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DO INFORMATION AND COMMUNICATION TECHNOLOGIES FOSTER ECONOMIC GROWTH IN INDONESIA?

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ABSTRACT

This paper investigates, using annual data from 1980 to 2014, whether adoption of information and communication technologies (ICT) fosters economic growth in Indonesia. We employ an Autoregressive Distributed Lag cointegration technique on an augmented neoclassical growth model. The empirical results indicate a positive effect of ICT development on economic growth in both the long-run and short-run. The other regressors, such as total factor productivity, human capital, and capital per worker, also positively affect economic growth. From a policy perspective, the Indonesian government should promote ICT development through greater investment.

Keywords: ICT development; Economic growth; ICT exports; ARDL bound test; Indonesia.
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I. INTRODUCTION

The literature widely recognizes that digital innovation in the form of information and communication technologies (ICT) has a significant influence on economic growth and productivity (see, for instance, Cette et al., 2005; Farkhanda, 2007; Venturini, 2009; Dimelis and Papaioannou, 2010; Heeks, 2010; Cortes and Navarro, 2011; Ahmed and Ridzuan, 2013; Rath, 2016; Niebel, 2018). As a consequence, rapid adoption of ICT in terms of access and use is observed worldwide (Chinn and Fairlie, 2007; Lam and Shiu, 2010; ITU, 2018). Adoption of ICT in advanced countries is much faster compared to underdeveloped and developing nations (Caselli and Coleman, 2001; Chinn and Fairlie, 2007). However, adoption of ICT, particularly the use of mobile phones and internet, has been rapidly increasing over time and now drives economic activity (see, for instance, Katz, 2009; Byrne et al., 2011; Avgerou et al., 2016; Rath, 2016).

While there is a considerable literature on the link between ICT development and economic growth in cross-country analysis and OECD countries, much less work has been devoted to understanding the link between ICT and economic growth with specific attention to single-country-level analysis for developing countries. We examine the impact of ICT development on economic growth in Indonesia. The research question is: Does greater access, use, and investment in the ICT sector foster economic growth in Indonesia? The motivation for undertaking this exercise is that, to best of our knowledge, there is no specific study that addresses this issue in the manner we do. Ahmed and Ridzuan (2013) is, to some extent, an exception in that it examines the impact of ICT on economic growth for ASEAN5+3 countries. By employing a panel cointegration and panel model, these authors find that labor, capital, and telecommunications investment positively affects economic growth. The limitation of this study is that it is a panel case study—a panel that includes Indonesia. There is nothing known exclusively with respect to Indonesia on this matter. That is, there is no study that takes a time-series approach to understanding the role of ICT in Indonesia's economic growth. The other limitation of this study is that it uses telecommunications investment as a proxy for ICT, but the International Telecommunication Union (ITU) considers many other variables for ICT (ITU, 2009). Our main reason for focusing on Indonesia is as follows.

First, Indonesia is the largest country by population in Southeast Asia and it is an emerging country on the world stage. The country ranks 17th in GDP and 7th in GDP on the basis of purchasing power parity. Despite a gradual increase in economic growth and improvement in ICT infrastructure in recent years, Indonesia still lags in ICT as compared to neighboring Southeast Asian countries like Singapore and Malaysia. Indonesia is the fourth most populous country in the world. Figure 1 shows Indonesia's ICT investment growing at an annual average of 20% over the 1980–2014 period, with GDP growing at 5.2% annually over the same time period. Thus, understanding the role played by ICT in increasing Indonesia's economic growth is worth examining.

Second, many studies examine the role of ICT in propelling productivity or output per worker (Cronin et al., 1993; Dewan and Kraemer, 2000; Oulton, 2002; Hu and Quan, 2005; O'Mahony and Vecchi, 2005; Atzeni and Carboni, 2006; Kumar et al., 2016). Thus, examining the effect of ICT on per capita output for Indonesia calls for investigation because the growth in ICT (as shown in Figure 1) both quantitatively (coverage, capacity, and accessibility) and qualitatively (adoption of advanced technologies, efficiency, and service quality) has been impressive.

Third, a plethora of studies examines the effect of ICT on productivity and economic growth, particularly via panel data sets (see, for instance, Roller and Waverman, 2001; Aker and Mbiti, 2010; Commander et al., 2011; Yousefi, 2011; Cardona et al., 2013; Jorgenson and Vu, 2016; Niebel, 2018). These studies find mixed evidence. This could be due to different methodologies, data sample periods, and measurement of different ICT indicators. However, studies on the ICT–growth nexus using time-series analysis for single developing countries are scarce (Kumar et al., 2016; Shahram and Woodside, 2017). One reason for this is lack of high quality data for these countries. On the other hand, the World Bank (2012) reveals that ICT has potential to increase productivity, boost economic growth, and thereby reduce poverty. Given this, the present paper fills an important gap in understanding how ICT development affects economic growth in Indonesia. Research on a single country provides in-depth analysis on the nexus between ICT and economic growth (see, for instance, Cronin et al., 1993; Khuong, 2013; Ishida, 2015; Kumar et al., 2016). Further, to best of our knowledge, the present paper is the first to examine the impact of ICT development on Indonesian growth.

