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THE NEXUS OF E-GOVERNMENT AND INCREASED PRODUCTIVITY RELATIVE TO INCOME LEVEL COMPARISON

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Abstract. *Purpose* – this study aims to determine the influence of E-government on productivity in the case of different countries comparing by income level.

Research methodology – static (fixed and random) and dynamic (GMM) panel regression.

Findings – a disaggregated analysis reveals that middle-income countries are driving global productivity growth by implementing ICTs infrastructure in the public sector.

Research limitations – this study focuses on severe developed and developing economies, whereas each country may not benefit from E-government implementation as gains might be offset with the enormous costs of implementation.

Practical implications – the government may rely more on online services in the provision of its responsibilities because it enhances the efficiency of public sectors.

Originality/Value – the study is a novel measure of E-government that covers additional multiple dimensions.

Keywords: electronic government, productivity growth performance, ICTs, trust, developed and developing countries, panel data.

JEL Classification: D02, O17, P31.

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Introduction

The adoption of novel and innovative industry technologies is essential to the economic development processes, which include, i.e. devices, machines, and production modules that can independently exchange, trigger information, and control such actions, thus enabling an intelligent business environment (Weyer et al., 2015). Several empirical studies have examined the relationship between the economic environment and the implementation of novel technologies. However, there is still no agreement about how have ICTs become the source and essential factors of cross-countries differences.

Economists have still extensively debated these pressing questions. Zhu, Kraemer, and Xu (2003) found a positive influence of competition on the application of new technologies can be found since they give the chance to outperform competitors. However, these technological driven changes implied serious effects on economic development, an adverse correlation is also revealed between competition and the adoption of online technologies (Rodríguez-Ardura & Meseguer-Artola, 2010).

The industrial revolutions had a strong influence on industrial processes, allowing increased productivity (GDP per capita) and efficiency through disruptive technological developments, i.e. steam engine, electricity or digital technology (Ślusarczyk, 2019). Industry 4.0, which may eventually represent a fourth industrial revolution, is a complex technological system that has been widely discussed and researched and has a significant influence in the industrial sector since it introduces relevant advances that are related to smart and future factories (Pereira & Romero, 2017).

Whereas investment in physical capital is considered a fundamental element of productivity growth, recently researchers are increasingly paying attention to discover how companies operating the phenomenon of Industry 4.0, Internet of Things (IoT), etc. tools to support their processes, and what critical issues they face during ICTs adaptation (Nagy et al., 2018).

Levine (1997) emphasizes that ICTs improves access to information, which facilitates investment and economic performance. In another study, Bai and Yuen (2002) suggest it increases awareness, knowledge, skills, and consumer sophistication. Furthermore, the implementation and adaption in the public sector have also attracted the attention of worldwide researchers and policymakers. The usage of ICTs by the government is referred to as E-Government (Chen et al., 2009). ICTs in the public sector also noted as "dealing and sharing" of public information and services for the citizens (UNDESA, 2003).

Majeed and Shah (2018) argue that the quality of public service depends upon the adaption of ICT in the public sector. Countries with a high level of E-government tend to provide quality public services. However, some other studies highlight the importance of E-government to overcome malpractices and bribery by improving transparency and accountability of economic transactions (Haigh, 2004; Zhao et al., 2015).

However, understanding the process and the transformative impacts of digitalisation on public administration is scarce and myth play important roles in policymaking (Bekkers & Homburg, 2007). Andersen et al. (2010) also demonstrated a substantial shift in the nature and directions of impacts in comparison to earlier studies. However, empirical studies have just focused on ICTs, ignoring its implementation in the government sector. These studies

do highlight the importance of ICTs for the public sector but not provide empirical evidence, mostly country-specific and generally focus only developed ones. Since the experience of E-government can also depend upon development level, it is necessary to conduct as well as disaggregated global analysis.

This study aims to contribute to the empirical literature by investigating E-government and productivity growth nexus at income level comparison. This study focuses directly on how the access to and usage of the E-government, and the adoption of telecommunication technologies, human capital are related to the pace of productivity change. The rest of this paper is divided into additional sections. The next section briefly describes the conceptual literature framework and background of this research topic. Section 3 describes the data and methodologies. Moreover, this approach attempts to address the potential endogenous and complex nature of E-government. Sensitivity analysis is also performed to check the robustness of the results. Finally, the paper ends with some conclusions and implications based on the empirical results.

