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Digital Leaders vs. Digital Followers: Convergence Theory

Testing in Digital Transformation 1990-2019

Marinko Škare*

Juraj Dobrila University of Pula, Faculty of Economics and Tourism
Preradovićeve 1/1, Pula, 52100, Croatia

**corresponding author*

mskare@unipu.hr

<https://orcid.org/0000-0001-6426-3692>

Małgorzata Porada-Rochon´

University of Szczecin, Faculty of Economics, Finance and
Management, ul. Cukrowa 8, Szczecin, 71-004, Poland

malgorzata.rochon@wp.pl

<https://orcid.org/0000-0002-3082-5682>

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ABSTRACT

Digital innovation (digitalization) is the leading factor of growth in the 21st century on the micro and macro level. Digital leading companies will soon drive 50%+ of the gross domestic product worldwide. The dynamics of digital convergence still need full explanation. In this study, we test for convergence in 129 countries from 1990 to 2019. We identify several convergence clubs by log t convergence test. Digital innovation (digitalization in general) is following a diversified transitional path across economies. Club convergence testing enables us to identify digital leaders vs. digital followers. Our results imply that by studying digital leaders' economies, we can estimate digital leadership's main determinants and sources. As drivers, we identify favorable financing conditions, a flexible legal framework for patent and licensing government subsidies for research and development connected innovations. Here, we provide empirical data needed to explore a new and unexplored field of digital convergence. To understand digitalization through digital innovation (firms' transition to digital business models) first, we need to capture quantitative knowledge to understand and explain the process of digital innovation.

KEYWORDS

Convergence, Digital adoption, Digital transformation, Innovation, Ranking

JEL CODES

O32, O33

OBJECTIVE & METHODOLOGY

The research objective is to identify digital leaders' economies from a sample of 129 countries from 1990 to 2019. By testing convergence of Digital Innovation in those countries, we identify several convergence clubs by log t convergence test.

RESULTS

The results identify digital leadership's main determinants and sources, favorable financing conditions, a flexible legal framework for patent and licensing government subsidies for research and development connected innovations.

LIMITATIONS

The study did not investigate digital transformation sources and determinants in deep focusing on digital transformation convergence.

PRACTICAL IMPLICATIONS

Worldwide digital transformation ranking gives policymakers quantitative knowledge on how a specific economy is doing on the digital transformation path and the implications for the country's economic growth. Policymakers may reconsider and reshape their growth models accordingly to the rankings. This will bring quantitative knowledge on where to seek digital leaders and followers and how the digital transformation map changes for practitioners. They perhaps seek the best digital environment, micro and macro policy, and practice in digital leader countries.

1. INTRODUCTION

Digital transformation through digital innovation is a necessary but not sufficient condition for economic growth. Data on digital innovation as a driver of competitiveness and value-added creation are impressive. Digital firms will, by 2023, produce about 55 trillion US\$, according to (Gens et al., 2019). In 2018, digital firms accounted for 13.5 trillion US\$. USA, Singapore, Sweden, Hong Kong, Switzerland, Korea, Norway, Finland, Taiwan, and Canada are the top ten digital leaders in 2020 (Bris & Christos, 2020). Factors driving digital transformation include customer experience, existing product/service improvement, new product/service design/creation, new market penetration, technology adoption, increased (cost) efficiency, supporting partners institutions (mature digital companies), staff re-skilling (Flexera, 2020), (Kane et al., 2019a).

Digital leadership is a novel term still in search of proper identification. For digital leaders, making an impact is a mixture of personal knowledge and team or group effort (Kane et al., 2019b). Leaders cope with new tools daily, and they decide according to the data they have access to (Cortellazzo et al., 2019). To advance their innovation efforts, digitally mature companies rely on inter-functional teams (Kane et al., 2019a). Digital leaders act on three levels: a) encouraging the members of the organization to consolidate knowledge from their activities; b) consolidate and share knowledge within the team or group to develop a deeper understanding; and c) share knowledge between the members of the organization, but also bring in external knowledge (Zupancic et al., 2016). Study of analysis how the characteristics of companies associated with management characteristics promote digital technology in Portuguese companies. More democratic leadership styles, higher levels of coherence towards the firm's mission, and higher efficacy of the strategic management processes are relevant conditions (Porfírio et al., 2021). Transition to digital leadership requires

a digital project team as a critical analysis unit, and that the composition, formation, and dynamics of the team are distinguished positively from negative experiences in the field of digital transformation (Guinan et al., 2019).

Motivation for this study is linked to the gap in the literature on understanding digital leaders and followers. The concept should be studying at a behavioral (personal), firm(micro), and economy(macro) level to understand and define the above concepts. Here we use the top-bottom approach to study digital leaders (leadership). By leading digital economies' identification, using nonlinear time-varying factor convergence testing, we provide a sample for testing and identifying digital leaders' patterns at micro and personal level data.

Our study is a novel work in digital convergence since it provides empirical results to support the convergence hypothesis in digital transformation. To this end, we use data from (The Conference Board, 2021). Data includes the growth of capital services provided by ICT assets, the contribution of capital services provided by ICT assets to GDP growth share of ICT capital compensation in GDP. Studying digital convergence allows us to identify leading digital economies. That is the top-bottom approach for digital leadership research we develop here. Our premise is that we should first identify digital leaders on a macro-scale (country convergence clubs). From the macro level, we can study digital leaders' attributes on the firm and individual levels. The Paper's primary research objective is to identify digital leaders' economies from a sample of 129 countries from 1990 to 2019. Acquired quantitative knowledge on macro digital leaders gives us the possibility to study firms' and individuals' digital skills in a digital leader environment. Since the digital leader (leadership) concept remains ambiguous, it is crucial to identify digital leader environments (countries) as a first step to the profound experience of digital leadership.