Fourth, many studies investigate the causal relationship between ICT development and economic growth (see, for instance, Cronin et al., 1993; Datta and Agarwal, 2004; Shiu and Lam, 2008; Koutroumpis, 2009). Most of these studies employ bivariate analysis (i.e., only using ICT and economic growth). However, this bivariate approach may lead to bias due to omitted variables (Gross, 2012; Ishida, 2015). Therefore, the present study uses other important variables, such as total factor productivity (TFP), human capital, and ICT exports, that potentially affect economic growth.

Fifth, the International Telecommunications Union (ITU, 2009) provides a detailed methodology for constructing an ICT development index using 11 indicators. This ICT development index is very useful for comparing ICT development across countries as well as within a country over time. Numerous studies use either non-monetary indicators of ICT (teledensity, mobile phone subscribers, percentage of internet users, fixed broadband connections, and percentage of households using computers) or a monetary variable (ICT investment) to examine the nexus between ICT and growth (for instance, Caselli and Coleman, 2001; Baliamoune-Lutz, 2003; Chinn and Fairlie, 2007; Koutroumpis, 2009; Ishida, 2015). Studies are likely to face two problems using any of these variables separately. First, each of these ICT indicators will have mixed evidence on economic growth (i.e., some variables may affect growth, and some may not affect growth). Second, ambiguity may arise over the real contribution of ICT on growth in case of exclusion of some of these ICT indicators. In such circumstance, the ICT development index developed by the ITU can exactly assess its impact on economic growth. However, ICT development index data are not readily available for longer time-series in the case of Indonesia due to unavailability of data on these 11 indicators. Thus, the present study constructs an ICT development index using only three variables (telephone subscriptions, cellular phone subscriptions, and fixed broadband subscriptions) employing principal component analysis.(Park et al., 2015; Rath, 2016).

Sixth, the present study differs from the literature by employing an Autoregressive Distributed Lag (ARDL) model with two structural breakpoints in the data, following Narayan and Popp (2010). To the best of our knowledge, no earlier study, including those that focus on single-country analysis, employs this technique. Examination of the long-run cointegrating relationship between ICT-related variables and economic growth in the presence of structural breaks would, ideally, reveal the true nature of this relationship. Gregory and Hansen (1996) nicely illustrate the importance of the cointegration model with the presence of structural breaks; for Indonesia, the importance of structural breaks in cointegration is demonstrated by Sharma and Syarifuddin (2019). The importance of modeling breaks in general is shown in Sharma et al., (2018).

Our approach provide the following insights. First, we find a long-run relationship between the ICT development index and economic growth. Second, the ICT index positively affects economic growth, whereas exports of ICT negatively affect growth in the long-run. Third, to check robustness, we use real GDP instead of per capita output as the measure of growth. We find that the ICT development index and ICT exports significantly affect growth positively and negatively, respectively, which corroborates our earlier findings. Apart from ICT development, this study uses TFP growth and human capital as other determinants of economic growth. Our results further reveal that apart from ICT development, both human capital and TFP growth boost economic growth in the long-run in the case of Indonesia, consistent with previous literature.

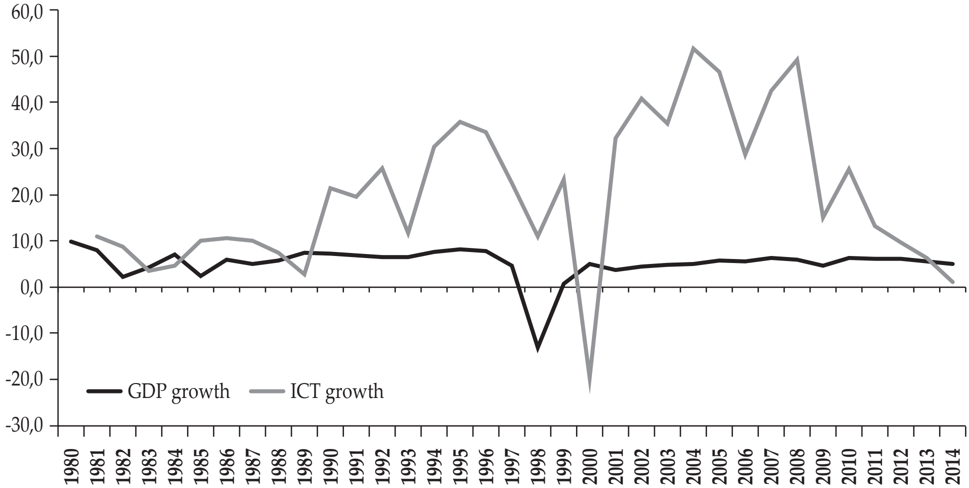
This paper proceeds as follows. Section II presents an overview of the performance of ICT-related variables and economic growth in Indonesia. In Section III, we explain our theoretical framework and empirical methodology pertaining to the nexus between economic growth and ICT. Section IV presents the data and results. Finally, Section V sets forth concluding remarks.

II. ICT IN INDONESIA

Figure 1 presents the annual growth rates of real GDP and ICT for Indonesia from 1980 to 2014. The graph shows that the annual growth rate of real GDP is lower than the annual growth of the ICT development index in most of the study period, except 1989, 2000, and 2014. The graph also shows that the gap between ICT development and real GDP growth rates was lower during the period 1981 to 1988, but thereafter widened drastically. This is due to tremendous growth of ICT development as compared to real GDP growth in Indonesia. The average annual ICT growth rate was quite impressive particularly over the 2001–2008 period, with annual growth of over 40%. Average annual ICT growth over the 1981–2014 period was observed at around 20%, whereas average real GDP growth was observed at 5.2% for the same period.