1. The linkage of E-government and productivity performance

The empirical research on the determinants of productivity growth has generally concluded favourable outcomes of investment in ICTs and environment sustainability (Majeed, 2018). Ma, Chung, and Thorson (2005) highlight the importance of the E-government initiative in the case of China. They argue that E-government boosts transparency and fiscal decentralization, thereby supporting economic development. Moreover, E-government provides information to the government to improve efficient monitoring and to steer economic activities.

The literature suggests various mechanisms to explain the effects of E-government. It facilitates fight against corruption by facilitating efficient monitoring of economic transactions and lowering transaction costs of accessing information (Batchelor et al., 2005). In the presence of information communication technology in the public sector, the discretionary power of public officials lower as they have fewer interactions with the citizens. E-government facilitates the dissemination of information of public sector in the economy, which motivates citizens to question "arbitrary and unfair procedures" in the public sector, thereby improving check and balances on public officials (Piatkowski, 2006). Therefore, E-government has enough power to control for many possible opportunities for corruption supporting productivity by lowering malpractices.

Recently, Majeed (2018) found a negative impact of E-government on corruption in a sample of 147 countries over the period 2003–2012. Corruption hinders development by escalating economic inefficiencies, weakening institutions, eroding the incentive systems, which are essential for productivity growth and sustainable development (Meyer et al., 2017). Trust is another institutional factor that matters in the case of E-government and productivity performance (Oláh et al., 2019b). Trust lowers transaction costs, increases investment, and GDP per capita growth (Goergen et al., 2013; Oláh et al., 2019a). E-government improves communication between citizens and government. Welch, Hinnant, and Moon (2005) suggested that increasing usage of government websites improve the relationship between people and government and people trust on government. Likewise, Tolbert and Mossberger (2006)

claimed that government citizens would trust more when the government provides efficient services through ICTs infrastructure. However, some survey studies do not confirm these proposed relationships. For instance, in a case study of Singapore, Teo, Srivastava, and Jiang (2009) analysed the data of 214 government websites and concluded that citizens could trust more on government when public policies work effectively rather than the usage of technology by the government.

Environmental degradation is another spillover channel that explains the relationship between E-government and economic performance. The implementation of E-government in the public sector inversely affects the movement of the vehicle, which lower the burden on the environment and resources. Krishnan and Teo (2012) provided evidence that e-government improves economic growth by lowering corruption and improving environmental quality, employing an unbalanced panel data of 105 economies over the period 2004–2008.

E-government also improves the productivity of labour inputs, such as the performance of public officials. Using a sample of OECD countries, Czernich et al. (2011) found a positive impact of broadband subscriptions. Mahyideen, Ismail, and Hook (2012) confirmed the positive impact of ICTs of ASEAN countries over the period 1976–2010. Bhuiyan (2010) explored the gains from the implementation of ICTs infrastructure in the public sector in the case of Kazakhstan and concluded that E-government had improved the GDP per capita growth by, i.e. lowering supervisory costs, controlling malpractices, decreasing disguised unemployment and improving international relationships. Kpodar and Andrianaivo (2011) argued that E-government improves productivity growth by facilitating capital accumulation, increasing financial inclusion, improving rural sector development and lowering market imperfections. A positive effect of ICTs for 44 African countries found over the period 1988–2007.

Another group of studies suggest adverse effects of ICTs, particularly in the case of developing countries. Maurseth (2018) found evidence of an unfavourable effect of E-government using a panel of 217 countries. The developing countries are argued to lack resources, and low implementation of E-government will divert resources from essential services, i.e. health, education, clean water and electricity (Morawczynski & Ngwenyama, 2007). Moreover, the benefits of ICTs largely depend upon complementary factors, such as technical skills and back up of finance to maintain different costs linked to ICTs (Ngwenyama et al., 2006).

2. Data and methodologies

A unique database has been constructed by the World Bank (The World Bank, 2019) and the Penn World Table (PWT, 2018) last available release to support the gathering of relevant, high-quality, and internationally comparable statistics. This study has employed an unbalanced panel data set of 168 countries across the World Bank's Databank from 2003 to 2015. The explained variable is per capita GDP measured by "natural log of GDP per capita at 2005 constant prices". The explanatory variables are initial GDP per capita, human capital, labour participation, physical capital, and E-government. For the sake of sensitivity analysis, the suggested control variables are inflation, trade openness and government consumption (Poór et al., 2018).

Gross Domestic Product (GDP) per capita (productivity) is based on purchasing power parity (PPP) and converted to constant 2005 dollar ($) prices. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources.

