Revisiting the Nexus between Digital Economy and Economic Prosperity: Evidence from a Comparative Analysis

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Abstract: In this paper, we try to investigate the contribution of digitalization on economic growth in both developed and developing countries over the period 1990-2020. For this end, different econometric tools are applied on a panel dataset. Overall, we show that the digital technologies seem to significantly and positively affect economic growth in both groups of countries. The digitalization impact level tends to differ across countries. Our empirical results also display that the short- and long-term relationship between information and communication technologies and economic growth is well documented. Such results can be useful for policymakers to enhance the digital economy and provide novel channels to develop adequate policies and promote new institutions. So, benefits from digitalization can lead to realize substantial economic growth.

Keywords: Digitalization, Economic growth, Impact, Generalized moments method, Economic Prosperity.

Introduction

By and large, overwhelmingly, the momentous evolution of the Internet has led to the emergence of the digital economy, which has increasingly changed the practices of production,

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distribution and consumption. The digital economy can be defined as a set of economic activities which employ digitized information and knowledge as crucial factors of production, new information networks as key activity space, and communication technologies to boost productivity growth (according to the World Economic Forum and the Group of Twenty). Indeed, individuals tend to frequently use mobile communication and social media to communicate, share information and even provide knowledge and services. Not only people rely on the transformational power of digital technologies, but also political authorities and entrepreneurs rush to use digital technologies for disclosing important information, providing services, and so on. Ben Youssef *et al.* (2020) report that digital technologies, including the Internet, smartphones and other applications, enable one to gather, store, treat and share information. They also reveal that such technologies play a transformational role in the worldwide economy. In this regard, the Information and Communication Technologies have enormously facilitated the creation of new entrepreneurship processes, jobs, products, market channels and marketing strategies. For instance, mobile banking helps individuals access to financial services (Myovella, Karacuka & Haucap, 2019). Digital technologies have also led to business transformations in the value chain of all sectors (Manyika & Roxburgh, 2011).

Most notably, the digital economy has increasingly contributed to boost economic growth (Brynjolfsson & Collis, 2019; Curran, 2018; Gomber *et al.* , 2018) by satisfying the demand for digital products, such as communication materials (Habibi & Zabardast, 2020), and enhancing productivity and investment in different economic sectors (Hofman, Aravena & Aliaga, 2016). In this respect, many researchers have investigated the relationship between the digital economy and economic development and have shown that the growing use of different digital technologies fosters economic growth (Bjorkroth, 2003; Roller & Waverman, 2001; Canning, 1999; Madden, 1998). For instance, Bukht & Heeks (2017) report that digitalization plays a crucial role in fostering economic prosperity. Nonetheless, there is a well-documented persistent digital divide between developed and developing countries even though digital technologies have been used around the world (Castells & Cardoso, 2006). Ward & Zheng (2016) report the nexus between the digital economy and economic growth can depend on the country's development level. Dewan & Kraemer (2000) argue that the improvement in digital infrastructure leads to more economic benefits to developed countries than to developing countries. However, Thompson & Garbacz (2011) show that the increasing development of broadband infrastructure tends to influence lower income countries more than higher income countries. The extent of such impact thus remains inconclusive even though digitalization is considered as a leading driver of economic growth.

Based on this crux, this paper attempts to examine the dynamic short- and long-term relationship between the digital economy and economic growth for different countries. More

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precisely, we analyze the contribution of digitalization to economic growth for developing and developed countries in the long and short term. The use of both groups of countries aims at gaining insight into whether such a nexus depends on the levels of development of the country. Herein, a panel dataset is used, consisting of 30 years from 1990 to 2020, for 28 developed and 27 developing countries. From a methodological standpoint, we perform cointegration analysis and use the generalized moments method to estimate the digital economy-economic prosperity nexus. Such econometric techniques allow us to overcome potential endogeneity issues and better explore the dynamic relationship between economic growth and infrastructure investment.

This paper is organized as follows. The following section presents a synopsis of empirical studies. The subsequent section reports methodology, data, descriptive statistics and empirical results. The final section is a conclusion.

Related Literature on the Digital Economy–Economic Development Nexus

Many researchers have investigated the relationship between digitalization and economic growth for different countries. For instance, Qiang & Rossotto (2009) analyze the impact of the digital revolution on economic growth for 120 developed and developing countries over the period 1980–2006. They clearly show that a rise of 10% in the adoption rate of digital innovation leads to an increase of 0.81% in economic growth for low- and middle-income countries. Using 42 developed and developing countries, Yousefi (2011) examines the relationship between digital economy and economic growth over the period 1993-2001. The empirical results indicate that the investment in digital technologies only improves economic growth in developed countries.

Thompson & Garbacz (2011) clearly show that the growing evolution of broadband infrastructure increasingly influences the economic growth for low-income countries compared to high-income countries. Sassi & Mohamed (2013) show a positive and significant effect of digital diffusion measured by mobile phone, fixed-line telephone, and Internet use on economic growth over the period 1960-2009 for 17 MENA countries. Niebel (2014) analyzes the effect of information and communication technologies (ICT) on economic growth for developing, emerging and developed countries. It clearly demonstrates that developing, emerging and developed countries do not show significant differences in the output elasticity of ICT between countries.

Pradhan, Arvin & Norman (2015) examine the relationship between digital innovation, financial development and economic growth for 21 Asian countries over the period 2001-2012.

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They report that digital innovation and financial development contribute to boost the long-run economic growth of Asian countries. Using panel data from India, Ghosh (2016) show the positive and significant effect of mobile phone penetration on economic growth and financial inclusion.

Aghaei & Rezagholizadeh (2017) explore the influence of information and communication technology on economic growth for Organization of Islamic Cooperation (OIC) countries from 1990 to 2014. They report that digitalization significantly influences economic growth for these countries. Pradhan, Mallik & Bagchi (2018) explore the extent and direction of the relationship between both broadband and Internet users and economic growth for G-20 countries over the period 2001-2012. They report a significant and positive relationship between digitalization and economic growth. Myovella, Karacuka & Haucap (2019) analyze the relationship between economic growth and digital technologies over the period 2006-2016 using a panel dataset of 41 Sub-Saharan African and 33 OECD countries. They report that digital innovations have a positive effect on economic growth in developed and developing countries. The effect of broadband Internet seems to be higher for OCDE countries than Sub-Saharan African countries, where it is minimal, and the impact of mobile telecommunications is lower for Sub-Saharan African countries than OECD countries. Bahrini & Qaffas (2019) examine the effect of information and communication technology on economic growth for the Middle East and North Africa (MENA) over the period of 2007–2016. They indicate that information and communication technology (e.g., mobile phones, Internet usage, and broadband adoption) seems to be a key driver of economic growth. In this respect, they clearly show that mobile phones have the most significant positive effect on economic growth; and Internet usage and broadband adoption are among the crucial factors that contribute to the economic growth of developing countries. Habibi & Zabardast (2020) examine the contribution of the education and digital technologies to economic growth for 10 Middle East and 24 OCDE countries. They use Internet users, broadband subscriptions and mobile phones to measure the digital economy. They show that better access to education is crucial for the Internet to create economic benefits, whereas it appears to be inadequate for mobile phone usage. Fernández-Portillo *et al.* (2019) investigate the effect of the digital economy on economic growth for the European Economic Community. They clearly show that digitalization is a key factor to boost economic growth. Solomon & van Klyton (2020) examine the effect of using digital technology on economic growth for 39 African countries from 2012 to 2016. The empirical results indicate that the difference between the effect of individual, business and government ICT usage on economic growth is well documented. As well, they indicate that only individual usage has a positive effect.