Figure 1. The Growth Rates of Real GDP and ICT in Indonesia

This figure exhibits the growth rates of real GDP and ICT in case of Indonesia from 1980 to 2014. The graph shows that the annual growth rate of real GDP is lower than the annual growth of ICT development index in most of the periods under the study except three years (1989, 2000 and 2014). The ICT development was growing slowly during 1980 to 1989, but thereafter, it has shown tremendous growth particularly from 2000 to 2008. The average annual ICT growth during 1981-2014 was observed around 20%, whereas, the average real GDP growth was seen at 5.2% during same periods.

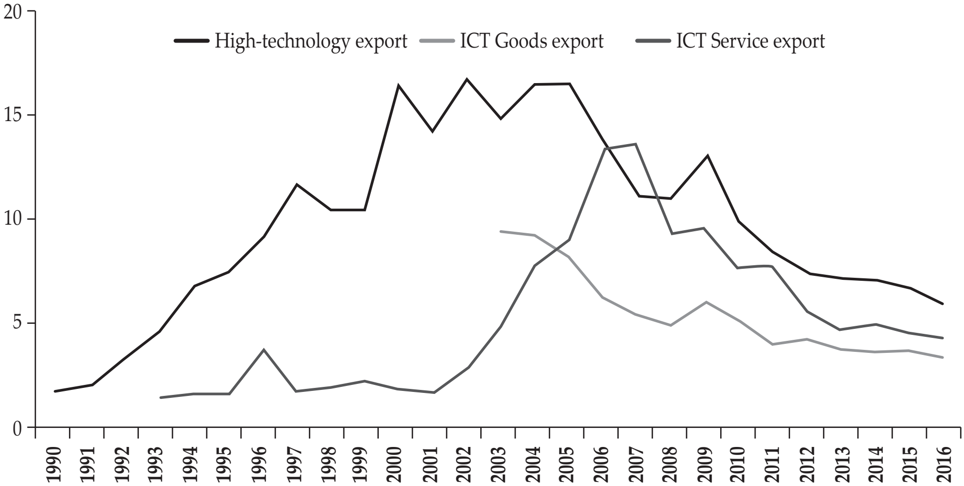


Source: World Development Indicators (WDI) database

Figure 2 shows several key indicators related to exports of ICT for Indonesia. Since there is no availability of ICT export data prior to 1990, this figure presents three indicators of ICT exports from 1990 to 2016. The trend-line of high-technology exports (measured as a percentage of manufacturing exports) shows that the share of exports of high-technology products to total manufacturing products increased from 1.59% in 1990 to 16.54% in 2005. Thereafter, this share of high-technology exports declined, except in 2009, and reached 5.78% in 2016. Since high-technology export figures may not be directly attributable to ICT development of the country, we show exports of ICT goods and services, which are directly related to ICT development. ICT goods exports are measured as a percentage of total goods exports, and ICT services export figures are the share ICT service exports to total service exports in the balance of payment account. The trendlines indicate that ICT exports of services are higher than ICT goods exports, except for 2003 and 2004, where the share of ICT goods exports was slightly higher than ICT service exports. Figure 2 also indicates that ICT good exports show a downward trend over the period 2003 to 2016. ICT service export share shows an upward trend from 1997 to 2007 and thereafter declines till 2016. Share of ICT service exports was just 4% in 2016; it peaked in 2007 at 13.5%.

Figure 2. ICT Exports of Indonesia

This figures portrays the ICT related exports of Indonesia. The trend line of high-technology exports indicates an upward trend in share of its exports (measured as a % to manufacturing exports) from 1990 to till 2002 and thereafter it declined and reached around 7% in 2016. ICT service exports also shows a similar trend along with the trend line of high-technology exports.

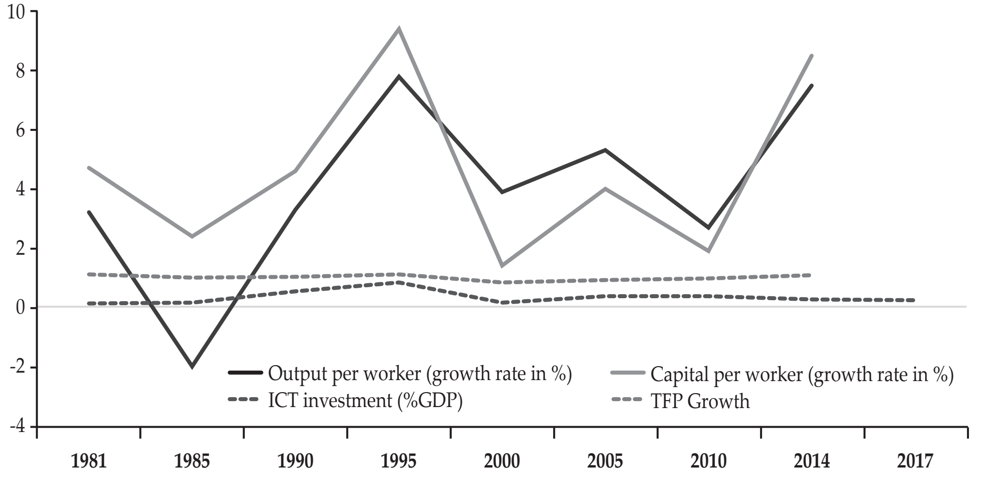


Source: WDI database.