The E-government comprises of three components based on the Global E-governance Reports (United Nations, 2019). (1) Web connection and online service component estimate the existing web content accessibility of a country and growing online presence in simple websites, which improves information provision by the arrangement of multimedia content, bilateral interactions between government and citizens and online transaction service. (2) Telecommunication service is based on the number of personnel computers, mobile phone and fixed telephone subscription and internet users. (3) Human capital measures the "adult literacy rate and gross enrollment of primary, secondary and tertiary education". Hence, the E-government variable is the "weighted average" of web connectivity and online service of the government, human capital and telecommunication infrastructure. The data ranges from 0 to 1: where the highest one shows the best quality of E-government and the lowest (zero) one indicates the worst one.

The indicator of physical capital is measured by gross capital formation as a ratio of GDP. It consists of "outlays on additions to the fixed assets of the economy plus net changes in the level of inventories. Fixed assets include land improvements (i.e. fences, ditches, drains, etc.); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. Inventories are stocks of goods held by firms to meet temporary or unexpected fluctuations in production or sales, and work in progress".

The indicator of human capital is measured by school enrollment, secondary (% gross). It is the "ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Secondary education completes the provision of basic education that began at the primary level, and aims at laying the foundations for lifelong learning and human development, by offering more subject or skill-oriented instruction using more specialized teachers".

The indicator of labor force is measured by the labor force participation rate. It is the "proportion of the population ages 15 and older that is economically active: all people who supply labor for the production of goods and services during a specified period".

General government final consumption expenditure is measured as a ratio of GDP. It includes "all current government expenditures for purchases of goods and services (including compensation of employees). It also includes most expenditures on national defense and security, but excludes government military expenditures that are part of government capital formation".

Urban population refers to "people living in urban areas as defined by national statistical offices. It is calculated using World Bank population estimates and urban ratios from the United Nations World Urbanization Prospects. Aggregation of the urban and rural population may not add up to the total population because of different country coverages". The indicator of fixed telephone lines is measured as a ratio per 100 inhabitants (The World Bank, 2019). The data sources and description of other control variables are given in Appendix.

Table 1 illustrates some descriptive statistics, as the maximum and minimum values of the data of variables. The quality of E-government is high in most of the European countries and poor in the case of the African ones. The highest mean value of E-government (0.65) belongs to the high-income countries, while the lowest mean value (0.22) belongs to low-income ones.

Table 1. Summary statistics of the data requirements (source: Authors' calculation)

Variable	Observations	Mean	Std. Dev.	Min	Max
GDP(Y) per capita	1448	12066.49	14946.42	181.75	136311.00
Labor	1376	63.54	10.54	38.60	89.60
Capital	1330	22.45	7.62	2.00	67.73
Human Capital	1091	78.45	28.79	7.35	159.15
E-government	1256	.42	.20	.00	.93
Trade	1448	89.74	47.72	1.80	433.05
Government Exp	1448	11.97	8.98	.90	55.25
Urban	1400	14.61	2.32	8.53	20.31
Fix_ telephone	1408	18.83	17.91	.01	73.03
Online service	1266	.32	.24	.00	1.00
Telecom Infra	1263	.20	.21	.00	.86
High-Income Countries					
GDP(Y) per capita	401	30752.75	16510.02	5411.61	136311.00
Labor	393	62.48	7.71	48.20	86.80
Capital	389	22.92	6.91	9.75	67.73
Human Capital	351	102.73	11.72	28.19	159.15
E-government	351	.65	.15	.00	.93
Trade	401	102.45	62.94	24.16	433.05
Government Exp	401	7.33	3.12	2.56	26.50
Urban	393	14.57	2.34	8.53	19.35
Fix_telephone	401	39.82	15.30	1.48	73.03
Online service	351	.54	.23	.00	1.00
Telecom Infra	351	.48	.19	.01	.86
Middle-Income Countries					
GDP(Y) per capita	776	6271.56	4379.40	491.95	32300.08
Labor	712	60.49	9.51	38.60	80.00
Capital	688	23.55	7.75	5.37	63.05
Human Capital	572	75.36	22.43	7.57	119.72
E-government	670	.38	.13	.00	.71
Trade	776	91.88	38.58	21.02	267.81
Government Exp	776	13.83	10.41	3.06	55.25