Digital transformation driving digital leadership on a country level shows a clear, distinct pattern across countries. Differences in digital convergence mirror the digital frontier gap by industries worldwide. Countries ranked in the same convergence club share the same digital frontier gap across industries, and digital solid leader companies share in the economy. Such a condition is easy to observe in Scandinavian countries dominating the top ten digital frontier economies. They also share a similar level of digital maturity and digital readiness in industries. Among the main determinants of the country (macro) digital leadership, we cite: a) speed of technology adoption, b) digital infrastructure and regulatory framework, c) users' and business' openness to digital technology use, d) government digital technology strategies, e) macroeconomic environment and human capital stock, f) subsidy scheme and flexible financing conditions for digital technology adoption.

This study reinforces the knowledge of digital convergence by using a modern panel club convergence and clustering process developed by (Phillips, 2007; Phillips & Sul, 2007; Phillips & Sul, 2009). This approach overcomes bias (stationarity, linearity) and constraints on research on convergence in digitalization.

The remainder of the article is structured as follows: Digital leaders and followers, theoretical background, and review are discussed in the next section. In section three, the most we present the methodological framework of the study. Section four analyses the results of the digital convergence testing. The overall results are discussed in the following section, and the main conclusions are summarized and presented in the conclusion section.

2. LITERATURE REVIEW

A systematic review of digital leaders and leadership literature shows the concept itself is in the early epistemological phase. In

this chapter, we review the existent literature related to digital leadership. Research on digital leaders and leadership starts with studies on leadership in the digitalized world (Cortellazzo et al., 2019). For any company, regardless of size or sector, digital transformation is an inherent decision. The authors' review showed no compelling coherent theory that bridges the gap between leadership and digital transformation and underscores the importance of theoretical contributions. How people lead in digital, text-based environments is explored in the study (Darcis, 2020). In their study, (Ruel et al., 2020) develop a theoretical framework for examining the role of leadership and organizational learning in developing digital business strategies within organizations to contribute to our understanding of how digital business strategies emerge.

A path to digital leadership is complex and multidimensional. It demands multiple strategic and operational practices that are strongly associated with the success of digital efforts. The path to digital transformations leads through real-time digital learning (Tulowitzki & Gerick, 2020), shared customers insight at digital speed, digital talent deployment (agility), resource reallocation flexibility, cultural shift (Bughin et al., 2019a). Digital learning is emerging as a future growth factor in knowledge-based industries and the skilled labor market. A clear transition from training to the "learning culture" is possible and feasible through strategically planned digital learning, learning, and development interventions benefiting businesses, employees, customers, and society as a whole (Hiremath et al., 2021). Building a digital environment requires special digital project teams. A study by (Guinan et al., 2019) shows that the digital project team is a critical analysis unit and that the composition, formation, and dynamics of the team distinguish positive from negative experiences of digital transformation. Cross-functional teams are an integral part of digitally mature organizations' innovation

efforts. Businesses that take the time to understand this risk and prepare for it will be better positioned (Kane et al., 2019b). Digital leaders must communicate strategic objectives so that front-line and middle managers can make sound operational decisions and have sufficient time and opportunity to experiment with new ways of leading in a digital environment (Kane et al., 2019a), (Li et al., 2016), (Belitski & Liversage, 2019), (Dery et al., 2017).

Given the rising prevalence of digital transformation, there is an essential need to develop digital leadership skills. The study deals with six critical elements of digital leadership: impact, media, design-oriented research, integration, digital areas, and leadership itself (Zupancic et al., 2016). Digital transformation in firms is closely connected to organizational learning and transformational leadership (Do & Mai, 2020). The study of (Pham & Hoang, 2019) examines the detailed dimensions of organizational learning capacity in terms of business performance and finds management's commitment to learning as the most critical factor in business performance. Leadership characteristics and skills in industry 4.0 are studies in (Guzmán et al., 2020). This study aimed to establish a connection between the characteristics of leadership 4.0 and specific leadership skills using a theoretical framework. According to this association, the primary skills that could make the most significant contribution to the context of Industry 4.0 are divided into three categories: cognitive skills, interpersonal skills, and strategic skills. Digital leadership is becoming a crucial issue in most advanced digital fields, such as cybersecurity (Lehto & Limnell, 2021). Strategic leadership in cybersecurity post on three strategic objectives: international cooperation, improved coordination of cybersecurity management, planning and preparedness, and the development of cybersecurity competence (Mitra & O'Regan, 2020).

Management in firms faces significant challenges in the digital transformation era. Digital education leaders refer to

teachers integrating digital technologies in the educational process (Bocconi et al., 2020), (Passey, 2014). In (Avidov-Ungar et al., 2020), nearly half of digital leaders described their role as local, in line with the framework for Islands of Innovation. Research of (Blau & Shamir-Inbal, 2017) underscores the critical features of the view of ICT integration as a multi-faceted process that takes place over time and requires a critical body of school staff to become an intrinsic part of school culture. The chief digital role has become increasingly crucial through digital innovation, data analytics, and customer engagement in a time of digital transformation (Tumbas et al., 2017), (Roepke, 2019), (Kunisch et al., 2020), (Kratzer et al., 2019).