Figure 3 presents four key indicators pertaining to overall economic performance of Indonesia. First, the growth of output per worker shows a zigzag pattern from 1981 to 2014. Output per worker growth rate declined from 1981 to 1985, then began to increase and peaked at 9.4% in 1995. This shows a fluctuating trend with increases and decreases until 2014. Growth of capital per worker shows a similar pattern, except that prior to 1997, growth of capital per worker was higher than output per worker. Post 1997, growth of output per worker was slightly higher than growth of capital per worker. TFP growth shows a declining trend in recent years as compared to 1981. TFP growth was 1.1% in 1981 and it almost consistently maintained the same rate until 1995, but TFP growth declined from 1.1% in 1995 to 0.84% in 2000. Although it began to increase after 2000, growth was relatively lower most years post-2000 as compared to the pre–Asian Financial Crisis period. Figure 3 also shows total investment made by Indonesia in the telecommunications sector, which we treat as the ICT investment. Investment in the ICT sector plays a critical role in production processes, and thereby in the economic growth of a country. ICT investment is measured as a percentage of GDP. Although the ratio is less than 1% of GDP, the ICT investment figures in absolute terms significantly increased from 1981 to 2017.

Figure 3. Growth Rate of Key Indicators in the Production Process of Indonesia

This figure presents the growth rates of output per worker and capital per worker. Additionally, this figure also depicts ICT investment and TFP growth.



Source: Authors own calculation based on Penn World data.

Table 1.
Basic Statistics of Key ICT Development Indicators

This table exhibits the key indicators pertaining to ICT development of Indonesia. The data relating to indicators such as fixed-telephone subscription, mobile cellular subscription, fixed broadband subscription, and internet users have consistently increased over the years except subscription fixed-telephone.

Year	Fixed-telephone subscriptions per 100 inhabitants	Mobile-cellular subscriptions per 100 inhabitants	ICT index	Fixed broadband subscriptions per 100 inhabitants	Internet users (%)	Household with computer (%)
1980	0.25		0.13			
1985	0.37		0.18			
1990	0.59	0.01	0.3			
1995	1.67	0.11	0.89		0.03	
2000	3.15	1.73	1.60	0.00	0.93	
2005	5.96	20.69	8.96	0.05	3.60	3.67
2010	16.88	87.12	35.34	0.94	10.92	10.80
2014	10.28	127.61	47.13	1.33	17.14	17.30
2017	4.23	173.84		2.29	32.29	19.11

Source: International Telecommunication Union (ITU) database.

Table 1 presents basic data on key ICT development indicators for Indonesia. This table also clearly reflects the non-availability of key ICT indicators for a longer time horizon, which is the prime reason for the absence of country-specific research on the nexus between ICT and economic growth, particularly for developing countries, including Indonesia. Table 1 shows five indicators pertaining to ICT that are broadly used to examine the effect of ICT on economic growth or productivity. The second column of Table 1 shows data on fixed-telephone subscriptions per 100 inhabitants. The figures clearly show that access to telephone landline connections was very low in 1980 (0.25), increasing to around 17 in 2010. But this figure began declining from 2010 and reached 4.23 in 2017. The reason for this decline is high penetration of mobile phones. Subscription to mobile phones has increased phenomenally across the globe, and Indonesia is no exception in this regard (as shown in column 3). The other ICT use indicators, such as fixed broadband connections, internet users, and households using computers also increased, particularly from 2005 (last three columns of Table 1). However, these figures are very low as compared to developed countries. Overall, this preliminary analysis indicates a general increase in ICT development in Indonesia in recent years as compared to 1980 or even 2000.

III. FRAMEWORK AND METHODOLOGY

A. Framework

We employ the commonly used Cobb-Douglas production function, as stated in the Solow (1956) framework and following Kumar et al. (2016, 2015) and Rao (2010). The equation for output per worker (y_t) can be written as:

$$y_t = A_t k^{\alpha}{}_t \quad \alpha > 0 \tag{1}$$

where A_t is technological progress, k_t refers to capital per worker, and α is share of capital. The Solow (1956) model assumes that the progression of technology is given by

$$\pi_t = A_0 e^{gt} \tag{2}$$

where g and A_0 are the growth of technological progress and initial TFP, respectively. π_t refers to aggregate technology, A_t. The impact of ICT development on TFP can be assessed when ICT development arrives as a shift in production function. Thus, we use an augmented Solow growth model by including the ICT-related variables in the production function.

$$\text{Let } \theta_t = f(ICT_t) = ICT_t^{\beta}. \tag{3}$$

Here θ_t is part of the technology component in equation (1), and A_t is redefined as follows:

$$A_t = \pi_t \theta_t = A_0 e^{gt} ICT_t^{\beta} \tag{4}$$

Thus, we can rewrite equation (1) as

$$y_t = A_0 e^{gt} k_t^{\alpha} ICT_t^{\beta} \tag{5}$$

Taking the natural logarithm of equation (5) yields the linear general production function equation for estimating the model as

$$lny_t = \delta + \alpha lnk_t + \beta ICT_t + e_t \tag{6}$$

where δ is the intercept term, β is the elasticity coefficient of ICT development, and e is the error term.