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Other researchers, rather, focus on explaining the impact of the digital divide on economic growth for different groups of countries. For example, Acemoglu & Zilibotti (2001) report that the potential for productivity benefits from using digital innovations relies mainly on the skills of the workforce in a developed/developing country. Indeed, developed countries possess skilled workers and thus are in a greater position to collect gains from digital technologies. Niebel (2014) indicates that the contribution of digitalization to economic growth in developing countries is different from developed countries because of the lack of absorptive capacity (e.g., an appropriate level of human capital) and additional factors (e.g., in research and development capacities). Samimi, Ledary & Samimi (2015) show that the impact of digitalization on economic growth in low-income countries can take more time, given that there is a lack of competitive environment and the importance of government control, compared to high income countries.

Empirical Validation

This section reports a battery of tests, econometric modelling and estimation methods used to investigate the contribution of the digital economy to sustainable economic development. As well, we report a panel of data employed to analyze such a relationship.

Data description and descriptive statistics

As aforementioned, we attempt to analyze the effect of the digital economy on sustainable economic development. To this end, we gather data from the World Bank and the International World Fund related to 55 (28 developed and 27 developing) countries over the period 1990-2020 on annual frequencies. Using panel data help us to have more flexibility in modelling differences and variability among two groups of countries in terms of digitalization infrastructure. That is why we attempt to use the criteria of intra-group homogeneity and inter-group heterogeneity in technology. We also prefer to exclude the United States and China, given that they are more digitized than others and adopt digital technologies in different economic fields. So, we avoid more variability in group in order to produce insightful findings. The developed countries are: Austria, Belgium, Canada, Chile, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Hungary, Luxembourg, New Zealand, Norway, Romania, South Korea, Panama, Poland, Portugal, Spain, Switzerland and United Arab Emirates. The developing countries are: Argentina, Bolivia, Brazil, Colombia, Ecuador, Egypt, El Salvador, Georgia, India, Indonesia, Jamaica, Jordan, Kazakhstan, Malaysia, Morocco, Mexico, Moldova, Paraguay, Philippines, Peru, Sri Lanka, Senegal, Thailand, Tunisia, Turkey, Vietnam and Zimbabwe.

The gross domestic product per capita (GDPH) is used to measure the sustainable development. In this paper, the sustainable economic development refers to the continuity

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without a great fluctuation in the economic growth rate: i.e., the development has been persistent during a longer time period. In this regard, Armeanu, Vintilă & Gherghina (2018) report that sustainable economic development includes three different facets: economic, social, and environmental growth. They also profess that sustainable economic development can be boosted when income is improved, with higher income being captured in gross domestic product, which consequently transmits into per capita income. So, Gross Domestic Product can be considered as a proxy for sustainable economic development. As well, the gross domestic product per capita has been largely employed as an indicator of sustainable economic development (e.g., Arias, 2006; Fernández-Portillo *et al.*, 2019; Vasylieva *et al.*, 2019).

The degree of economic openness is measured by the ratio of the sum of exports and imports to the Gross Domestic Product for each country (Ouvcom). The people's growth rate (Pop) tends to approximate the evolution of population for each country. The Gross fixed capital formation[i] (GFCF) is used as tangible investment and includes land improvements, as well as machinery and road building. The public consumption is approximated by the governments' current spending for the purchases of goods and services (Conpub). Three indicators are used to highlight the global digital economy:[ii] the mobile subscription corresponds to the cellular mobile phone subscriptions (per 100 people) (AbMobile); individuals using the Internet (% of population) (Utint); and the fixed broadband subscriptions (per 100 people) (AboLb). Finally, we use the inflation rate based on the Consumer Price Index (CPI) and the control of corruption (CONCOR).

The descriptive statistics of data used in this study are reported in Table 1. Descriptive statistics comprise the mean, median, standard deviation, minimum, maximum, skewness and kurtosis, and Jarque-Bera for normality test. The first part of Table 1 reports the statistical indicators for developed countries; the second part for developing countries.

Table 1. Descriptive Statistics of Different Variables

Part 1. *Statistical Indicators for Developed Countries*						
	Mean	St. Dev	Variance	Skewness	Kurtosis	Jarque-Bera
LGDPH	10.2223	0.8410	0.7073	-1.2117	1.8345	334.1109
LOUVCOM	4.3267	0.5038	0.2538	0.3972	1.2267	77.2499
POP	-0.4876	1.3698	1.8763	3.0392	1.3602	60.7245
LGFCF	3.1201	0.2089	0.0436	0.3837	2.7416	293.14118
LCONPUB	2.8966	0.7502	0.5629	24.5269	0.7884	168.2865
LABMOBILE	3.4292	2.1376	4.5695	-1.9231	3.8449	169.6758
LUTINT	2.6052	2.6363	6.9502	-1.7442	2.8468	733.2403
LABOLB	0.5078	3.4180	11.6825	-0.9151	-0.2116	122.7742
LCPI	4.1546	0.3413	0.1165	-0.4011	2.2006	198.4154
LCONCOR	4.4527	1.2079	1.4589	15.8104	2.2602	120.254

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Part 2. *Statistical Indicators for Developing Countries*						
	Mean	St. Dev	Variance	Skewness	Kurtosis	Jarque-Bera
LGDPH	8.1033	0.7315	0.5351	-0.1181	-0.5984	14.4347
LOUVCOM	4.1648	0.5174	0.2677	-0.2449	0.0665	8.5243
POP	0.2644	0.6127	0.3754	-2.4145	16.3156	9361.1402
LGFCF	3.0619	0.3152	0.099375	-2.6404	15.4071	9251.1550
LCONPUB	2.5439	0.3263	0.106447	-0.6499	2.1410	218.7820
LABMOBILE	2.0628	3.3570	11.26942	-1.2514	0.7441	237.7587
LUTINT	0.6967	3.8035	14.46646	-1.0221	0.4271	152.0946
LABOLB	-2.2664	4.1572	17.28263	-0.5573	-0.7998	65.6383
LCPI	3.4946	0.2751	0.075691	-0.5385	0.4903	48.8435
LCONCOR	3.4839	1.0467	1.095689	5.3193	113.301	451643.434

Note: L refers to the natural logarithm

From the first part of Table 1, all the variables seem to have positive mean values, which range from 0.5078 and 10.2223, expect for the people's growth rate. The standard deviation seems to be very small for each variable. Some asymmetries between different variables in terms of skewness and kurtosis seem to be well documented. For instance, the values of skewness are less than zero for the gross domestic product per capita, the cellular mobile phone subscriptions (per 100 people), individuals using the Internet (% of population), the fixed broadband subscriptions (per 100 people), and the inflation rate. Hence, these variables are asymmetrical on the left. However, the other variables (LOUVCOM, POP, LGFCF, LCONPUB and LCONCOR) are characterized by a positive skewness. All the variables seem not to follow the normal distribution, given that the Jarque-Bera statistics are higher than the critical chi-squared value.