Studies on digital leaders on micro, mezzo, and macro-level lack in the primary literature. The difficulty in formulating a clear and universal digital leader definition is attributed to the lack of empirical research. Digital transformation, digital platforms, digital channels, digital leadership, chief digital officers, digital learning. Qualitative patterns and characteristics of digital leaders and leadership on a theoretical ground are widely explored. We are missing quantitative knowledge (empirical link) between qualitative patterns and characteristics already identified in the literature. Our study tries to bridge the gap in the literature, providing needed empirical knowledge as a start on the macro level. We provide empirical ranking on digital leaders' economies to answer the question: Who are digital leaders, and how do we recognize them? Moreover, what about digital followers? Can we identify them as well?

The solution proposed here is based on the top-down mechanism. We must first learn who global digital leaders are, provide empirical data on ranking and isolate general characteristics and patterns of digital leaders. Continuing on the same line, we can use the same approach on the micro and mezzo level to finally identify and define digital leaders in the literature.

3. DATA AND METHOD

The rationale and theoretical foundation for using the growth of capital services provided by ICT assets (change in the natural log) as indicators of digitalization are that we want to assess digital convergence globally. Not only are the data supporting this point scarce, but they are also circumstantial, so using globally comparable indicators is essential.

Digital convergence is measured for 129 countries, including ex-transitional economies, using data on companies and households, total investments, and spending on ICT assets.

Apart from outcomes, it is essential to examine indicators of digital transformation such as extensions per employee, network lines per employee, innovation software use, companies size, knowledge-intensive sectors, security software use, current account, and country presence in high-technology sectors. The use of aggregate (ICT) measures to assess changes and trends in technology adoption is likely to obscure the breakdown of various forms and bundles of (ICT) use over time. Given that future production is expected to be driven by the convergence of different types of hardware, software, and (ICT) services, our understanding of technology must be based not only on aggregate investment totals but also on disaggregated measures of digital technology at the micro-level (DeStefano et al., 2017). These benchmarks provide information about a country's current digital transformation, but they cannot be used to forecast future events or to determine a country's level of digitalization in future perspectives. However, they can serve as 'time trials' on the country's potential future digital path.

The key term here is convergence. Measuring convergence in (ICT) assets growth, contribution, and share (in the GDP) resulting from convergence in particular types of hardware, software, and (ICT) services drives future digital transformation and production. A higher convergence rate in digital products and

services reflects the country's digital environment, policy, and digital adoption. Thus, countries with a high digital convergence rate have a competitive and advanced digital environment supported by efficient digital policy (policymakers), resulting in a high digital adoption rate. High convergence means high digital transformation, increasingly high digital adoption, and finally, it awards the status of digital leaders of followers to countries.

We can define digital leaders' countries as achieving a high convergence rate in digital products and services (ICT assets), resulting in digital technology adoption acceleration and high ICT capital share in the GDP.

For digital leader's identification, the starting point is to test for the convergence in the sample of 129 countries with data from 1990 to 2019. To test for convergence in digital products and services, we use data on (ICT) assets;

- (ICT1) = growth of capital services provided by (ICT) assets, change in the natural log (in %),
- (ICT2) = contribution of capital services provided by (ICT) assets to GDP growth (in %),
- (ICT3) = share of (ICT) capital compensation in GDP (in %).

For a detailed description of (ICT) capital assets and services sources and methodology, see (The Conference Board, 2021).

To test for digital convergence, this study follows (Phillips, 2007; Phillips & Sul, 2007; Phillips & Sul, 2009) taking the form

$$\log ICT = \delta \log ICT_t + e, \quad (1)$$

with $\log ICT^o$ as the growth of capital services provided by ICT assets, change in the natural log, contribution of capital services

provided by ICT assets to GDP growth, the share of ICT capital compensation in GDP. The common ICT trend across countries equals $\log ICT_t^o$ and e as idiosyncratic technology cycle component.

Testing the null hypothesis of no digital convergence assume

$$\log \frac{H_1}{H_t} - 2\log(\log t) = a + \gamma \log t + u_t, \text{ for } t = T_0, \dots, T \quad (2)$$

with transition distance $H_t = N^{-1} \sum_{i=1}^N (h-1)^2$, $h = \log y / N^{-1} \sum_{i=1}^N \log y_i$ as defined in (Phillips, 2007; Phillips & Sul, 2007; Phillips & Sul, 2009).

We are proceeding with the model above; we group countries in initial convergence clubs (ICT) digital indicators. To form final convergence clubs, we test for club merging, ruining the t -test for all pairs of initial convergence clubs. Finally, we check for cross-sectional means across convergence clubs using relative transition parameters (plotting relative transition curves across clubs). Plots of relative transition parameters across clubs display a trend of convergence or divergence in the and between clubs. Data entering t -test are pre-filtered using (Hodrick & Prescott, 1997) of the form

$$\text{Min}_{\{g_t\}_{t=1}^T} \left\{ \sum_{t=1}^T c_t^2 + \lambda \sum_{t=1}^T \left[(g_t - g_{t-1}) - (g_{t-1} - g_{t-2}) \right]^2 \right\}$$

Possible bias in the smoothing parameter (annual data) is adjusted, as discussed in (Hamilton, 2018).

Table 1 presents the statistical properties of the data series in the sample.

The following section provides results on convergence testing on (ICT) indicators (ICT1, ICT2, ICT3) to identify convergence clubs.