Equation (6) can be further expanded by adding the control variables ICT exports and structural break dummy variables, which can be presented as:

$$lny_t = \delta + \alpha lnk_t + \beta lnICT_t + \gamma lnICTEXP_t + \sigma TD_{b<t} + e_t \tag{7}$$

where ICTEXP is ICT exports, y is the coefficient of elasticity of ICT exports, TD is the structural break dummy based on two-stage structural unit root break test (Narayan and Popp, 2010) of the dependent variable (i.e., per capita output), σ is the coefficient associated with TD, b is the double break period, which is less than t, and t is the time period, t = 1980, 1981,….., 2014.

B. Methodology

B1. Unit Root Tests

Let us now empirically analyze the stationary property of all time-series variables used in this study. First, Augmented Dickey-Fuller (1979) and Philips-Perron (1988) unit root tests are employed to check stationarity. These conventional tests do not address the presence of structural breaks in the data. To account for structural breaks, we further employ the Narayan and Popp (2010) unit root test, which captures structural breaks.

B2. ARDL Model

After checking the unit root, we next use an ARDL bound testing approach (Pesaran et al., 2001) to inspect the long-run association between ICT and economic growth. We apply the ARDL model to equation (7). The main advantages of the ARDL model are: (i) it can use any data series irrespective of whether the variable is stationary I(0) or non-stationary I(1) or mixed order of condition I(0) and I(1); (ii) it can generate the unknown parameters for both the long-run and short-run without dropping any information; and (iii) the model simply takes care of the endogeneity issue among the explanatory variables (Pesaran et al., 2001). The procedure for ARDL follows two steps. First, it examines the presence of a long-run relationship between the variables. Second, it obtains the long-run and short-run coefficients of explanatory variables using ARDL and error correction models (ECMs) together. Based on conjectural reinforcement and related work, we employ the following models:

Model I: $lny_t = \alpha + \beta_1 lnk_t + \beta_2 lnICTINDX_t + \beta_3 lnICTEXP_t + \beta_4 TD_t + v_t$ (8)

Model II: $lnGDP_t = \delta + \beta_1 lnTFP_t + \beta_2 lnHC_t + \beta_3 lnICTINDX_t + \beta_4 lnICTEXP_t + v_t$ (9)

where *y* represents output per worker, *k* refers to capital per worker, *ICTINDX* is defined as ICT development index, *ICTEXP* is ICT exports, *GDP* is real gross domestic product, *TFP* is the TFP, and *HC* is the human capital in equation (8) and equation (9). Thus, we can write the error correction representation of the ARDL bound testing for model I and model II as, respectively:

$$\Delta lny_t = \alpha + \beta_1 lnk_{t-1} + \beta_2 lnICTINDX_{t-1} + \beta_3 ICTEXP_{t-1} + \beta_4 TD_{t-1} + \sum_{i=1}^{p}\gamma_1 \Delta lny_{t-i} + \sum_{i=1}^{p}\gamma_2 \Delta lnk_{t-i} + \sum_{i=0}^{p}\gamma_3 \Delta lnICTINDX_{t-j} + \sum_{i=0}^{p}\gamma_4 \Delta lnICTEXP + v_t \quad (10)$$

$$\Delta lnGDP_t = \delta + \beta_1 lnTFP_{t-1} + \beta_2 lnHC_{t-1} + \beta_3 lnICTINDX_{t-1} + \beta_4 lnICTEXP_{t-1} + \sum_{i=1}^{p}\gamma_1 \Delta lnGDP_{t-i} + \sum_{i=1}^{p}\gamma_2 \Delta lnTFP_{t-i} + \sum_{i=0}^{p}\gamma_3 \Delta lnHC_{t-i} + \sum_{i=0}^{p}\gamma_4 \Delta lnICTINDX_{t-j} + \sum_{i=0}^{p}\gamma_5 \Delta lnICTEXP + v_t \quad (11)$$

In equations 10 and 11, Δ refers to the first difference operator of the corresponding variable. To inspect the cointegration relationship between ICT development and economic growth, the null hypothesis (no cointegration) can be elaborated as: $H_0: \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$, and the alternative hypothesis (presence of cointegration) as $H_1: \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq 0$ by conducting the F test developed by Pesaran et al. (2001) and later refined by Narayan (2005). If the calculated F-statistics are less than the lower bound value I(0), then the null hypothesis of no cointegration cannot be rejected. On the contrary, if the calculated F-statistic is greater than upper bound value I(1), then we reject the null hypothesis. However, if the value of the F-statistic falls between the lower and upper bounds, then the relationship among the variables is inclusive.