From the second part of Table 1, all the variables are characterized by positive mean values, which range from 0.6967 to 8.1033, except for the fixed broadband subscriptions (per 100 people). For the developing countries as well, there exists a very low standard deviation for each variable. The values of skewness are less than zero for all variables, except for the control of corruption. All of the variables do not follow the normal distribution: the Jarque-Bera statistics are higher than the critical chi-squared value.

Figures 1 and 2 illustrate the evolution of different variables for both groups of countries during the period 1990-2020. As we can see in Figures 1 and 2, time series plots evolve differently, although all plots show cyclical swings. As well, the issue of the non-stationarity and volatility clustering behaviour are well documented.

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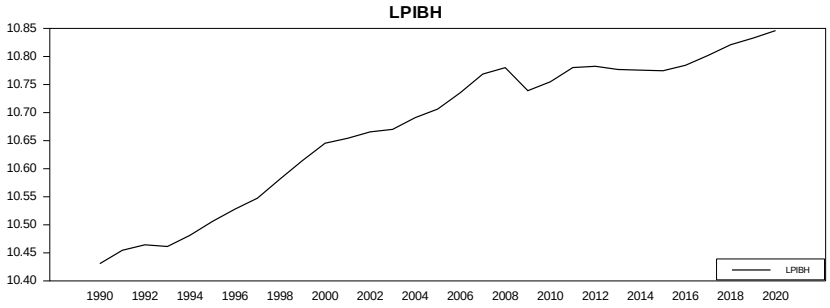

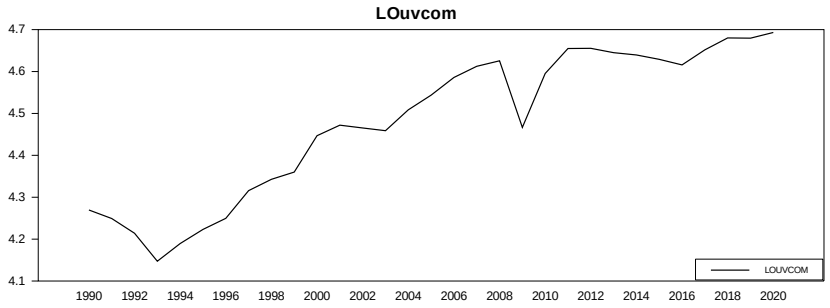

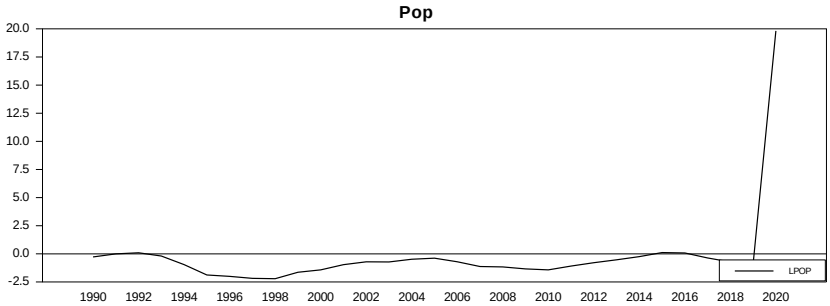

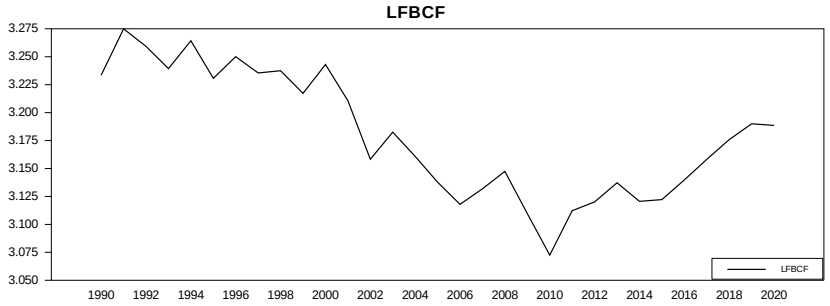

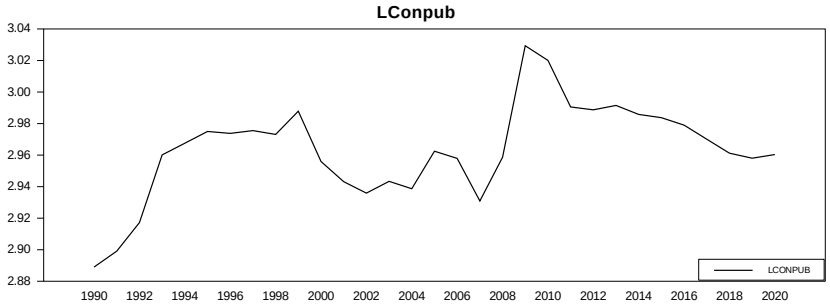

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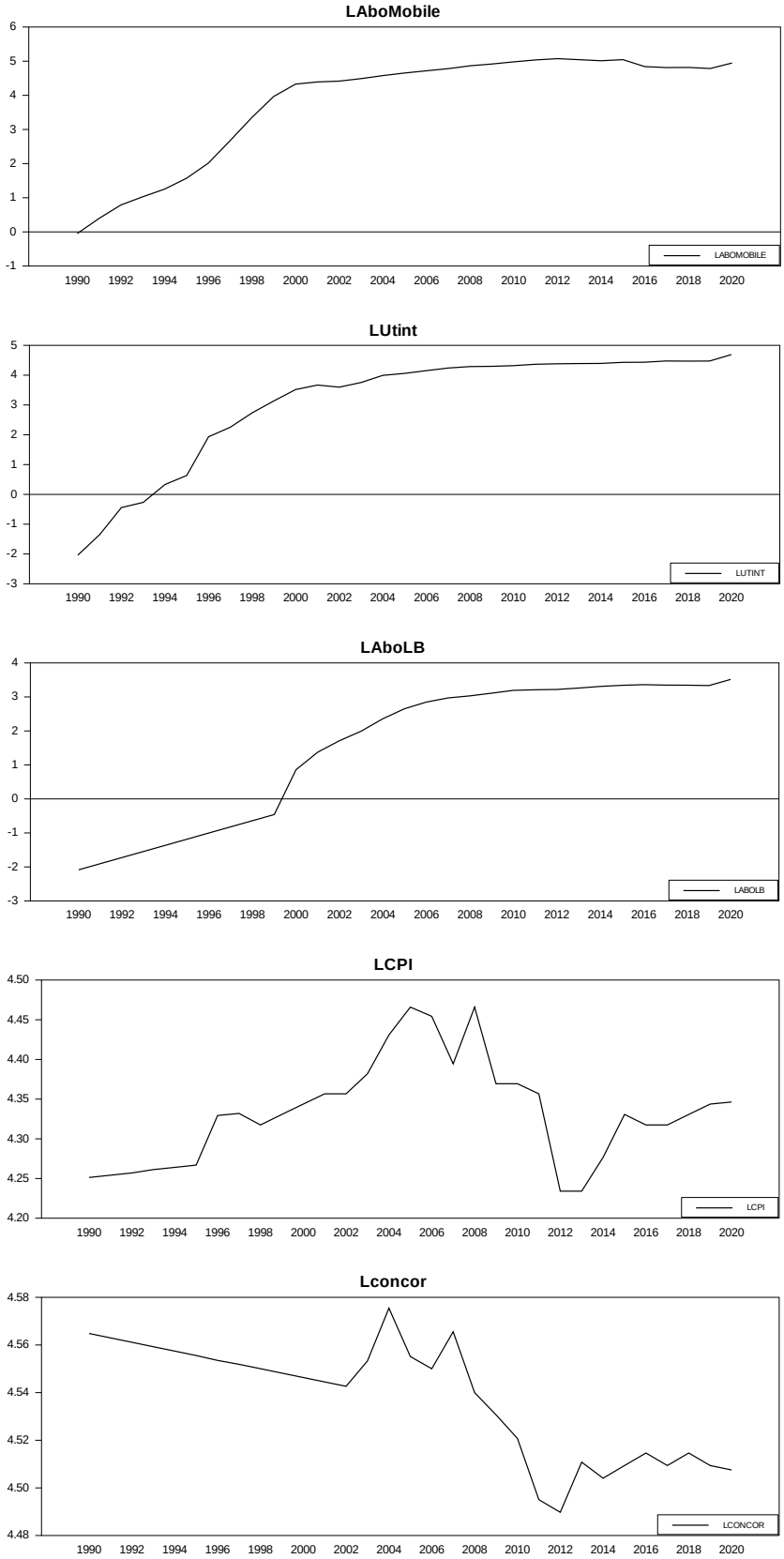