To identify digital leaders and followers, we construct a summary index using the standardized inverse-covariance weighted average of indicators (Anderson, 2008), (Schwab et

Table 1. Statistical Properties of the Sample (Data Series)

Variable	Obs	Mean	Std.Dev.	Min	Max
ICT1	3870	18.19	14.96	-32.02	426.28
ICT2	3870	0.54	0.57	-4.59	7.27
ICT3	3870	2.94	2.1	0.01	17.59

Source: Own Research

al., 2020). The digital transformation rankings by countries we construct for 2019 are provided in Table A4 in the appendix.

4. RESULTS

Digital competitiveness globally shows a distinct convergence pattern. We observe top digitally competitive countries like the USA, Singapore, Denmark, Sweden, Hong Kong, Switzerland, Netherlands, Korea, Norway, Finland, Taiwan, Canada, United Kingdom. Less digitally developed economies follow Ukraine, Argentina, South Africa, Colombia, Mongolia, Venezuela (Figure 1).

The ranking is evident and expected, but it is interesting to observe Scandinavian countries are in the top ten digitally competitive economies. Figure 1 gives us a brief but close glimpse of potential digital leaders in 2020 (data available from authors on request).

Figure 2 present a list of most drivers of digital transformation in firms worldwide in 2020.

Customer experience is the primary driver of digital transformation in companies globally. Improving firms' existing products and services is the second, followed by new products/services development. We can observe demand-driven (customers' wants and needs) digital transformation through customer experience and customer satisfaction for existing products and services. Technology pushed digital transformation (supply push) drivers like new products and services design and innovation,

developing new markets, and technological advancement is the second most crucial group of determinants. Management policy, including increasing efficiency/cost savings, human capital re-skilling, and partnership improvement as the final group of determinants.

In summary, digital transformation is still significantly customers (demand) driven. Supply (innovation, technology) driven digital transformation is catching (converging) but still lagging. Management policy as a digital transformation determinant remains significant but not crucial for digital change.

We can observe a significant digital transformation gap across industries worldwide in 2018 (Figure 3). Digital maturity is higher in retailing and traveling industries, reaching the 50% digital frontier threshold. The automotive and telecommunications industries are following with the average industry digital maturity of 24.1%. A sure convergence in digital maturity is visible, but the relative transition path across industries is sluggish. In the latest report, a shift toward pharmaceutical, medical products, and the healthcare industry is observable through the Covid-19 pandemic crisis.

Figure 4 presents nominal GDP driven by digitally transformed and other enterprises worldwide from 2018 to 2023 (in trillion U.S. dollars). We can observe significant convergence in nominal GDP created by digitally transformed companies and other firms. The convergence is clear and visible, which represents the power of digital transformation.

To identify the digital leaders globally, we test for digital convergence using the method described in the previous section. Digital convergence is a result of a digital transformation across industries, sectors, firms, households, and markets driven by customers' experience, new markets discovery, current products/services upgrading, improved business/management policy, new products/services innovation and development, technological

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Ranking

23.99 100.00

Source: Adaptation from (Bris & Christos, 2020).

advancement, human capital life-long education and supply chains transformation.

Table 2 reports the $\log(t)$ regression coefficient, standard errors, and t-statistic for $\log(t)$ for the whole sample over three (ICT) indicators.

Ranking of simple average growth of Capital Services provided by (ICT) Assets (change in the natural log) provides evidence on digital convergence across countries. Digital frontier economies, such as the USA, Singapore, Denmark, Sweden, Hong Kong, Switzerland, Netherlands, Korea, Norway, Finland, Taiwan, Canada, United Kingdom, achieve long-run, stable growth rates (ICT) assets (**Figure 5**).

Worldwide digital convergence is evident from figure 5. Countries like Zambia, Mozambique, Vietnam, Uzbekistan, Burkina Faso, Sudan, India, Costa Rica, and other developing economies are catching up with digital frontier economies. For economic growth, the convergence dynamics are different. Countries with the highest average growth of (ICT) capital services do not have the highest capital services (ICT) assets contribution to the GDP. While Zambia is ranked first on growth on (ICT) capital assets, it is ranked thirty-six on capital services (ICT) assets contribution to the GDP. Economic growth in countries with rapid digital transformation still misses multiplicative effects from digital transformation, but they aggressively catch up with growth frontier economies. Digital frontier economies soon could become growth frontier economies as well.

Table 2 reports the $\log(t)$ regression coefficient, standard errors, and t-statistic for $\log(t)$. Since the value of the t statistics for (ICT1, ICT2, and ICT3) are smaller than test statistics ($t_{\beta} \leftarrow 1.65$), the null hypothesis of convergence in digital transformation is rejected at the 5% level for the whole sample. Despite (ICT) globalization, institutional associations, and economic

Figure 2. Digital Transformations Drivers Worldwide in 2020

Source: Adaptation from (Flexera, 2020).

Figure 3. Digital Frontier Gap Across Industries in 2018

Source: Adaptation from (Bughin et al., 2019b).

Figure 4. Nominal GDP driven by digitally transformed and other enterprises worldwide 2018-2023

Source: Adaptation from (Gens et al., 2019).

Table 2. Log (t) Convergence Test Results in Competitiveness

Variable	Coeff	Standard error	T-stat
(ICT1)			
log (t)	-1.39	0.13	-10.47*
(ICT2)			
log (t)	-1.02	0.1	-10.51*
(ICT3)			
log (t)	-0.44	0.05	-9.25*

Source: Own Research

growth, we find no evidence to support the hypothesis of digital convergence for the entire sample (129 countries). Digital transformations differ significantly across the countries and groups of countries in the sample.