Next, we examine the short-run relationship by employing an error correction mechanism. The short-run dynamic ECMs can be explained using equations (12-13).

$$\Delta lny_t = \alpha + \sum_{i=1}^{p}\gamma_1 \Delta lny_{t-i} + \sum_{i=1}^{p}\gamma_2 \Delta lnk_{t-i} + \sum_{i=0}^{p}\gamma_3 \Delta lnICTINDX_{t-j} + \sum_{i=0}^{p}\gamma_4 \Delta lnICTEXP + \sigma ECT - 1 + v_t \quad (12)$$

$$\Delta lnGDP_t = \delta + \sum_{i=1}^{p}\gamma_1 \Delta lnGDP_{t-i} + \sum_{i=1}^{p}\gamma_2 \Delta lnTFP_{t-i} + \sum_{i=0}^{p}\gamma_3 \Delta lnHC_{t-i} + \sum_{i=0}^{p}\gamma_4 \Delta lnICTINDX_{t-j} + \sum_{i=0}^{p}\gamma_5 \Delta lnICTEXP + \sigma ECM_{t-1} + v_t \quad (13)$$

In equations 12 and 13, σ is the speed of adjustment parameter and ECM is the residual series from the estimated model.

IV. DATA AND RESULTS

A. Data

This study uses annual data for Indonesia for the period 1980–2014.[1] The data are collected mainly from three sources. Data on real GDP, GDP growth, and ICT exports are collected from the World Development Indictors. ICT exports (ICTEXP) are measured as exports of communications, computers, etc., as a percentage of service exports in the balance of payments account. Data on output per worker and capital per worker are estimated using Penn World Table 9.0, from Feenstra et al. (2015). Similarly, data on human capital and TFP growth are directly collected from the Penn World Table. Finally, all variables related to information communication technologies are collected from the ITU database. All variables related to ICT are presented in Section 2. Typically, the empirical literature on the relationship between ICT and economic growth broadly uses fixed-telephone subscriptions per 100 inhabitants, fixed broadband subscriptions per 100 inhabitants, fixed internet subscriptions per 100 inhabitants, mobile-cellular subscriptions per 100 inhabitants, and proportion of households with use of computer as measures of ICT development. We employ these variables in Section 2. Ideally, one could examine the impact of each of these ICT indicators on Indonesia's overall economic growth. However, due to non-availability of data for longer periods and missing data for key indicators like fixed broadband use, use of internet, and computer use, the present study confines its analysis by constructing an ICT development index using principal component analysis.[2]

B. Results and Discussion

This section presents the results of the effect of ICT on economic growth. The empirical analysis includes examination of unit root test, cointegration, and ECM.

Table 2.
Results for Narayan and Popp (2010) Unit Root Test with Two Structural Breaks

This table presents the unit root test with two endogenous structural breaks proposed by Narayan and Popp (2010). The results indicate that the *TFP* and *ICTINDX* are stationary at the level form and the remaining variables are I(1), i.e. nonstationary at levels. M1 stands for a model which includes an intercept whereas the M2 model includes both an intercept and a time trend. TB1 refers to the first break while TB2 denotes the second break. Critical values for M1 are: −5.259 (1%); −4.514 (5%); −4.143 (10%). Critical values for M2 are: −5.949 (1%); −5.181 (5%); −4.789 (10%). *k* stands for optimum lag. *T* refers to observations. Finally, *** (**) represent statistical significance at 1% (5%) levels.

Variable	T	M1				M2			
		Test Statistic	TB1	TB2	k	Test Statistic	TB1	TB2	k
TFP	35	-16.67***	1987	1996	0	-2.207	1997	2004	3
lnGDP	35	-1.43	1997	1999	0	-4.105	1988	1997	2
lny	35	-2.441	1994	1997	0	-3.914	1994	1997	0
lnk	35	0.5849	1996	1998	0	-0.335	1996	1998	0
ICTINDX	35	-4.855**	1997	1999	3	-2.689	1999	2005	5
lnICTINV	35	0.7131	2000	2006	0	0.9176	2000	2006	4
lnICTEXP	35	-2.789	1987	2003	5	-1.95	1988	2003	0
FTS	35	-2.92	2005	2007	2	-4.167	2003	2006	4
MPS	35	-1.52	1994	1997	0	3.534	1994	1998	5

[1] The empirical results in this paper stem from data prior to 2014 because of non-availability of data for various indicators used in the ARDL model.

[2] The factor scores and corresponding eigenvalues for constructing the ICT index are not presented here but the results are available upon request.

Table 3.
Bound Test Results

This table depicts the bound test results of the ARDL cointegration model. Model I is based on per capita output as depicted in Equation (8) and Model II is based on real GDP as depicted in Equation (9). The *F*-statistic values of both Models I and II reject the null hypothesis of no cointegration, which implies the existence of a long-run relationship between ICT development and economic growth. The bound test critical values developed by Narayan (2005)[a] and Pesaran et al. (2001)[b] at 1%, 5% and 10% are provided.

Test Statistic		Model I		Model II	
F - statistic		5.66		7.45	
	Significance level	I(0)[a]	I(1)[a]	I(0)[b]	I(1)[b]
	1%	4.483	6.320	3.74	5.06
	5%	3.120	4.560	2.86	4.01
	10%	2.560	3.828	2.45	3.52

We first examine the stationarity of the variables using traditional ADF and Phillips and Perron unit root tests. The results of the unit root tests indicate that all variables are non-stationary at level, I(1). As discussed earlier, these unit root tests do not address the issue of structural break in the data. To overcome this limitation, we additionally employ the Narayan and Popp (2010) two-stage break test. The results are delineated in Table 2 and it is notable that, except for TFP and ICT index, all variables are non-stationary at level. However, both TFP and ICT index are stationary at level I(0). The results further reveal that both output per worker (y) and real GDP series have two structural break points.