Figure 1. The Behaviour of Different Variables for Developed Countries

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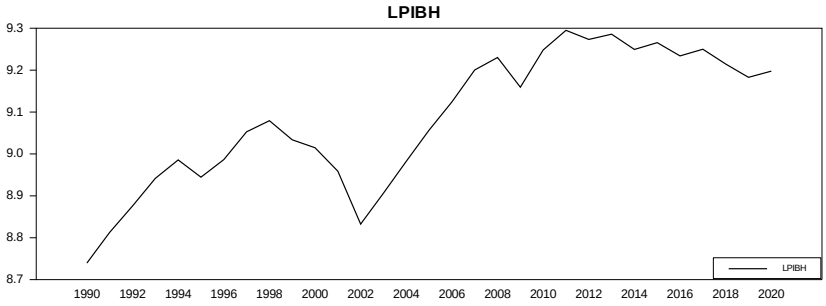

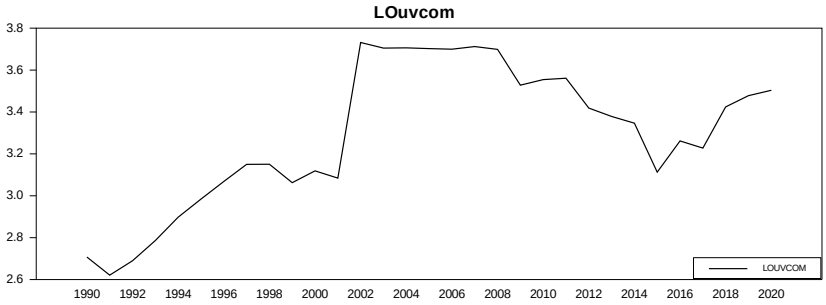

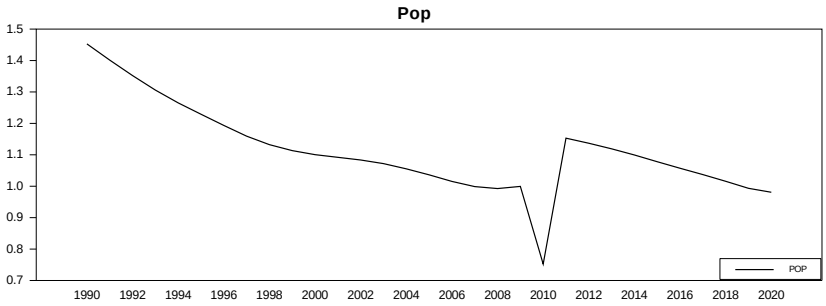

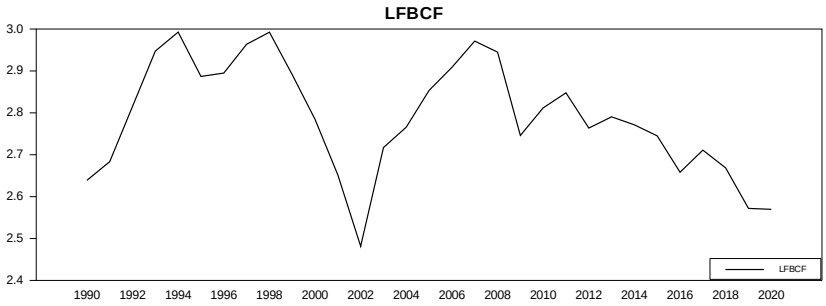

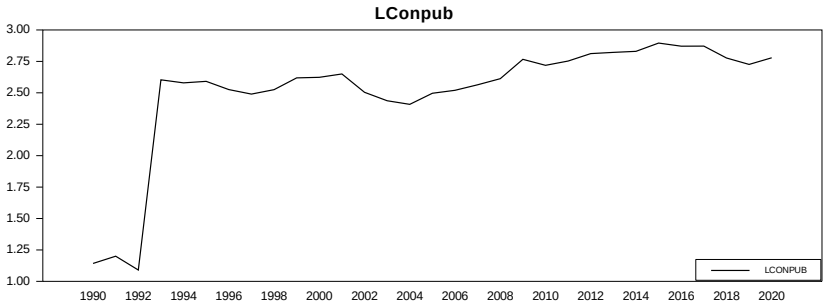

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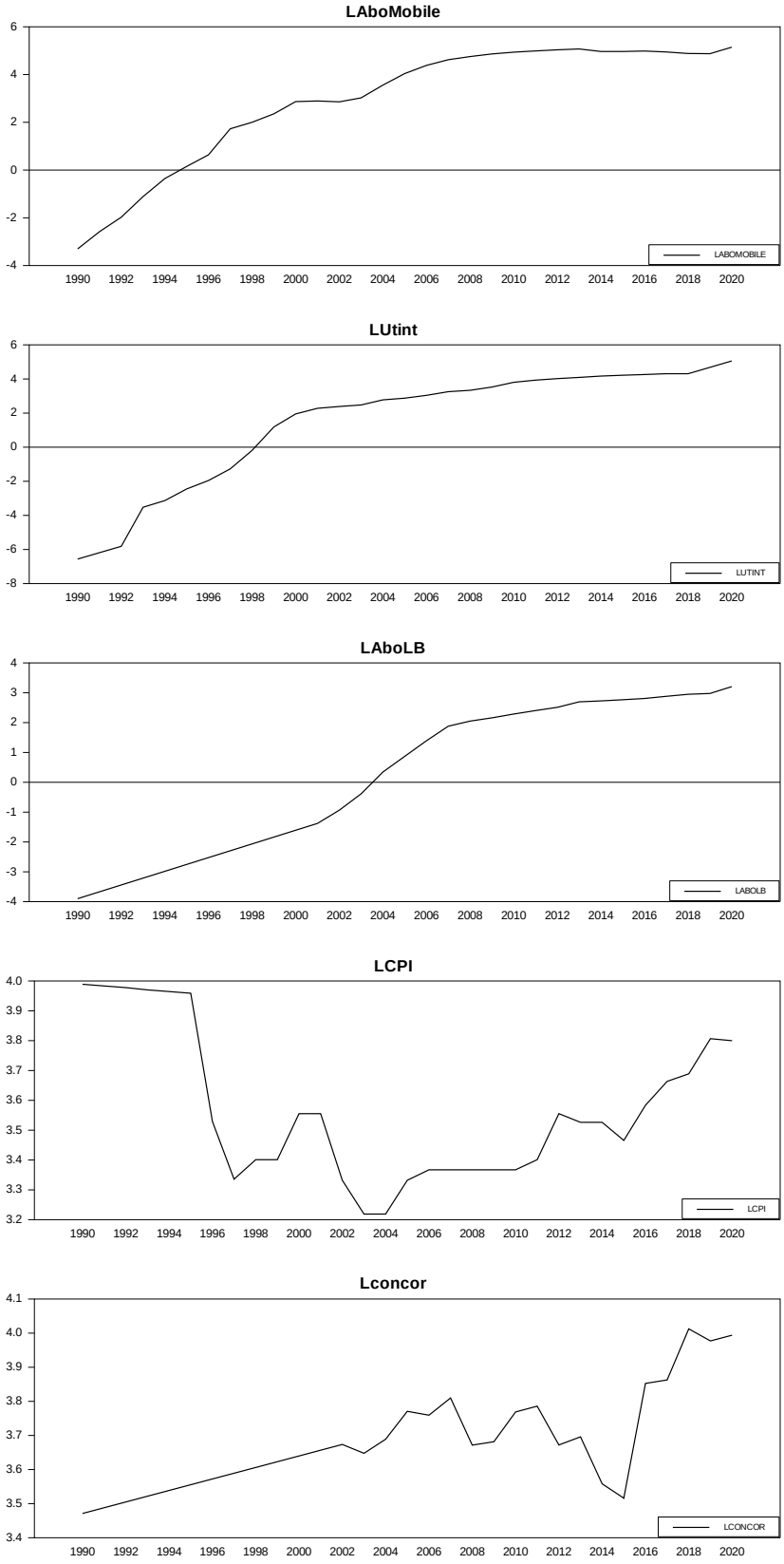

Figure 2. The Behaviour of Different Variables for Developing Countries

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We afterwards study the relationships between different variables for the developed and developing countries over the period 1990-2020. The variance-covariance matrices for the developing (Part 1) and developed (Part 2) countries are reported in Table 2.

Table 2. Variance-Covariance Matrix for Different Variables

Part 1. *Variance-Covariance Matrix for Developed Countries*										
	LGDPH	LOUVCOM	POP	LGFCF	LCONPUB	LABOMO	LUTINT	LABOLB	LCPI	LCONCOR
LGDPH	**0.7160**	0.1433	0.0843	-0.0466	0.0616	0.7970	1.0081	1.1694	0.2083	0.1635
LOUVCOM	0.1433	**0.2461**	0.1668	-0.0203	-0.0096	0.3218	0.4000	0.6107	0.0372	0.0006
POP	0.0843	0.1668	**1.8740**	0.0347	-0.0842	0.0008	-0.1007	-0.0161	0.0371	0.0731
LGFCF	-0.0466	-0.0203	0.0347	**0.0450**	-0.0177	-0.0046	-0.0253	-0.0568	-0.0145	-0.0158
LCONPUB	0.0616	-0.0096	-0.0842	-0.0177	**0.0656**	0.0827	0.1266	0.2031	0.0304	0.0273
LABOMO	0.7970	0.3218	0.0008	-0.0046	0.0827	**4.6252**	5.4492	6.3535	0.1990	-0.0893
LUTINT	1.0081	0.4000	-0.1007	-0.0253	0.1266	5.4492	**7.0316**	8.0078	0.2985	-0.0901
LABOLB	1.1694	0.6107	-0.016	-0.0568	0.2031	6.3535	8.0078	**11.9143**	0.3203	-0.1636
LCPI	0.2083	0.0372	0.0371	-0.0145	0.0304	0.1990	0.2985	0.3203	**0.1187**	0.0777