End of Table 1

Variable	Observations	Mean	Std. Dev.	Min	Max
Urban	760	14.73	2.38	9.60	20.31
Fix_telephone	753	13.39	10.46	.18	46.97
Online service	678	.27	.18	.00	.82
Telecom Infra	675	.12	.09	.00	.77
Low-Income Countries					
GDP(Y) per capita	272	1026.10	788.54	181.75	5627.73
Labor	272	73.06	11.13	47.70	89.60
Capital	254	18.80	7.21	2.00	48.60
Human Capital	169	38.59	22.84	7.35	99.50
E-government	236	.22	.09	.00	.45
Trade	272	64.80	34.41	1.80	190.04
Government Exp	272	13.47	7.92	.90	47.15
Urban	248	14.32	2.05	10.04	17.56
Fix_telephone	255	1.91	3.68	.01	21.04
Online service	238	.12	.10	.00	.39
Telecom Infra	238	.02	.02	.00	.13

Table 2 shows that there is a positive correlation between E-government and GDP per capita. The E-government components, such as online service and telecom infrastructure, are positively correlated with per capita income.

Table 2. Correlation matrix of independent variables 1 (source: Authors' calculation)

Variables	1	2	3	4	5	7	8	9	10	11
Labor	–.362									
Capital	.060	–.037								
HC	.693	–.471	.132							
E-government	.707	–.296	.077	.739						
Trade	.234	–.227	.121	.259	.252					
Govern. Exp.	–.305	.087	.089	–.302	–.432	–.075				
Urban	.073	–.114	.032	.171	.152	–.065	–.155			
Fix_telephone	.753	–.448	.184	.744	.688	.240	–.303	.115		
Online service	.519	–.202	.055	.469	.827	.113	–.394	.189	.463	
Tele. Infra.	.745	–.374	.132	.652	.771	.309	–.327	.050	.762	.540

Note: The Link-test results confirm the correct functional form as well (See Appendix, Table A2). The "Variance Inflating Factor" (VIF) test is applied to check tmulticollinearity. The values of VIF range from 1.29 to 2.33, which indicates that the problem is not detected in the model (Appendix).

The empirical model relies on an extended Cobb-Douglas production function (Mankiw et al., 1992). There are three primary sources of production, namely labour, physical capital, and human capital:

$$Y_{it} = A_{it} K_{it}^{\alpha_{it}} \; HC_{it}^{\beta_{it}} \; L_{it}^{\chi_{it}} . \tag{1}$$

Note that i stands for cross-section units, $i = 1,2,3 \ldots n$ and t denotes time period, $t = 1,2,3 \ldots t$. Equation (1) is transferred by taking natural of both input and output variables:

$$\log y_{it} = \log A_{it} + \beta_1 \log k_{it} + \beta_2 \log HC_{it} + \beta_3 \log L_{it} , \tag{2}$$

where y refers to the growth rate of GDP per capita, K represents the stock of physical capital, L indicates the labour force, and HC refers to human capital. The term 'A' substitutes the given state of technological progress and known as the total factor productivity. Technological developments are the principal source of economic growth over time. Equation (3) represents the exponential form of the technology level:

$$A_i = A(0) e^{\theta it} . \tag{3}$$

Applying natural log on both sides of equation (3) gives the following equation:

$$\log = \log A_0 + \varnothing_{it} . \tag{4}$$

The symbol $\varnothing$ represents the growth rate of technology in an economy. E-government is an important source of economic growth and advances sources of knowledge, access to information, investment in research and development. $\varnothing$ can be described as follows:

$$\varnothing_{it} = \alpha_1 + \alpha_2 E\_government_{it}$$

Substitute Equation (5) in Equation (4):

$$\log A_{it} = \alpha_0 + \alpha_1 + \alpha_2 E\_government_{it} \tag{6}$$

Equation (6) is substituted into Equation (2) as a regression formula:

$$\log y_{it} = \beta_0 + \beta_1 E\_government_{it} + \beta_2 \log k_{it} + \beta_3 \log HC_{it} + \beta_4 \log L_{it} + e_{it} \tag{7}$$

where e is the error term. Since economic growth depends upon initial conditions of growth (Barro, 1991), initial GDP per capita is also incorporated into the neoclassical growth model:

$$\begin{aligned} \log y_{it} = {} & \beta_0 + \beta_1 y_{it-1} + \beta_2 E\_government_{it} + \beta_3 \log Physical\_Capital_{it} + \\ & \beta_4 \log Human\_capital_{it} + \beta_5 \log Labor_{it} + \beta_5 \log X_{it} + e_{it} \end{aligned} \tag{8}$$

The robustness of our results is also checked by using control variables. X_{it} is the matrix of additional control variables, i.e. inflation, government consumption, and trade openness.

