance economic growth. In particular, the level of ICT goods import (percentage of total imports) should be greater than our proposed level. However, these results should be used carefully due to the data limitations mentioned at the end of Section 4 (Results and Interpretations). Based on these results, the policymakers and ICT sector are performing well since the current level of ICT goods imports (4.95 percent of total imports) is higher than our proposed threshold level of 4.13 percent of total imports.

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