LCONCOR	0.1635	0.0006	0.0731	-0.0158	0.0273	-0.0893	-0.0901	-0.1636	0.0777	**1.5379**
Part 2. *Variance-Covariance Matrix for Developing Countries*										
	LGDPH	LOUVCOM	POP	LGFCF	LCONPUB	LABOMO	LUTINT	LABOLB	LCPI	LCONCOR
LGDPH	**0.5553**	-0.0523	-0.0669	0.0175	0.04409	0.9724	1.1991	1.3422	0.0545	0.1493
LOUVCOM	-0.0523	**0.2694**	-0.0361	0.0323	-0.0055	0.25104	0.2297	0.1176	0.0102	-0.0490
POP	-0.0669	-0.0361	**0.3749**	0.0153	-0.0114	-0.44512	-0.5529	-0.63053	-0.0055	0.0083
LGFCF	0.01749	0.0323	0.0153	**0.0946**	-0.0060	0.0417	-0.0498	-0.0635	0.0192	0.0888
LCONPUB	0.0441	-0.0055	-0.0114	-0.0060	**0.1058**	0.0707	0.1726	0.1656	0.0305	0.0588
LABOMO	0.9724	0.2510	-0.4451	0.0417	0.0707	**10.6307**	11.2562	11.5047	0.1304	0.3835
LUTINT	1.1991	0.2297	-0.5529	-0.0498	0.1726	11.2562	**14.3724**	13.6584	0.1702	0.341
LABOLB	1.3422	0.1176	-0.6305	-0.0634	0.1656	11.5048	13.6584	**17.0611**	0.1963	0.4187
LCPI	0.0546	0.0102	-0.0055	0.0192	0.0305	0.1304	0.1702	0.1963	**0.0727**	0.1497
LCONCOR	0.1493	-0.0490	0.0083	0.0888	0.0588	0.3835	0.3406	0.4187	0.1497	**1.0460**

The elements on the diagonal refer to the variances of variables, whereas the off-diagonal elements refer to the covariances between different variables for developed (Part 1) and developing (Part 2) countries. Overall, negative and positive relationships between different variables are well documented among developed and developing countries.

We thereafter analyze the issue of stationarity (in level and first difference) of all the variables for the developed and developing countries over the period 1990-2020. To this end, we use the homogeneous unit root test on panel data proposed by Levin, Lin & Chu (2002). Table 3 reports the results obtained from such test.