2. Empirical findings of E-government and productivity nexus

The baseline parameter estimates are drawn using the Fixed Effects approach of estimation. This approach is better than OLS as it takes care of the time-invariant characteristics of each cross-sectional unit. Moreover, it controls unobserved heterogeneity in a model by allowing

separate intercept for each cross-sectional unit in the panel data. Baltagi (2013) argues that the presence of time-invariant characteristics in panel data give bias results with OLS. The empirical findings reported in Table 3 show that E-government has a positive and significant impact on productivity growth. The coefficient also suggests that with one unit increase in E-government increases GDP per capita by 0.10 percentage points.

Columns (1–4) indicate that the coefficient on E-government remains significant and positive in all examined regressions. In order to analyze the strength of results, additional controls of trade, government consumption and human capital added, respectively are incorporated in columns (2–4). The coefficient of trade is positively and significantly associated with productivity growth, which is consistent with Majeed and Shah (2018). In column 2, the influence of government consumption is negative and significant. In column 4, the effect of human capital is positive, as theoretically expected. Columns (4–8) report the results of estimated regressions for the high-income countries, where E-government positively correlated with productivity growth, but insignificantly.

Table 3. Fixed effects results for global sample and high-income countries

Models/	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	Global Sample				High-Income Countries			
$Y_{(t-1)}$	.801***	.799***	.797***	.745***	.677***	.638***	.632***	.665***
	(.014)	(.014)	(.014)	(.017)	(.040)	(.040)	(.035)	(.035)
Labor	–.115	–.124	–.107	–.046	.481**	.516**	.520***	.437**
	(.076)	(.076)	(.076)	(.071)	(.223)	(.216)	(.195)	(.184)
Capital	.037***	.028***	.039***	.075***	.064***	.050***	.053***	.151***
	(.008)	(.008)	(.008)	(.010)	(.019)	(.019)	(.017)	(.019)
E-govern.	.109***	.093***	.101***	.119***	.010	.005	–.053	–.016
	(.032)	(.032)	(.032)	(.033)	(.050)	(.049)	(.044)	(.042)
Trade		.057***				.185***		
		(.015)				(.045)		
Gov. Exp.			–.056***				–.307***	
			(.014)				(.036)	
HC				.020				–.101
				(.017)				(.070)
Constant	2.058***	1.902***	2.183***	2.091***	1.132	.597	2.088***	1.656**
	(.324)	(.324)	(.322)	(.303)	(.740)	(.727)	(.656)	(.712)
Observations	972	972	972	760	287	287	287	256
R-squared	.827	.830	.831	.823	.716	.736	.784	.821
Countries	168	168	168	154	49	49	49	47

Note: Standard errors in parentheses *** p < .01, ** p < .05, * p < .1".

Table 4. Fixed effects results for middle-income and low-income countries

Models/	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	Middle-Income Countries				Low-Income Countries			
$Y_{(t-1)}$	.829***	.829***	.824***	.759***	.743***	.742***	.743***	.679***
	(.017)	(.017)	(.017)	(.022)	(.035)	(.035)	(.036)	(.062)
Labor	–.229**	–.261***	–.225**	–.171**	.110	.143	.110	.059
	(.093)	(.092)	(.092)	(.085)	(.186)	(.188)	(.186)	(.206)
Capital	.024**	.017	.024**	.061***	.037***	.031**	.037***	.027
	(.012)	(.012)	(.011)	(.014)	(.014)	(.015)	(.014)	(.025)
E-govern.	.154***	.126***	.148***	.211***	.195**	.173*	.195**	.151
	(.047)	(.047)	(.047)	(.049)	(.095)	(.097)	(.095)	(.123)
Trade		.074***				.024		
		(.021)				(.024)		
Gov. Con			–.043**				.0001	
			(.019)				(.023)	
Human Cap				0.0314				.052
				(0.0299)				(.032)
Constant	2.276***	2.115***	2.405***	2.375***	1.139	.931	1.139	1.68*
	(.409)	(.406)	(.411)	(.386)	(.805)	(.830)	(.808)	(.934)
Observations	495	495	495	378	191	191	191	127
R-squared	.876	.880	.878	.863	.789	.790	.789	.771
Countries	88	88	88	79	32	32	32	29

Note: Standard errors in parentheses *** p < .01, ** p < .05, * p < .1".

Empirical findings reported in Table 4 show that E-government exerts a significant and positive influence on GDP per capita growth in middle-income countries (columns 1–4). The coefficient of E-government suggests that if E-government increases by one unit, then productivity growth will increase by 0.15 percentage points. Thus, comparatively the influence of E-government on GDP per capita growth is stronger in the case of middle-income countries. The coefficient for low-income countries is also positively associated with productivity. The magnitude implies that if E-government index increases by one unit, then the growth rate will increase by 0.09 percentage points.

