Using a digitization index to measure the economic and social impact of digital agendas

Raul Katz, Pantelis Koutroumpis and Fernando Martin Callorda

Raul Katz is based at Columbia Business School, Columbia University, New York, NY, USA. Pantelis Koutroumpis is based at Innovation and Entrepreneurship Group, Imperial College Business School, London, UK. Fernando Martin Callorda is based at the Center of Technology and Society, Universidad de San Andres, Buenos Aires, Argentina. All three are affiliated with Telecom Advisory Services LLC.

Abstract

Purpose – *The purpose of this paper is to measure the cumulative, holistic impact of discrete information and communication technologies. It also provides a glimpse of applications and service adoption, which complements more traditional perspectives such as technology penetration. This approach is utilized to measure achievements in implementing a policy such as Europe's Digital Agenda.*

Design/methodology/approach – *Measuring digitization should cover the transition to digitally intensive societies across multiple sets of metrics, capturing not only technology penetration, but also its use in order to understand the full impact of digitization. For this purpose, a composite index was developed based on six overarching components: affordability, infrastructure investment, network access, capacity, usage, and human capital.*

Findings – *These concepts were utilized to assess Europe's performance in terms of its digitization. Significant gaps were highlighted both in terms of its uneven development, but also in terms of lags in the areas of infrastructure investment and digital technology usage. The economic payback to be generated by pro-actively addressing these gaps promises to be significant.*

Practical implications – *From a policy standpoint, the paper raises an interesting hypothesis to be explored in the European context: while the implementation of the Digital Agenda could be tackled in an overarching continental manner, particularities in each member country digitalization might raise the need for a more differentiated approach. In particular, European countries at the transitional stage should emphasize the creation of necessary incentives to accelerate investment in telecommunications networks. Additionally, demand promotion strategies focused on digital literacy and content development appear to be a critical lever to enhancing digitization. On the other hand, the policy challenges for the advanced countries appear to cluster around investment in infrastructure and the development of human capital.*

Originality/value – *Previous attempts to measure the impact of ICT have focused primarily on measuring and assessing the economic effects of widespread access to either wireless or broadband technology. This approach puts additional emphasis on two dimensions: cumulative impact of information and communication technologies and usage.*

Keywords *Economic development, European Union, Development, Communication technologies, Government policy, Broadband networks*

Paper type *Research paper*

Introduction

Digitization is the process of converting analog information into a digital format. In a broader societal context, digitization is defined as the economic and social transformation triggered by the massive adoption of digital technologies to generate, process, share and transact information. Digitization builds on the evolution of network access technologies, semiconductor technologies, and software engineering. It leverages the spillover effects resulting from their use (common platforms for application development, e-government services, e-commerce, social networks, and availability of online information).

Received 1 October 2013
Revised 1 October 2013
Accepted 18 October 2013

The explosive growth of ICT is confronting policy makers with three challenges. First, there is a lack of standard performance indicators to measure the extent to which ICT is being assimilated in societies. During most of the sector's development, ICT stakeholders focused primarily on access, building telecommunications networks, and devised metrics accordingly. In a world of near ubiquity in terms of access, policy makers need a new way to look at the ICT sector. The second challenge is the lack of tools to measure the impact that the mass adoption of connected digital technologies and applications are having on their societies and economies. The third challenge for policy makers is to adopt new policy approaches to accelerate digitization and reap its derived benefits. Over the past two decades, policy makers established rules to enhance access to communication services-setting policies to introduce competition and promote infrastructure sharing, for example. Now, they need to gain a similar understanding of the ways in which they can encourage adoption and boost usage of digital applications by consumers, businesses, and public institutions.