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Table 3. Results from Unit Root Tests for Panel Data

Results from Levin, Lin & Chu (2002) Test												
	Developed Countries						Developing Countries					
	In Level			In First Difference			In Level			In First Difference		
	Levin-Lin rho-stat	Levin-Lin t-rho-stat	Levin-Lin ADF-stat	Levin-Lin rho-stat	Levin-Lin t-rho-stat	Levin-Lin ADF-stat	Levin-Lin rho-stat	Levin-Lin t-rho-stat	Levin-Lin ADF-stat	Levin-Lin rho-stat	Levin-Lin t-rho-stat	Levin-Lin ADF-stat
LGDPH	2.2511	2.1749	2.6333	-41.965	2.9690	2.4493	3.2839	4.1455	4.2579	-36.4270	2.9923	2.2591
LOUVCOM	0.7794	1.4298	1.6563	-42.7387	2.5667	1.9626	-1.0911	0.3004	0.5002	-47.0663	-0.35124	-0.6848
POP	-3.5822	-0.2737	-0.9137	-45.5018	0.9908	1.5987	0.5008	0.3594	1.1232	-39.4665	0.3630	0.9365
LGFCF	-4.3869	-1.6664	-1.5613	-46.2473	2.1341	2.3705	-4.3614	-1.055	-0.7250	-40.8615	0.7053	0.1647
LCONPUB	-2.7733	0.2804	0.5835	-44.0065	2.3121	2.1391	-2.6405	-0.7469	-0.4735	-41.9551	0.7885	0.1262
LABOMO	-1.2126	-5.6712	-0.3977	-19.8439	3.0714	2.5144	0.2259	-3.0217	0.5697	-19.9522	-2.2687	-2.1619
LUTINT	-1.6992	-6.4585	-1.8438	-22.8651	1.1416	1.3937	0.4621	-2.0316	-0.0032	-32.0896	-8.1799	-6.2408
LABOLB	1.7013	0.4660	1.7558	-26.876	-0.2126	-0.2907	2.5222	1.8560	3.4887	-25.3695	-3.2694	-3.9821
LCPI	-1.9771	-0.1128	-0.0166	-44.6396	2.3457	1.8955	-1.0881	0.6763	0.6630	-48.782	0.3744	0.4151
LCONCOR	-1.1349	0.4549	0.5484	-52.9870	-0.8429	0.3832	-0.6677	0.3442	0.6224	-49.3861	-1.3276	-1.5572

Results from IPS Test				
	Developed Countries		Developing Countries	
	In Level	In First Difference	In Level	In First Difference
LGDPH	2.8411	-3.3117	4.2891	-3.0062
LOUVCOM	0.5405	-2.6820	-1.185	-2.7914
POP	1.1721	-2.7591	-1.4965	-2.5740
LGFCF	4.4714	-3.2482	2.8397	-2.2556
LCONPUB	2.6165	-2.4791	2.7818	-2.0380
LABOMO	-0.4376	-3.1734	1.0212	-2.8366
LUTINT	2.2600	-1.7479	-1.0144	-8.8033
LABOLB	2.0408	-2.2416	4.3471	-5.5041
LCPI	-0.1231	-2.4555	-1.1260	-2.7340
LCONCOR	1.2923	-2.4221	0.7886	-7.0527

From Table 3, we clearly show that all variables for developed and developing countries seem to be non-stationary in level using the homogeneous unit root test on panel data proposed by Levin, Lin & Chu (2002). After a first difference, such variables become stationary, given that the calculated values of the test statistics are less than the critical value of -1.64. Hence, the variables for the developed and developing countries are integrated of order one. Table 3 also reports the results from the IPS (Im, Pesaran & Shin, 2003) test for different variables in terms of level and first difference related to the developed and developing countries over the period 1990-2020.

As shown in Table 3, the exogenous and endogenous variables seem to have unitary roots in levels for both developed and developing countries given that the values of IPS statistics are greater than the critical value of -1.64. After a first difference, all variables become stationary since the values of IPS statistics are less than the critical of value of -1.64. Hence, the different

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variables are integrated of order one. Such findings thus confirm those of the homogeneous unit root test on panel data proposed by Levin, Lin & Chu (2002).

Statistics estimation results and interpretation

From the foregoing, we apply the cointegration analysis approach on panel data in order to analyze the long-term relationship between sustainable development and other variables over the period 1990-2020. In this regard, the error correction model (ECM) is considered as a useful framework for examining the short- and long-term linkages between different variables under study, for both developed and developing countries. Formally, the model is given as follows:

$$Log(GDPH_{it}) = c + \alpha Log(Ouvcom_{it}) + \beta POP_{it} + \chi Log(GFCF_{it}) + \delta Log(CONPUB_{it}) + \varphi Log(ABMobile_{it}) + \phi Log(UTINT_{it}) + \eta Log(ABOLB_{it}) + \lambda Log(CPI_{it}) + \mu Log(CONCOR_{it}) + \varepsilon_{it}$$

where:

- $GDPH_{it}$ is the gross domestic product per capita for the country i at year t;
- $Ouvcom_{it}$ is the degree of economic openness for the country i at year t;
- POP_{it} is the people's growth rate for the country i at year t;
- $GFCF_{it}$ is the gross fixed capital formation for the country i at year t;
- $CONPUB_{it}$ is the public consumption for the country i at year t;
- $ABMobile_{it}$ is the mobile subscription for the country i at year t;
- $UTINT_{it}$ corresponds to individuals using the Internet in percentage of population for the country i at year t;
- $ABOLB_{it}$ is the fixed broadband subscriptions (per 100 people) for the country i at year t;
- CPI_{it} is the consumer price index for the country i at year t;
- $CONCOR_{it}$ is the control of corruption for the country i at year t.

But before estimating the model, we analyze the stationarity of the residuals in the long-term relationship based on seven tests of Pedroni (1995, 1997). The results of these tests are reported in Table 4. Needless to say, Pedroni's seven tests include four tests based on within-dimension and three tests based on between-dimension. Both types[iii] of tests are based on the null hypothesis of no cointegration.[iv] Overall, the results indicate that the residuals of the long-term relationship are stationary in level, given that the seven statistics of Pedroni (1995, 1997) are lower than the critical value of -1.64.

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Table 4. Results of Pedroni (1995, 1997) Tests

	Rho-stat	v-stat	pp-stat	Adf-stat	Rho-stat*	pp-stat*	Adf-stat*
Residuals for developed countries	-3.1764	-2.453	-3.1334	-3.0976	-2.12543	-1.8976	-1.9988
Residuals for developing countries	-2.7853	-2.432	-3.4521	-4.4031	-1.9842	-1.9932	-2.0986

Note: * refers to tests based on 'between' dimension

Based on the aforementioned results, we estimate the long-term relationship between the natural logarithm of gross domestic product per capita and other variables (macroeconomic variables, indicators of the digital economy, and institutional variables) for both developed and developing countries over the period 1990-2020. To this end, we apply the Fully-Modified procedure on annual panel data described in Hansen (1995). The empirical results are reported in Table 5.