Since Fixed Effects model allows a separate intercept for each country, many degrees of freedom is consumed. It might exacerbate the problem of multicollinearity in the model because of the dummy variables trap. Therefore, the results are also obtained using Random Effects Model (REM) in Table 5. Our baseline findings remain consistent. The impact of E-government is robustly significant and positive in all regressions. However, the magnitude of the coefficient slightly falls, implying that FEM results are overestimated.

Table 5. Random effects results for global sample and high-income countries

Models/	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	Global Sample				High-Income Countries			
$Y_{(t-1)}$	.989***	.988***	.988***	.984***	.974***	.970***	.971***	.981***
	(.003)	(.003)	(.003)	(.004)	(.010)	(.010)	(.011)	(.010)
Labor	–.027*	–.025*	–.029*	–.039**	.032	.037	.023	.002
	(.015)	(.015)	(.015)	(.019)	(.041)	(.042)	(.046)	(.041)
Capital	.027***	.025***	.027***	.028***	.038**	.035**	.035**	.088***
	(.006)	(.006)	(.006)	(.008)	(.015)	(.016)	(.016)	(.016)
E-govern.	.028	.030***	.025	.038***	–.006	.003	–.0078	–.026
	(.020)	(.020)	(.021)	(.024)	(.030)	(.031)	(.033)	(.031)
Trade		.010**				.013		
		(.005)				(.009)		
Gov. Con			–.006				–.016	
			(.005)				(.015)	
Human Cap				.008				.032
				(.009)				(.031)
Constant	.142**	.101	.169**	.197**	.034	–.001	.143	–.202
	(.070)	(.074)	(.073)	(.096)	(.153)	(.160)	(.185)	(.219)
Observations	972	972	972	760	287	287	287	256
R-squared	0.82	0.83	0.82	0.81	0.70	0.71	0.71	0.79
Countries	168	168	168	154	49	49	49	47

Note: Standard errors in parentheses *** p < .01, ** p < .05, * p < .1".

Table 6 reports the results estimated using Random Effects method for middle, Columns (1–4), and low-income, Columns (5–8), countries. All columns indicate that the influence of E-government adaption on the productivity performance of middle-income countries is consistently positive and significant. This finding implies that middle-income economies can significantly benefit from the adaption and implementation of ICTs in the public sector. Table 6 also reports the results for low-income countries. In this case, the effect of E-government is positive, but insignificant, suggesting that the growth effect of E-government is sensitive to the estimation.

In the case of the lag dependent (Y_{i-t}) variable on the right side of the equation, OLS, FE and RE techniques of estimation may produce biased findings. In such a condition, the generalized method of moments (GMM) estimation is more appropriate. It tackles endogeneity in the model by using the instrumental variables for each endogenous variables. Arellano and Bond (1991) proposed a GMM model by employing condition lies between lag dependent variable and error term in order to get the instruments to resolve the endogeneity problem.

Table 6. Random effects results for middle-income and low-income countries

Models/	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	Middle-Income Countries				Low-Income Countries			
$Y_{(t-1)}$	.980***	.979***	.980***	.964***	.984***	.985***	.983***	.996***
	(.006)	(.006)	(.006)	(.010)	(.011)	(.011)	(.011)	(.013)
Labor	–.015	–.014	–.015	–.038	–.046	–.041	–.044	–.044
	(.021)	(.021)	(.021)	(.029)	(.036)	(.037)	(.036)	(.040)
Capital	.009	.007	.009	.011	.035***	.034***	.035***	.018
	(.008)	(.009)	(.008)	(.011)	(.010)	(.010)	(.010)	(.015)
E-govern.	.088***	.088***	.089***	.107***	.047	.037	.045	.062
	(.033)	(.033)	(.034)	(.042)	(.064)	(.067)	(.064)	(.082)
Trade		.008				.006		
		(.008)				(.012)		
Gov. Con			.001				–.006	
			(.007)				(.010)	
Human Cap				.017				–.012
				(.015)				(.014)
Constant	.203**	.177*	.203*	.353**	.217	.168	.237	.213
	(.100)	(.107)	(.104)	(.141)	(.185)	(.208)	(.189)	(.217)
Observations	495	495	495	378	191	191	191	127
R-squared	0.87	0.87	0.87	0.85	0.78	0.78	0.78	0.76
Countries	88	88	88	79	32	32	32	29

Note: Standard errors in parentheses *** p < .01, ** p < .05, * p < .1".