After examining the unit root tests, we now employ an ARDL model to investigate the long-run relationship between economic growth and ICT. We use two alternative models to examine this issue. Model I is based on a production function approach, and we particularly examine the impact of the ICT development index on output per worker.[3] To further substantiate our argument, we also use model II to examine the impact of ICT on real GDP (economic growth) by controlling TFP, human capital, and ICT exports. The bound test results are presented in Table 3. The calculated F-statistics value is greater than the critical values except for model I (the upper bound critical value based on Narayan (2005) is greater than the calculated value). Thus, Table 3 shows a cointegrating relationship between ICT development and economic growth at 5% and 1% levels of significance for model I and model II, respectively.

Table 4.
Estimated Long-run Elasticities Using ARDL Approach for Model I (2,4,4,0,3)
Based on the Schwarz Bayesian Criterion

This table depicts the long-run elasticities based on an ARDL (2,4,4,0,3) model, and *** (**) represent statistical significance at the 1% (5%) levels.

Variable	Coefficient	*t*-statistic
lnk	0.28***	3.71
lnICTINDX	0.08***	5.18
lnICTEXP	-0.01**	-2.38
TD	-0.30***	-2.52
C	19.13***	-23.17

3 Per capita output is synonymously used for economic growth.

After identifying the cointegrating relationship, we now estimate the long-run coefficients using equation (10) for model I. The results of long-run elasticities are presented in Table 4. Table 4 offers the following insights. First, a 1% increase in capital per worker (*k*) on average increases output per worker by 0.28%. Theoretically, one would always expect a positive relationship between the capital–labor ratio and output per worker. As per capita capital increases, there is greater use of machinery and equipment per worker and thus an increase in output per worker. As an emerging country, both Indonesia's capital stock and number of workers is increasing. Our preliminary results in Table 3 also show a strong positive correlation between output per worker and capital per worker, which supplements the finding of long-run elasticity obtained in Table 4. Second, the long-run elasticity coefficient of the ICT development index (ICTINDX) is positive and statistically significant at the 1% level. This result indicates that a 1% increase in overall ICT development on average increases output per worker (as a measure of economic growth) by 0.08%. Although this coefficient is very small, it nevertheless reflects the importance of greater access to and use of ICT in Indonesia's overall growth process. As a developing country where overall ICT development is quite low (see preliminary analysis in Section 2) compared to developed countries or even neighboring countries like Singapore and Malaysia, the positive effect on output per worker is notable. Third, ICT exports[1] negatively affect output per worker, which is bit surprising. But the coefficient has only a weak effect (only at the 10% level of significance) and its magnitude is negligible. The structural dummy (TD) variable introduced in the model shows a negative sign with 1% level of significance. The coefficient 0.30 implies that output per worker declines by 0.3% in the break periods as compared to the remaining sample periods.

Table 5.
Error Correction Representation for Selected ARDL for Model I

This table presents the error correction representation for the selected ARDL for model, and *** (**) indicate statistical significance at the 1% (5%) levels. The diagnostic tests are reported in the second half of the table.

Regressor	**Coefficient**	***t*-statistic**
Δlnk	1.48***	7.30
ΔlnICTINDX	0.06	1.47
ΔlnICTEXP	-0.02**	-2.39
ΔlnTD	-0.009	-0.45
ECMt-1	-0.76***	-3.59
Diagnostic tests	**Coefficient**	***p*-value**
R^2	0.93	
Adjusted R^2	0.85	
χ^2 *Auto(1)*	1.52	0.25
χ^2 *Norm(2)*	1.35	0.50
χ^2 *Hetero(1)*	0.20	0.65
CUSUM	Not stable	
CUSUM -SQ	Stable	

4 We also run an ARDL model by replacing ICT imports with ICT exports in Equation (8). However, we obtain no robust results. The chosen model (4,4,3,3,4) based on the Schwartz criterion with 4 lags yields an F-stat of 12.56, which rejects the null hypothesis of no cointegration at the 1% level of significance. Although there exists a long-run relationship among these variables, none of the long-run slope coefficients are statistically significant (at the 10% level). The cointegration equation can be written as $lny = 120.96 - 11.07lnk + 2.28lnICTINDX + 5.42lnICTIM + 16.75TD$. The error correction coefficient turns out to be 0.02 with probability value of 0.06.

After studying the long-run elasticities of model I, it is important to discuss the speed of adjustment through ECM and the short-run relationship of model I. The results are illustrated in Table 5. The coefficient of the error correction term (ECM_{t-1}) is (-0.76) and is significant in the short-run, which confirms that long-run equilibrium exists among the variables in model I. The coefficient -0.76 implies that once shocked, convergence to equilibrium is very high with 76% rectification occurring in the first year. The short-run impact of other explanatory variables is the same as the long-run relationship except that the ICT development index (ICTINDX) does not significantly affect output per worker in the short-run, which is as expected. Greater use of and investment in ICT will always impact the overall growth and productivity of a country in the long-run. Based on the diagnostic tests presented in Table 5, we can rely on the results of the ARDL bound testing approach.

Table 6.
Estimated Long-run Elasticities Using ARDL Approach for Model II (2,4,4,0,3) Based on Schwarz Bayesian Criterion

This table depicts the long-run elasticities results of based real GDP as economic growth using an ARDL (2,4,4,0,3) model. Finally, *** indicates statistical significance at 1% level.