After rejecting the competitiveness convergence hypothesis for the sample, we identify convergence clubs (set of countries converging in ICT assets). Following initial convergence clubs (set up from the 129 countries), we test for possible club merging to obtain the final convergence club structure (ICT1, ICT2, ICT3).

Using the convergence test modeling, we identify convergence clubs from the sample of 129 countries using (ICT1) as a digital transformation indicator.

Here we list the final identified convergence clubs and countries clustered according to the *log (t)* test results on the (ICT1) indicator (*log t*-test results and clubs merging test results are presented in the appendix-Tables A1-A3).

Convergence club 1: Algeria Angola Argentina Armenia Australia Austria Azerbaijan Bahrain Bangladesh Belarus Belgium Bolivia Bosnia & Herzegovina Botswana Brazil Burkina Faso Cambodia Cameroon Canada Chile China Colombia Costa

Rica Croatia Czech Republic Côte d’Ivoire Denmark Dominican Republic Ecuador Egypt Estonia Finland France Georgia Germany Ghana Guatemala Hong Kong Hungary Iceland India Indonesia Iran Ireland Israel Italy Jamaica Japan Kazakhstan Kenya the Kuwait Kyrgyz Republic Latvia Lebanon Lithuania Luxembourg Macedonia Madagascar Malawi Malaysia Mali Malta Mauritius Mexico Moldova Morocco Mozambique Myanmar the Netherlands New Zealand Niger Norway Pakistan Peru Philippines Poland Portugal Qatar Russian Federation Saudi Arabia Senegal Serbia Singapore Slovenia South Africa South Korea Spain Sri Lanka Sweden Switzerland Taiwan Tajikistan Tanzania Thailand Tunisia Turkey Turkmenistan Uganda Ukraine United Arab Emirates United Kingdom United States Uruguay Uzbekistan Vietnam Zimbabwe

Convergence club 2: Chad Paraguay

Convergence club 3: Rwanda Zambia

Convergence club 4: Greece Romania Libya Oman Syria

Convergence club 5: Albania Gabon

Convergence club 6: Bulgaria Trinidad & Tobago

Convergence club 7: Congo, Republic Ethiopia

Convergence club 8: Jordan Yemen

Convergence club 9: Nigeria Venezuela

Non-convergent group 10: Cyprus Namibia Slovak Republic Sudan

The largest digital convergence club is *convergence club1* listing 106 countries with a converging relative transition path (ICT1). Merging test clubs' results in table A1 supports the club's final listing above. We identify nine different digital convergence clubs and one non-convergent group of countries (digital divergence). Non-convergent countries show different transition paths and are in a different phase of digital transition (transformation) to other countries in the sample.

Figure 5. Average Growth of Capital Services provided by ICT Assets Worldwide 1990-2019

Source: Authors' Calculation on Data from (The Conference Board, 2021).

Digital transformation dynamics (relative transition path in ICT1) differ from the dynamics registered in the transitional path (ICT2). After convergence clubs testing and merging results, we identify seven different convergent clubs and one

non-convergent group using the contribution of capital services provided by (ICT) assets to GDP - (ICT2), see below.

Convergence club 1: Algeria Austria Azerbaijan Bahrain Belgium Bolivia Botswana Burkina Faso Cambodia Croatia Czech

Republic Côte d'Ivoire Denmark Egypt Estonia Finland France Georgia Ghana Iceland India Ireland Israel Italy Kuwait Latvia Lithuania Madagascar Malawi Malta Mauritius Mozambique Netherlands New Zealand Niger Norway Philippines Portugal Rwanda Senegal Serbia Singapore Slovenia South Africa South Korea Spain Sweden Taiwan Tajikistan Thailand Turkmenistan Ukraine United States Uzbekistan Vietnam Zambia

Convergence club 2: Angola Argentina Armenia Australia Bangladesh Belarus Bosnia & Herzegovina Brazil Cameroon Canada Chile China (Alternative) Colombia Costa Rica Cyprus Dominican Republic Ecuador Gabon Germany Greece Guatemala Hong Kong Hungary Indonesia Iran Jamaica Japan Kazakhstan Kenya Kyrgyz Republic Lebanon Libya Luxembourg Macedonia Malaysia Mexico Moldova Morocco Myanmar Namibia Oman Pakistan Paraguay Peru Poland Qatar Romania Russian Federation Saudi Arabia Slovak Republic Sri Lanka Switzerland Tanzania Trinidad & Tobago Tunisia Turkey Uganda United Kingdom Uruguay Zimbabwe

Convergence club 3: Bulgaria Mali

Convergence club 4: Chad Nigeria Syria

Convergence club 5: Albania United Arab Emirates

Convergence club 6: Jordan Yemen

Convergence club 7: Sudan Venezuela

Non-convergent group 8: Congo, Republic Ethiopia

The role of digital transformation (ICT3) in economic growth shows a different world convergence map (share of ICT capital compensation in GDP). After testing, we identified merely three convergence clubs, with club one being the largest. Capital (ICT) compensation corresponds to the value-added of the ICT industry, minus the wage share (labor compensation). (ICT) capital is becoming a dominant factor in economic growth. We observe a strong convergence in (ICT) capital share in the GDP (*club 1*).

The second convergence club lists the group of countries sharing the same transition path in digital transformation. The last convergence club is convergence *club 3*.