It is also possible that the installation of E-government applications depend on the GDP per capita of an economy that will cause a problem of reverse causation. Comin and Hobijn (2004) noted that developed economies initially adopted twenty leading technologies of the world. In order to address these problems, the baseline model estimated by using Arrelano-Bond (AB), dynamic model. The "fixed telephone lines and initial urban population" are used as external instruments. Czernich et al. (2011) used "fixed telephone lines" as instruments for broadband because broadband access is possible through cable-TV and fixed telephones lines. According to Urban Density Theory (UDT) cost of ICTs gradually decreases as the urban population increases due to knowledge spillover and availability of other complementary tools of ICTs (Andersen, 2009).

The empirical results of AB model (Table 7) also confirm the positive influence of E-government on GDP per capita growth. The coefficient on E-government is consistently positive and significant in all regressions. Table 8 also reports *AB* results for middle and low-income countries. The results remain consistent with the baseline findings.

Table 7. Arrelano-Bond results for global sample and high-income countries

Models/	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	Global Sample				High-Income Countries			
$Y_{(t-1)}$	.978***	.968***	.911***	.870***	.916***	.919***	.921***	.965***
	(.007)	(.007)	(.010)	(.011)	(60.07)	(59.05)	(62.43)	(67.07)
Labor	–.010	–.011	–.784***	–.625***	.145*	.157**	.117	.116
	(.019)	(.018)	(.076)	(.0594)	(1.858)	(1.998)	(1.550)	(1.293)
Capital	.173***	.158***	.244***	.097***	.111***	.105***	.116***	.193***
	(.012)	(.012)	(.014)	(.017)	(4.381)	(4.019)	(4.728)	(8.295)
E-govern.	.078*	.127***	.299***	.185***	.148***	.151***	.146***	.026
	(.042)	(.043)	(.054)	(.047)	(3.675)	(3.754)	(3.779)	(.658)
Trade		.034***				.0157		
		(.009)				(1.100)		
Gov. Con			–.003				–.089***	
			(.023)				(–3.159)	
Human Cap				.229***				.061
				(.026)				(.984)
Constant	–.309***	–.340***	3.175***	2.397***	–.159	–.299	.057	–1.001**
	(.116)	(.114)	(.328)	(.274)	(–.578)	(–.988)	(.208)	(–2.454)
Observations	927	927	927	730	281	281	281	250
Countries	162	162	162	150	48	48	48	46

Note: z-statistics in parentheses *** p < .01, ** p < .05, * p < .1".

Table 8. Arrelano-Bond results for middle-income and low-income countries

Models/	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	Middle-Income Countries				Low-Income Countries			
$Y_{(t-1)}$	.960***	.960***	.961***	.937***	.939***	.901***	.940***	.983***
	(129.70)	(130.10)	(125.30)	(116.40)	(56.51)	(46.80)	(48.84)	(42.03)
Labor	–.022	–.018	–.023	.014	–.003	–.142	–.003	–0.120
	(–1.177)	(–.930)	(–1.179)	(.748)	(–.041)	(–1.637)	(–.033)	(–1.427)
Capital	.031**	.028**	.031**	.014	.132***	.162***	.133***	.076***
	(2.494)	(2.085)	(2.435)	(1.167)	(8.512)	(9.238)	(8.003)	(2.789)
E-govern.	.195***	.194***	.195***	.030	.348***	.318***	.350***	.139
	(4.998)	(4.987)	(4.982)	(.608)	(3.850)	(3.307)	(3.807)	(1.215)
Trade		.009				.081***		
		(.828)				(5.004)		
Gov. Con			.002				.002	
			(.140)				(.096)	

End of Table 8

Models/	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	Middle-Income Countries				Low-Income Countries			
Human Cap				.103***				–.019
				(5.879)				(–.925)
Constant	.286**	.241*	.283**	.016	–.013	.438	–.030	.471
	(2.375)	(1.823)	(2.318)	(.136)	(–.033)	(1.003)	(–.068)	(1.105)
Observations	481	481	481	365	166	166	166	116
Countries	86	86	86	77	29	29	29	28

Note: z-statistics in parentheses *** p < .01, ** p < .05, * p < .1".

3. Discussion

The extant literature has primarily focused on the relationship between ICTs and productivity growth. An equally important issue of whether ICTs adaption in the public sector leads to high growth in developing countries has still received less attention. This study contributes to the existing literature by empirically examining the effect of E-government on GDP per capita growth by utilizing an extensive panel data set of income level comparison over the period 2003–2015. The study is a novel measure of E-government that covers additional multiple dimensions. Fixed Effects, Random Effects and GMM methods of estimation, validate the empirical results.