Table 5. Estimation Results for Long-Term Relationship based on Fully-Modified Procedure

	Developed Countries		Developing Countries	
	Coefficients	Signification	Coefficients	Signification
LOUVCOM	0.09	8.33	-0.05	-3.73
POP	-0.03	-3.22	-0.10	-1.80
LGFCF	0.26	22.14	0.16	13.64
LCONPUB	-0.01	-4.07	-0.03	-1.78
LABOMO	0.05	3.93	-0.01	-0.12
LUTINT	0.12	3.07	0.01	2.45
LABOLB	0.53	24.16	0.04	18.53
LCPI	-0.11	-3.86	0.09	5.23
LCONCOR	-0.17	-3.34	-0.03	-3.36

From Table 5, the estimation of the long-term relationship based on the Fully-Modified technique provides significant results for most explanatory variables for developed countries. The ratio of the sum of exports and imports to the Gross Domestic Product for each country (Ouvcom) has a significant and positive effect on the Gross Domestic Product per capita. However, the people's growth rate (Pop) seems to negatively and significantly affect sustainable economic development. The Gross Capital Formation (GFCF) has a positive and significant effect on sustainable development. Nevertheless, the three indicators related to the global digital economy —mobile phone subscriptions (per 100 people) (AbMobile); individuals using the Internet (% of population) (Utint); and the fixed broadband subscriptions (per 100 people) (AboLb) — tend to positively and significantly affect sustainable economic development, indicating the relevance of the digital economy in boosting economic development by creating more jobs and enhancing people's wellbeing. The negative effects of

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the inflation rate and the control of corruption on the Gross Domestic Product per capita seem to be well documented.

The estimation results seem to be quite different for developing countries. Indeed, the estimation of the long-term relationship based on the Fully-Modified technique gives significant results for explanatory variables, expect for the Gross Capital Formation (GFCF). Unlike the developed countries, the ratio of the sum of exports and imports to the Gross Domestic Product for each country (Ouvcom) significantly and negatively influences sustainable development. But, like the developed countries, the people's growth rate (Pop) has a negative and significant impact on sustainable development. The indicators related to the digital economy have a slight effect on economic development. Therefore, the digital economy sector has no participation in the economic development for developing countries. As well, the control of corruption and the consumer price index slightly influence economic development.

We thereafter analyze the linear fit of the long-term relationship between variables within the error correction model (ECM) based on the Fully-Modified technique. The estimation results from the ECM are presented in Table 6.

$$\Delta Log(GDPH_{it}) = \alpha + \beta_1 \Delta Log(Ouvcom_{it}) + \beta_2 \Delta POP_{it} + \beta_3 \Delta Log(GFCF_{it}) + \beta_4 \Delta Log(CONPUB_{it}) + \beta_5 \Delta Log(ABMobile_{it}) + \beta_6 \Delta Log(UTINT_{it}) + \beta_7 \Delta Log(ABOLB_{it}) + \beta_8 \Delta Log(CPI_{it}) + \beta_9 Log(CONCOR_{it}) \rho \varepsilon_{it-1} + \nu_{it}$$

Recall that the Error Correction Model encompasses the short-run equilibrium, where the variables are stationary in first difference, and the long-run equilibrium, where residuals of the long-run relationship are stationary in level based on unit root tests. The adjustment of this long-term relationship is caused by the negative and significant coefficient of residuals delayed by a single period.

Table 6. Estimation Results for ECM based on Fully-Modified Procedure

	Developed Countries		Developing Countries	
	Coefficients	**Signification**	**Coefficients**	**Signification**
Intercept	0.1525	0.0000	0.0841	0.000003
Δ LOUVCOM	0.0556	0.0001	-0.0343	0.0138
Δ POP	2.2112	0.9737	0.0025	0.1957
Δ LGFCF	0.1283	0.0000	0.1064	0.0000
Δ LCONPUB	-1.2675	0.3331	0.0245	0.0422
Δ LABOMO	9.7512	0.0236	0.0021	0.5781
Δ LUTINT	1.7961	0.5743	-0.0087	0.0000
Δ LABOLB	5.1666	0.0191	0.0077	0.0308
Δ LCPI	-0.0100	0.3164	0.0226	0.2203

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	Developed Countries		Developing Countries	
	Coefficients	**Signification**	**Coefficients**	**Signification**
Δ LCONCOR	-8.7676	0.1193	0.0013	0.5602
$Residuals_{it-1}$	**-0.0136**	**0.0000**	**-0.0078**	**0.0005**

From Table 6, the estimation results clearly show that most variables are significant for developed countries, except for the people's growth rate (Pop), the governments' current spending for the purchases of goods and services (Conpub), and individuals using the Internet (% of population) (Utint). Overall, the digital economy sector seems to exert a remarkable short-term influence on the gross domestic product per capita for the developed countries. As well, this sector appears to affect economic development in developing countries. As expected, the results clearly display that the ECM offers significant short-term coefficients with a negative and significant adjustment speed.

In the literature on the estimation of dynamic models using panel data, it is worth noting that a series of techniques, such as the methods proposed by Anderson & Hsiao (1982) and Arellano & Bond (1991), can be increasingly used. Although the Anderson & Hsiao (1982) method provides convergent estimators, it suffers from some shortcomings (e.g., it does not take into account the error structure). This is why it is interesting to use the Arellano & Bond (1991) method, which calls for instrumental variables to more explore the dynamic long-term relationship between variables. We also add the lagged gross domestic product per capita in the following model:

$$Log(GDPH_{it}) = \rho Log(GDPH_{it-1}) + \alpha Log(Ouvcom_{it}) + \beta POP_{it} + \chi Log(GBCF_{it}) + \delta Log(CONPUB_{it}) + \phi Log(ABMobile_{it}) + \varphi Log(UTINT_{it}) + \eta Log(ABOLB_{it}) + \lambda Log(CPI_{it}) + \mu Log(CONCOR_{it}) + \alpha_i + e_t + \varepsilon_{it}$$

where:

- $GDPH_{it}$ is the gross domestic product per capita for the country i at year t;
- $Ouvcom_{it}$ is the degree of economic openness for the country i at year t;
- POP_{it} is the people's growth rate for the country i at year t;
- $GFCF_{it}$ is the gross fixed capital formation for the country i at year t;
- $CONPUB_{it}$ is the public consumption for the country i at year t;
- $ABMobile_{it}$ is the mobile subscription for the country i at year t;
- $UTINT_{it}$ corresponds to individuals using the Internet in percentage of population for the country i at year t;
- $ABMobile_{it}$ is the mobile subscription for the country i at year t;
- CPI_{it} is the consumer price index for the country i at year t;
- $CONCOR_{it}$ is the control of corruption for the country i at year t.