Convergence club 1: Algeria Angola Armenia Australia Austria Azerbaijan Bahrain Bangladesh Belarus Belgium Bolivia Bosnia & Herzegovina Botswana Brazil Cambodia Cameroon Canada Congo, Republic Costa Rica Croatia Cyprus Czech Republic Côte d'Ivoire Denmark Ecuador Egypt Estonia Finland France Gabon Georgia Germany Ghana Greece Guatemala Hungary Iceland India Iran Ireland Israel Italy Japan Kazakhstan Kenya Kuwait Kyrgyz Republic Latvia Libya Lithuania Luxembourg Macedonia Madagascar Malawi Malaysia Malta Mauritius Mexico Morocco Mozambique Namibia Netherlands New Zealand Niger Nigeria Norway Oman Peru Poland Portugal Qatar Romania Rwanda Saudi Arabia Senegal Serbia Singapore Slovenia South Africa South Korea Spain Sri Lanka Sudan Sweden Switzerland Syria Taiwan Tajikistan Thailand Trinidad & Tobago Turkey Turkmenistan Ukraine United Kingdom United States Uruguay Uzbekistan Vietnam Zambia Zimbabwe

Convergence club 2: Bulgaria Burkina Faso Chile China Colombia Ethiopia Hong Kong Indonesia Jamaica Lebanon Moldova Philippines Russian Federation Slovak Republic Tanzania Tunisia Uganda

Convergence club 3: Albania Argentina Chad Dominican Republic Jordan Mali Myanmar Pakistan Paraguay United Arab Emirates Venezuela Yemen

5. DISCUSSION

Digital transformation convergence is present worldwide, as this study shows. The convergence in digital transformation varies across growth in (ICT) capital assets, contributing to economic growth and share of (ICT) capital contribution in GDP. Testing

for convergence analysis using three different digital transformation indicators enables identifying the digital leaders and digital followers among different economies.

Investments in (ICT) capital assets are increasing worldwide. Growth of capital services provided by (ICT) assets (change in the natural log), registered annual growth rate from 3.45% (Jordan - rank 129) to 40.39% (Zambia - rank 1) from 1990 to 2019. The growth of capital services provided by (ICT) assets is driven by digital maturity and investments in (ICT) for retailing, traveling industry, automotive, telecommunications, and financial industry. Countries recognize the importance of (ICT) investing, the dynamics of investments depending on financial conditions, economic structure, and the country's growth model. For example, South Africa from 1990 to 2019 registered average annual growth in (ICT) capital assets of 24.73%. We know that when digital transformation takes off from the initial phase during the transition phase, high growth rates for (ICT) capital assets are expected due to a low level in the initial phase. That is the case for Zambia, Mozambique, Vietnam, Uzbekistan, Burkina Faso, Sudan, Costa Rica, Ghana, Egypt, achieving high growth rates in (ICT) capital assets and remaining in lower digital competitiveness country groups. We can observe convergence in (ICT) capital assets' growth worldwide, with nine convergence clubs (one divergent group) grouped according to their dynamic convergence. Divergence club (Cyprus, Namibia, Slovak Republic, Sudan) includes a group of economies decoupling (not converging) in the growth of (ICT) assets compared to the (ICT) growth of other countries in the sample (DeStefano et al., 2017).

Closely connected to the growth of capital services provided by (ICT) assets is the contribution of the (ICT) assets to GDP growth. Testing for convergence in the contribution of capital services provided by (ICT) assets to GDP growth, this study

identifies seven convergence clubs and one divergent group. We can observe two significant convergence clubs (clubs 1 and 2) with economies with a similar relative transition path (ICT) assets contribution to GDP growth. Comparing convergence test results for (ICT1) and (ICT2) shows countries tend to achieve convergence in (ICT) investments. However, many of the countries in the sample do not succeed in transforming positive (ICT) capital stock growth to a more significant contribution of (ICT) assets to economic growth. Thus, convergence clubs for growth in (ICT) assets (ICT1) and its contribution to GDP growth (ICT2) differ in convergence dynamics (difference between ICT1 and ICT convergence clubs). Here, the divergence clubs consist of the Republic of Congo and Ethiopia. They have a different relative transition path (convergence in ICT assets contribution to GDP growth) from the rest of the sample. They are ranked in the bottom sample according to the (ICT) assets contribution to GDP growth (Bris & Christos, 2020) (Gens et al., 2019).

The last convergence indicator for digital transformation is the share of (ICT) capital compensation in GDP (ICT3). Using this indicator, testing for convergence results shows only three convergence clubs and no divergent group of countries. The share of (ICT) capital compensation in GDP is strongly converging worldwide. Evidently, (ICT) capital is becoming an increasingly more critical growth factor on a global level. A robust global convergence on (ICT) capital compensation share in GDP is proof (Kane et al., 2019b).

6. CONCLUSION

In summary, who are the digital leaders and followers of 2019? The World map of digital transformation appears different to 1990. For example, according to the summary index we construct here using the standardized inverse-covariance weighted aver-

age of indicators (ICT1, ICT2, ICT3), Ghana is ranked as number one (most progressive, digitally converging economy), and in 1990, its rank was 49. The summary index we construct in this study supports the strong convergence in digital transformation theory. Countries like Ghana, Rwanda, Azerbaijan, Turkmenistan, Egypt, Zambia, Kuwait, Malawi, and Botswana are in the top ten digital progressives (leaders) in 2019. These are economies registering the highest growth of capital services provided by (ICT) assets, contribution of capital services provided by (ICT) assets to GDP, and share of (ICT) capital compensation in GDP. Advanced, digitally competitive economies today and in 1990 are Singapore, Sweden, and Thailand. Other digitally advanced economies moved from sixteen positions in 1990 to sixty-three in 2019.