Variable	Coefficient	*t*-statistic
lnTFP	1.53***	5.21
lnHC	2.18***	4.31
lnICTINDX	0.10***	2.72
lnICTEXP	-0.04	-1.4
C	25.47***	-64.49

After discussing the empirical results of model I, let us now discuss the results obtained from model II. We use model II[5] as an alternative specification in which real GDP is treated as the dependent variable and TFP growth, human capital, ICT development, and ICT exports are included as the regressor. The bound testing results presented in Table 3 reject the null of no cointegration at the 1% level of significance based on both Narayan (2005) and Pesaran (2001) critical values. Thus, our finding indicates a long-run relationship among the variables. Next, the long-run elasticity coefficients are presented in Table 6. The effect of ICT development appears similar to the results presented in Table 4. The coefficient of ICT development (ICTINDX) indicates that a 1% increase in ICT development on average increases the economic growth of Indonesia by 0.10%. Similarly, note that the ICT export coefficient is negative but not statistically significant, which is similar to the results obtained in Table 4. In addition to ICT development and ICT exports, TFP growth and human capital positively influence Indonesia's economic

5 We also use an alternative form of model II, based on a reviewer suggestion. We run the model by taking labor and capital inputs along with other explanatory variables already presented in Equation (9). However, the results based on the ARDL bounds testing approach produces no convincing results. We select the ARDL (4,4,4,4,4) model based on Schwarz Criterion with 4 lags. The bound test result (F-stat. = 6.87) shows evidence of a long-run relationship between economic growth and other variables at the 1% level of significance. The cointegration equation can be written as: $lnGDP = 16.09^{**} + 0.70^{**} lnlab + 0.50^{**} lncap - 0.36 lnHC + 0.67^{**} lnTFP + 0.03^{*} lnICTINDX$ The error correction coefficient term is -3.01 with a probability value of 0.18. The model is also not stable based on the CUSUM and CUSUM SQ plots.

growth. In the literature, it is well established that TFP growth and human capital play a critical role in boosting national economic growth. Thus, the results in Table 6 are not surprising.

Table 7.
Error Correction Representation for Selected ARDL for Model II

This table presents the error correction representation for the selected ARDL for model and *** (*) indicate statistical significance at 1% (10%) levels. The diagnostic tests are reported in the second half of the table.

Regressor	Coefficient	*t*-statistic
ΔlnTFP	0.79***	12.75
ΔlnHC	0.43***	2.80
ΔlnICTINDX	0.02*	1.89
ΔlnICTEXP	-0.007	-1.27
ECMt-1	-0.19***	-3.28
Diagnostic tests	**Coefficient**	***p*-value**
R^2	0.87	
Adjusted R^2	0.85	
χ^2 *Auto(1)*	1.92	0.13
χ^2 *Norm(2)*	2.76	0.25
χ^2 *Hetero(1)*	1.76	0.25
CUSUM	Stable	
CUSUM -SQ	Stable	

After discussing the long-run elasticities, we present the results of ECM based on equation (13). The results are presented in Table 7. The coefficient of ECM_{t-1} is negative and statistically significant at the 1% level. The coefficient -0.19 confirms a long-run relationship between economic growth and ICT development, along with other control variables. The error correction term implies that the speed of convergence to equilibrium is relatively slow, with 19% adjustment occurring in the first year. TFP growth, human capital, and ICT development positively affect economic growth in the short-run, but the effect of ICT on economic growth is very weak in the short-run. The results of cointegration and ECM are quite reliable based on various diagnostic tests.

V. CONCLUSIONS

This paper investigates the impact of ICT on economic growth in Indonesia. Although many studies examine the impact of ICT development on economic growth or TFP, our focus exclusively on Indonesia is our main contribution to the literature. A plausible reason that the nexus between ICT and economic growth is less explored for individual emerging countries is the non-availability of data for all ICT-related variables. Our paper fills this research gap. To address this issue, we use the augmented neoclassical growth framework and the ARDL model to examine the long-run and short-run relationship between ICT development and economic growth by considering annual data from 1980 to 2014. The major findings can be summarized as follows. First, preliminary analysis indicates that the key indicators of ICT development have shown an increasing trend in recent years as compared to 1980 or even 2000. Second, empirical results based on the ARDL model show evidence of a long-run cointegrating relationship between ICT development and economic growth. Third, we use two alternative models, one based on a production function approach and the other on determinants of economic growth by including ICT development as a regressor. The coefficient of long-run elasticity of economic growth with respect to change in ICT development is positive and statistically significant. This implies that ICT development positively affects the economic growth of Indonesia; however, the magnitude of this effect is very low. Other indicators like capital per worker, TFP and human capital also positively affect economic growth in Indonesia. Fourth, based on the export-led growth hypothesis, we use ICT exports as a regressor and assess its effect on economic growth. The results, surprisingly, show a negative effect on economic growth, although the impact is weak. From a policy perspective, our study shows that indicators of ICT are imperative for long-run growth in Indonesia. Thus, Indonesia should focus on not only increasing the use of ICT, but also target increased ICT-related investment. National governments always play a critical role in fostering adoption of ICT-related indicators; thus, an effective strategy to reap ICT's benefits would promote improved economic growth.

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