The results confirm a positive and significant impact of E-government on GDP per capita growth. A disaggregated analysis reveals that middle-income countries are driving global economic growth by implementing ICTs infrastructure in the public sector. Findings of the study are robust to different specifications, alternative methods of estimation and endogeneity problem. In the light of empirical findings, it is recommended that government may rely more on online services in the provision of its responsibilities because it enhances the efficiency of public sectors.

Conclusions

Though findings of the study are aligned with the theory, it has certain limitations. This study focuses on severe developed and developing economies, whereas each country may not benefit from E-government implementation as gains might be offset with the enormous costs of implementation. The data set is not available over a long period. Moreover, the sensitivity analysis for this research is based on a few additional control variables

Future researchers need to extend this analysis for other groups of countries, such as regional groups of countries or group of emerging economies. This research highlights positive dimensions of E-government, whereas future research may focus on its potential downside as well. For instance, developing economies are abundant with low-skilled labour force, and unemployment remains a major issue. The increasing implementation of E-government may aggravate this phenomenon by reducing job opportunities for workers in the public sector. Moreover, income distributional consequences of E-government also need to be estimated.

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Author contributions

Conceptualization, G.F., M.M.T., A.I. and D.M.; methodology, G.F. and M.M.T.; validation, G.F. and D.M.; formal analysis, G.F., M.M.T., and A.I; investigation, M.M.T; resources, G.F. and D.M.; data curation, M.M.T., and A.I.; writing-original draft preparation, G.F., M.M.T., and V.L.Z.. Writing-review and editing, G.F., M.M.T., and A.I.; visualization, M.M.T; D.F. M and V.L.Z.; supervision, G.F. and D.M.; project administration, G.F.; funding acquisition, D.M. All authors have read and agreed to the published version of the manuscript.

Disclosure statement

The authors declare no conflict of interest.

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Appendix

Table A1. Summary of variables (sources: [1] Penn World Tables (PWT, 2018); [2] Global E-governance Reports (United Nations, 2019); [3] World Development Indicators (The World Bank, 2019); [4] (International Telecommunication Union, 2019))

Variables	Definition	Source
Productivity (Y) Growth	"Natural log of the GDP per capita at 2005 constant prices".	[1]
E-government	"Extent of online availability of the government, telecom infrastructure, and human capital".	[2]
Online service	"Extent of the online availability of the government".	[2]
Telecom service	"Extent of telecom infrastructure of the government".	[2]
Human capital	"Gross secondary school enrollment of the total population".	[3]
Physical capital	"Gross fixed capital formation in the percentage of GDP".	[3]
Labour force	"Share of labour force participation in the total population".	[3]
Government Expenditure	"Government spending in the share of GDP at 2005 constant prices".	[1]
Urban population	"Natural log of Urban population".	[3]
Fix_Telephone	"Fixed telephone lines per 100 inhabitants".	[4]

Table A2. Results of link-test (source: Authors' estimation)

All Countries						
Y	Coef.	Std. Err.	t	P > t	[95% Conf.	Interval]
_hat	1.020	.014	72.38	.000	.993	1.048
_hatsq	–.001	.001	–1.44	.151	–.003	.0004
_cons	–.084	.060	–1.41	.158	–.201	.033
High Income Countries						
Y	Coef.	Std. Err.	t	P > t	[95% Conf.	Interval]
_hat	–1.482	3.061	–.48	.629	–7.504	4.540
_hatsq	.123	.1511	.81	.418	–.175	.420
_cons	12.553	15.501	.81	.419	–17.939	43.046
Middle Income Countries						
Y	Coef.	Std. Err.	t	P > t	[95% Conf.	Interval]
_hat	1.122	.056	20.21	.000	1.013	1.232
_hatsq	–.007	.003	–2.21	.028	–.014	–.001
_cons	–.504	.229	–2.20	.029	–.955	–.053
Low-Income Countries						
Y	Coef.	Std. Err.	t	P > t	[95% Conf.	Interval]
_hat	1.027	.078	13.13	.000	.873	1.182
_hatsq	–.002	.006	–.35	.725	–.013	.009
_cons	–.094	.269	–.35	.728	–.625	.438

Table A3. The highest rate of variance inflating factor in each group of models (source: Authors' estimation)

Samples	All Countries	High-Income Countries	Middle-Income Countries	Low-Income Countries
Mean VIF	2.33	1.29	1.39	1.34