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In the aforementioned model, α_i and e_t represent the specific and temporal effects. Using a lagged dependent variable does not allow us to employ standard econometric techniques. Indeed, the model estimation based on classical methods (OLS and Within) leads to biased and non-convergent estimators. That is why one might apply the generalized moments method on dynamic panel data, which can control the specific individual and temporal effects and overcome the endogeneity bias of explanatory variables. Overall, the model is presented as follows:

$$\begin{aligned}\Delta Log(GDPH_{it}) = {} & \theta \Delta Log(GDPH_{it-1}) + \beta_1 \Delta Log(Ouvcom_{it}) + \beta_2 \Delta POP_{it} + \beta_3 \Delta Log(GBCF_{it}) \\ & + \beta_4 \Delta Log(CONPUB_{it}) + \beta_5 \Delta Log(ABMobile_{it}) + \beta_6 \Delta Log(UTINT_{it}) \\ & + \beta_7 \Delta Log(ABOLB_{it}) + \beta_8 \Delta Log(CPI_{it}) + \beta_9 \Delta Log(CONCOR_{it}) + \Delta e_t + \Delta \varepsilon_{it}\end{aligned}$$

where:

- $GDPH_{it}$ is the gross domestic product per capita for the country i at year t;
- $Ouvcom_{it}$ is the degree of economic openness for the country i at year t;
- POP_{it} is the people's growth rate for the country i at year t;
- $GFCF_{it}$ is the gross fixed capital formation for the country i at year t;
- $CONPUB_{it}$ is the public consumption for the country i at year t;
- $ABMobile_{it}$ is the mobile subscription for the country i at year t;
- $UTINT_{it}$ corresponds to individuals using the Internet in percentage of population for the country i at year t;
- $ABOLB_{it}$ is the fixed broadband subscriptions (per 100 people) for the country i at year t;
- CPI_{it} is the consumer price index for the country i at year t;
- $CONCOR_{it}$ is the control of corruption for the country i at year t.

The estimation results for developed and developing countries over the period 1990-2020 based the two-step procedure of Arrelano & Bond (1991) are presented Table 7.

Table 7. Estimation Results based on the Method of Arrelano & Bond (1991)

	Developed Countries		Developing Countries	
	First Step Coefficients	Second Step Coefficients	First Step Coefficients	Second Step Coefficients
Intercept	-8.6392	2.9706**	-0.4397	-0.0097
$LPIBH_{it-1}$	0.0247	1.0869*	-0.9730*	-0.9966*
$LOUVCOM_{it}$	4.0499	-0.0902***	-0.0367	0.0023
POP_{it}	-0.00000038	0.000000102	-0.0529**	-0.0151*
$LGFCF_{it}$	-4.3967	-0.3339**	0.1055**	0.0224***
$LCONPUB_{it}$	5.1684	-0.0122	-0.1462	-0.0193**
$LABOMO_{it}$	-0.0835	-0.1254	0.0139	0.0020
$LUTINT_{it}$	0.0958	0.1100	-0.0136	0.0111

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	Developed Countries		Developing Countries	
	First Step	Second Step	First Step	Second Step
	Coefficients	Coefficients	Coefficients	Coefficients
$LABOLB_{it}$	-0.1869	-0.0032	-0.0044	-0.0091
$LCPI_{it}$	0.0333	0.2051	0.0109	0.0210
$LCONCOR_{it}$	0.1256	-0.7011***	0.2483**	-0.0163
Over-identification Test				
Sargon	1.7138×10^{-9}	53204.0271	15.8103	339.1426
Signification of Sargon	1.0000	0.0000	0.9203	0.0000
Test of Absence of Residual Autocorrelation				
m2	0.8889	0.1519	0.6854	0.1789
LB = Q	1398.040 (0.0000)	7.175 (1.0000)	659.918 (0.0000)	2.907 (1.0000)

Notes: -*, ** and *** denote significant level at 1%, 5% and 10%, respectively;
- LB refers to LJUNG-BOX error autocorrelation statistic in level.
- The values in parentheses correspond to the probability of rejecting the null hypothesis.

From Table 7, estimating the dynamic long-term relationship between economic development and other variables provides insightful results for both developed and developing countries using the two-step procedure of Arrelano & Bond (1991). Most notably, the lagged value of the endogenous variable has a positive (respectively, negative) and significant effect on the economic development of developed (respectively, developing) countries under the second step of the procedure of Arrelano & Bond (1991). The other explanatory variables seem not to have a significant effect on economic development under the single step of the same procedure for different countries. In particular, the three indicators related to the digital economy sector have no effect on economic development for different countries. The instrumental variables seem not to be effective, given that the Sargon statistic is not significant and such variables are under-identified. Also, there is a two-order autocorrelation problem, given the LJUNG-BOX statistic.

Conclusion

Interestingly enough, the question of how digitalization exerts an important influence on economic growth in both developed and developing countries is still open. Cognizant of this fact, we attempt to examine the effect of digitalization on sustainable economic growth for the most and the least developed countries in the long and short term. The main reason for using two different groups of countries is to get some insights on if the effect of digitalization relies on the level of the economy's development. We perform a quantitative, empirical analysis on a panel of 28 developed and 27 developing countries from 1990 to 2020. At the empirical level, we apply cointegration analysis and the generalized moments method on panel data. The empirical results clearly show that the digital technologies seem to be significantly and positively associated with economic growth in both groups of countries. The digitalization

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impact level differs across countries. The effects of Internet users, cellular mobile phone subscriptions and fixed broadband subscriptions tend to be lower for the developing countries than developed countries. The short- and long-term dynamics of such relationships are well documented.

Our findings seem to confirm those of other researchers (e.g., Myovella, Karacuka & Haucap, 2019; Pradhan, Mallik & Bagchi, 2018), which show that digitalization positively contributes to economic growth, dependent on a country's development level. At the practical level, policymakers in developing countries should pay particular attention by developing a specific policy approach for the co-development of digital-technology infrastructure and economic prosperity in such countries. Developing countries should also undertake adequate actions to receive gains from the positive role of digitalization in boosting sustainable economic growth by enhancing human capital and adopting sound government policies in all sectors of the economy.

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Endnotes

[i] We initially opted for capital services as a proxy for tangible investments. However, using this variable leads to a serious multicollinearity issue and the linear goodness of fit of the model appeared to be poor. That is why we replace this variable by Gross fixed capital formation (GFCF) to quantify tangible investments. As a matter of fact, Myovella, Karacuka & Haucap (2019), among others, use Gross fixed capital formation as a proxy of tangible investments.

[ii] The choice of variables is substantially related to the availability of the data, especially for the developing countries. It was challenging to provide detailed data for some of the indicators related to digitalization infrastructure for developing countries. Needless to say, it is interesting to consider a balanced panel in order to estimate the econometric model. Nonetheless, further studies can include variables related to digitalization infrastructure by choosing other sets of countries. As well, using a dummy variable to analyze the evolution of ICT usage is very interesting. But, in our case, the purpose is to analyze the degree of digitalization using a comparative approach.

[iii] For tests based on Between dimension, the alternative hypothesis is $\rho_i = \rho < 1 \ \forall$ i, while for tests based on Within dimension, the alternative hypothesis is $\rho_i < 1 \ \forall$ i.

[iv] The estimated results under the alternative hypothesis, $\hat{\varepsilon}_{it} = \rho_i \hat{\varepsilon}_{it-1} + \eta_{it}$, indicate that the autoregressive coefficients are stable over time.