The world is digitally converging. Our study is the first to test for digital convergence worldwide and analyze global digital transformation since 1990. Growth frontier economies from the 1960s are losing pace in the 21st-century race on digital transformation. Developing economies are strongly converging with digital leaders since the 1990s. Digital followers are countries like Jordan, Mexico, Peru, Indonesia, Philippines, Ukraine, Argentina, South Africa, Colombia, Mongolia, Venezuela. In this study, constructed summary index using the standardized inverse-covariance weighted average of indicators (ICT1, ICT2, ICT3) supports empirical evidence we get from convergence testing (*log t-tests*) and identifies convergence clubs. This study has also derived digital rankings from the ranking report (Bris & Christos, 2020).

Quantitative knowledge we present here opens the window for future research on digital transformation by focusing on digital changes in top digital leaders as benchmarking. Comparing digital transformation dynamics in digital leaders helps

policymaker and practitioners to identify digital transformation limiting factors – financing conditions (digital bonds), human capital, policy incentives, lack of digitalization strategy, IT infrastructure, and university programs not digitally oriented. Main drivers of digital transformation are policy incentives, IT infrastructure availability, IT university programs offered, narrow IT labor market supply. These are also main limitations in our study since we did not investigate digital transformation sources and determinants in deep focusing on digital transformation convergence. Thus, the main contribution of our study lies in providing a digital transformation map since 1990 identifying digital leaders. Future studies can use as a benchmarking pool to investigate digital transformation determinants in detail and compare digital transformation patterns in country leaders to followers and isolate main determinants driving digital transformation.

Here we provide comprehensive digital leaders and followers ranking for 129 countries using data from 1990 to 2019. A constructed digital transformation ranking in this study contributes to the digital transformation and leadership body of literature. Policymakers using data from our study digital transformation ranking can get deep insight into the world digital transformation since 1990. A worldwide digital transformation ranking gives policymakers quantitative knowledge on how a specific economy is doing on the digital transformation path and the implications for the country's economic growth. Policymakers may reconsider and reshape their growth models accordingly to the rankings. For practitioners, this will bring quantitative knowledge on where to seek digital leaders and followers and how the digital transformation map changes. They may seek the best digital environment, micro and macro policy, and practice in digital leader countries. Thus, they will advise

policymakers on the regulatory and institutional framework they need to enhance digital leadership and transformation in their businesses.

The empirical analysis in this study needs corroborative research on the firm (micro) level study. Future studies should

examine more deeply on digital transformation determinants to provide a comprehensive definition of digital leaders and leadership. Here we seek a contribution to digital transformation by encouraging new studies and methods on digital transformation measurement and rankings.

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APPENDIX

Table A1. Growth of Capital Services provided by ICT Assets, change in the natural log Convergence Club Classification (NEER)

Initial	Tests of club merging γ^* (T-stat of γ^*)		Final
Club1 [104]	-0.104 (-1.08)		Club 1[106] -0.129 (-1.27)
Club2 [2]	5.017 (1.86)	Club 1+2	Club2 [2] 2.349 (0.984)
Club3 [2]	2.349 (0.98)	Club 2+3*	Club3 [2] -1.123 (-0.44)
Club4 [2]	-1.123 (-0.44)	Club 3+4*	Club4 [5] -1.033 (-1.35)
Club5 [2]	1.669 (0.82)	Club 4+5*	Club5 [2] -3.523 (-1.35)
Club6 [3]	-1.572 (-1.30)	Club 5+6	Club6 [2] -0.874 (-0.45)
Club7 [2]	-3.523 (-1.35)	Club 6+7*	Club7 [2] -0.427 (-0.41)
Club8 [2]	-0.874 (-0.45)	Club 7+8*	Club8 [2] -0.356 (-0.23)
Club9 [2]	-0.427 (-0.41)	Club 8+9*	Club9 [2] -2.909 (-1.63)
Club10 [2]	-0.356 (-0.23)	Club 9+10*	
Club11 [2]	-2.909 (-1.63)	Club 10+11*	
Non Conv. [4]	-6.342 (-6.25)		Club 11+g12* Non-conv. [4] -6.342 (-6.52)

Source: Own Research

Notes: **Reject the null hypothesis of growth convergence at the 5% level. The number in brackets indicates the number of countries in identified convergence group.

Table A2. Contribution of Capital Services provided by ICT Assets to GDP growth

Initial		Tests of club merging $\gamma^{\wedge}$ (T-stat of $\gamma^{\wedge}$)		Final	
Club1 [49]	-0.14 (-1.4)			Club 1[56]	-0.12 (-1.3)
Club2 [4]	1.660 (2.62)	Club 1+2		Club2 [60]	-0.16 (-1.0)
Club3 [3]	1.118 (1.79)	Club 2+3		Club3 [2]	-0.22 (-0.3)
Club4 [25]	1.252 (9.68)	Club 3+4		Club4 [3]	-3.23 (-0.9)
Club5 [10]	1.473 (1.15)	Club 4+5		Club5 [2]	-1.34 (-0.6)
Club6 [2]	5.865 (2.34)	Club 5+6		Club6 [2]	0.10 (0.08)
Club7 [14]	0.441 (0.46)	Club 6+7		Club7 [2]	-0.14 (-0.2)
Club8 [9]	0.405 (1.02)	Club 7+8			
Club9 [2]	-0.22 (-0.3)	Club 8+9			
Club10 [3]	-3.23 (-0.9)	Club 9+10*			
Club11 [2]	-1.43 (-0.6)	Club 10+11*			
Club12 [2]	0.107 (0.08)	Club 11+12*			
Club13 [3]	-0.14 (-0.2)	Club 12+13*			
Non Conv. [4]	-1.60 (-2.9)			Club 13+g14*	Non- Conv. [2]
					-1.6 (-2.9)

Source: Own Research

Notes: **Reject the null hypothesis of growth convergence at the 5% level. The number in brackets indicates the number of countries in identified convergence group.