Previous attempts to measure the impact of ICT have focused primarily on measuring and assessing the economic effects of widespread access to either wireless (Jensen, 2007; Muto, 2008; Klonner and Nolen, 2010; Batzilis *et al.*, 2010; Gruber and Koutroumpis, 2011) or broadband (Crandall *et al.*, 2007; Thompson and Garbacz, 2008; Koutroumpis, 2009; Qiang and Rossotto, 2009; Katz *et al.*, 2010) technologies. From a conceptual standpoint, digitization puts additional emphasis on two dimensions: cumulative impact of information and communication technologies and usage. The cumulative, holistic analysis recognizes that impact of discrete technologies cannot be conducted in isolation given that their adoption and usage is highly complementary. Secondly, the study of usage of the telecommunications and IT infrastructure provides a glimpse of applications and service adoption, which complements more traditional perspectives such as technology penetration.

From a metrics standpoint, most indices that measure progress towards this new era have until recently focused on metrics such as wireless telephony penetration, access to the internet and broadband adoption. We argue that these indices, even those that are more comprehensive in scope (Network Readiness Index by the World Economic Forum, or the Digital Opportunity Index by the International telecommunication Union) capture only a portion of the ongoing transformations. In particular, the transition to digitally intensive societies is associated not only with technology adoption, but also with the use of these technologies (e.g. new applications and services).

In the past two years, research has been conducted to develop an index aimed at measuring the development of digitization in a given country (see Katz *et al.*, 2013a, Katz and Koutroumpis, 2013b, Friedrich *et al.*, 2011, Holbling *et al.*, 2011, Sabbagh *et al.*, 2012). One of the most important applications of this index is to track progress achieved by a given country or region in terms of its digitization path. Additionally, the index can serve to measure the impact of pro-digitization policies[1]. Along these lines, the purpose of this paper is to rely on the digitization index to determine the progress achieved by Europe in the implementation of its Digital Agenda. The paper begins by briefly restating the approach to measure digitization. It follows then by presenting the state of digitization in Europe, both in the aggregate and at the country level. The assessment sets the context to stipulate key elements of future digitization policies.

The digitization index

To achieve a significant impact, digitization has to be widely diffused within the economic and social fabric of a given nation. For this to happen, it has to be adopted at three levels: utilized by individuals, economic enterprises and societies, embedded in processes of production of goods and services, and relied upon to deliver public services. For this condition to occur, digitization has to fulfill several conditions. It has to be affordable to allow scalable impact. In addition, it has to be ubiquitous (reaching most population of a national territory), and accessible by multiple fixed and mobile voice and data devices. Finally, it needs to be reliable, providing sufficient capacity to deliver vast amounts of information at speeds that do not hinder their effective use.

Measuring digitization should cover the transition to digitally intensive societies across multiple sets of metrics, capturing not only technology penetration, but also its use in order to understand the full impact of digitization. For this purpose, a composite index was developed based on six overarching components: affordability, infrastructure investment, network access, capacity, usage, and human capital. These components encompassed 24 sub-indicators (see Table I).

The index is built on six equally weighted components that constitute a developmental path towards a digital society. The first step in this process is identified by the capability to gain some access to a network. ''Network Access'' includes coverage and penetration metrics in two equally weighted subcomponents. Insufficient coverage and rudimentary network reach are often impediments to the digitization process.

Beyond access other technical characteristics are also crucial in this process. The reliability of the infrastructure plays an important role and is proxied by the investment per subscriber on an annual basis. Well-maintained and continuously expanding networks help businesses and individuals to access high quality services and linking them to the rest of the country and

Table I Indicators, and sub-indicators of the digitization index

Indicators	*Components*	*Sub-components*
Affordability	Residential fixed line cost adjusted for GDP per capita	Residential fixed line tariff (three minute call to a fixed line at peak rate) adjusted for GDP per capita
		Residential fixed line connection fee adjusted for GDP per capita
	Mobile cellular cost adjusted for GDP per capita	Mobile cellular prepaid tariff (one minute call off-net at peak rate) adjusted for GDP/capita
		Mobile cellular prepaid one-time connection fee adjusted for GDP per capita
	Fixed broadband internet access cost adjusted for GDP per capita	Monthly residential price for a fixed broadband connection
Infrastructure reliability	Investment per telecom subscriber (mobile, broadband and fixed)	Mobile investment per telecom subscriber
		Broadband investment per telecom subscriber
		Fixed line investment per telecom subscriber
Network access	Network penetration	Fixed broadband penetration per household
		Mobile phone penetration
	Other penetration metrics and coverage infrastructure	3G/4G penetration
		Mobile broadband penetration
		PC population penetration
		Mobile cellular network coverage
Capacity	International internet bandwidth	International internet bandwidth (kbps/user)
	Broadband speed	Broadband speed (Peak Mbps, Average Mbps)
Usage	Internet retail	Internet retail as percent of total retail
	e-Government	UN web measure index
	Individuals using the internet	Percentage of individuals using the internet
	Non-voice services as percent of wireless ARPU	Non-voice (data, message, VAS) spending as percentage of wireless ARPU
	Social network visitors	Dominant social network unique visitors per month per capita
	SMS usage	SMS usage per subscriber
Human capital	Engineers	Engineers as a percentage of total population
	Skilled labor	Labor force with more than a secondary education as a percentage of the total labor force

Source: Adapted from Sabbagh *et al.*, 2012

region. On top of quality the final speed achieved by each user is also important for a digitized nation. The level of services that can be offered over a slow connection is significantly circumscribed *vis-à-vis* modern technology capabilities.

Even the best networks have little or no meaning if they are not reasonably priced. Affordability is a crucial social inclusion criterion and has to be linked to the local economic conditions of each country and region. Engaging with the technology is the next step through the Usage component. Social networks, e-Gov applications, mobile data usage and internet retail activity are some of the metrics capturing this ever-expanding process. The human capital component is another key proxy for the impact of digitization. Countries with highly educated and skilled staff can easily adapt to the changes and use the new tools to catch up with the leaders or overtake regional counterparts.

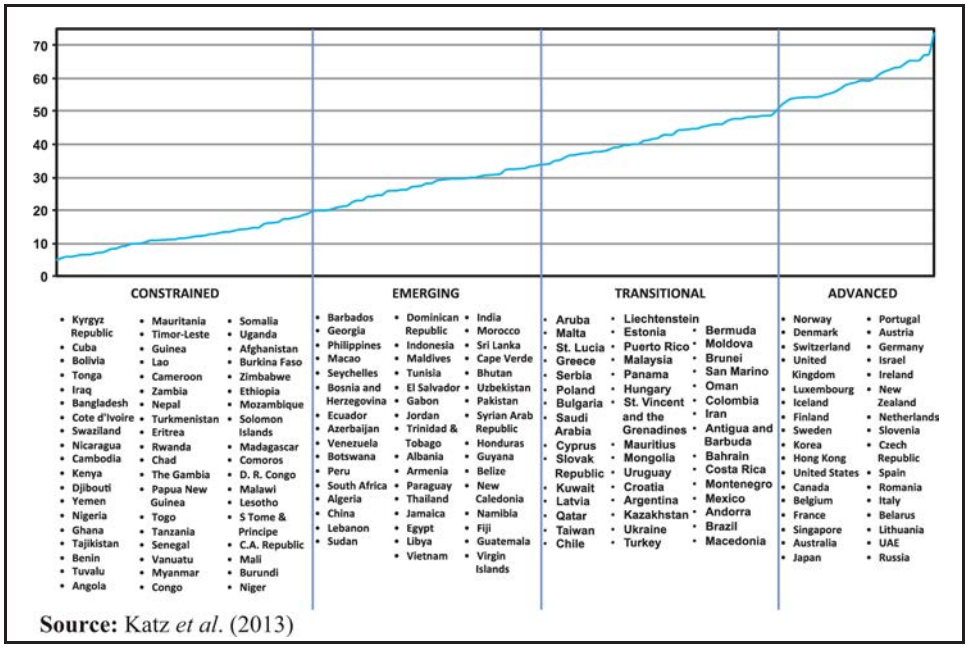
Once completed, the 2011 the Index was calculated for 184 countries throughout the period of 2004-2011. This examination led to the identification of four clusters:

1. *Advanced* (Index > 50).
2. *Transitional* (Index > 35 & < 50).
3. *Emerging* (Index > 20 & < 35).
4. *Constrained* (Index < 20) (see Figure 1).