Table A3. Share of ICT Capital Compensation in GDP

Initial		Tests of club merging γ^A (T-stat of γ^A)		Final	
Club 1 [97]	-0.023 (-0.905)			Club 1 [100]	-0.034 (-1.631)
Club 2 [3]	3.263 (4.475)	Club 1+2 -0.0343 (-1.6310)		Club 2 [17]	0.648 (5.542)
Club 3 [17]	0.648 (5.542)	Club 2+3 -0.5928 (4.3846)		Club 3 [12]	0.354 (2.706)
Club 4 [12]	0.354 (2.706)		Club 3+4 -0.4332 (-9.1499)		

Source: Own Research

Notes: **Reject the null hypothesis of growth convergence at the 5% level. The number in brackets indicates the number of countries in identified convergence group.

Table A4. Digital Leaders and Followers by Country Worldwide 2019 (Summary Index

Rankings)

Country/Index					
1. Ghana	2.277	25. New Zealand	0.286	49. Norway	-0.071
2. Rwanda	1.941	26. Austria	0.233	50. Croatia	-0.122
3. Azerbaijan	1.717	27. Saudi Arabia	0.231	51. Belarus	-0.147
4. Turkmenistan	1.704	28. Israel	0.229	52. Algeria	-0.162
5. Egypt	1.684	29. Switzerland	0.227	53. Namibia	-0.175

Country/Index

6. Zambia	1.68	30. United States	0.192	54. South Korea	-0.178
7. Kuwait	1.472	31. Malaysia	0.184	55. Zimbabwe	-0.214
8. Malawi	1.259	32. Georgia	0.145	56. Cote d'Ivoire	-0.215
9. Botswana	1.032	33. Bahrain	0.132	57. Portugal	-0.246
10. Singapore	0.965	34. Ireland	0.131	58. Costa Rica	-0.253
11. Bolivia	0.963	35. Cambodia	0.102	59. Vietnam	-0.263
12. Sweden	0.908	36. Trinidad & Tobago	0.102	60. Brazil	-0.268
13. Mozambique	0.868	37. Estonia	0.096	61. Latvia	-0.275
14. Thailand	0.588	38. Serbia	0.092	62. United Kingdom	-0.288
15. Mauritius	0.541	39. Belgium	0.089	63. Finland	-0.298
16. Czech Republic	0.453	40. Iceland	0.076	64. Slovenia	-0.31
17. Lithuania	0.444	41. Armenia	0.052	65. Gabon	-0.335
18. Madagascar	0.435	42. Denmark	0.045	66. Canada	-0.357
19. Taiwan	0.422	43. Burkina Faso	0.032	67. Luxembourg	-0.359
20. Netherlands	0.421	44. India	0.028	68. Cameroon	-0.366
21. France	0.378	45. Hungary	0.023	69. Iran	-0.369
22. Uzbekistan	0.373	46. Spain	-0.002	70. Colombia	-0.374
23. Malta	0.371	47. Niger	-0.01	71. Italy	-0.375
24. Senegal	0.308	48. Japan	-0.014	72. Poland	-0.389

Country/Index					
73. Morocco	-0.397	100. Greece	-0.761	127. Congo, Republic	-1.966
74. South Africa	-0.404	101. Tanzania	-0.781	128. Venezuela	-2.338
75. Australia	-0.407	102. Cyprus	-0.782	129. Yemen	-2.592
76. Bosnia & Herzegovina	-0.416	103. Mexico	-0.785		
77. Macedonia	-0.425	104. Ecuador	-0.787		
78. Tajikistan	-0.466	105. Tunisia	-0.791		
79. Bangladesh	-0.467	106. Slovak Republic	-0.803		
80. Angola	-0.477	107. Mali	-0.847		
81. Indonesia	-0.483	108. Jamaica	-0.905		
82. Romania	-0.485	109. Paraguay	-0.915		
83. Guatemala	-0.488	110. Libya	-0.921		
84. Ukraine	-0.504	111. Russian Federation	-0.949		
85. Uruguay	-0.538	112. Uganda	-0.957		
86. Kenya	-0.543	113. Peru	-0.978		
87. Turkey	-0.545	114. Sudan	-1.052		
88. Kyrgyz Republic	-0.56	115. Bulgaria	-1.068		
89. Lebanon	-0.561	116. Myanmar	-1.116		
90. Oman	-0.57	117. Chile	-1.134		
91. China	-0.577	118. Nigeria	-1.151		
92. Moldova	-0.637	119. Chad	-1.16		

Country/Index			
93. Philippines	-0.658	120. Pakistan	-1.163
94. Germany	-0.664	121. Argentina	-1.315
95. Kazakhstan	-0.679	122. Syria	-1.47
96. Qatar	-0.689	123. Ethiopia	-1.5
97. Sri Lanka	-0.699	124. United Arab Emirates	-1.573
98. Dominican Republic	-0.745	125. Albania	-1.653
99. Hong Kong	-0.746	126. Jordan	-1.955

Source: Own Research