Beyond the assessment of digitization development paths, the examination tracked the evolution of digitization over time for selected countries. To do so, a time series displaying the digitization evolution for selected countries between 1995 and 2011 was constructed. The examination of the index's evolution attempted to determine idiosyncratic country paths to digitization. This assessment found that emerging countries undergo quantum leap changes in digitization triggered by key policy initiatives. Mature countries, on the other hand, exhibit a consistent, yet gradual, change in digitization performance. An analysis of changes in the index attempted to identify specific events or policies that triggered changes at specific points in time.

Most industrialized countries consistently increased their digitization levels over the course of the fifteen years studied, albeit at different rates. For instance, in 1997 – before the dot com bubble – the US was leading the way, and it is now gradually making its way to the top

Figure 1 Four clusters of digitization (2011)



Source: Katz *et al.* (2013)

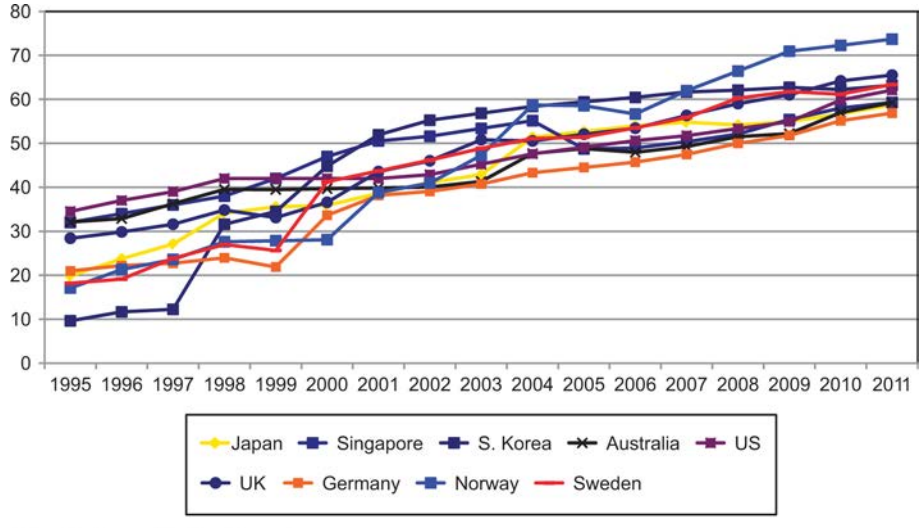
of the charts again. In comparison, the Scandinavian countries have significantly changed their digitization development paths. Norway and Sweden have leapfrogged as a result of systematic adoption and the timely launch of network access, skills, and services. In terms of the Asian countries, Korea experienced the same leapfrogging in the late 1990 s, largely due to the government intervention to encourage 100 percent broadband coverage, while Japan has experienced a slower digitization growth rate. Germany has managed to keep its pace during this period but never made any significant step forward contrary to the rest of the leaders' cluster. The UK maintained a strong position throughout the last two decades ending up in the second place in 2011 (see Figure 2).

Meanwhile, when looking at the emerging countries, specific public policies dictate divergent digitization development paths (see Figure 3).

Brazil, for instance, leapfrogged in 1999 following privatization and liberalization. The privatization of Telebras in 1998 immediately triggered an improvement in the deployment of telecommunications infrastructure, which resulted in a jump in digitization levels. On the other hand, the country's income redistribution policies put in place by the Lula and Rouseff administrations since 2003 led to an increase in adoption of broadband and wireless communications, which drove a dramatic increase in digitization after 2005. In a similar vein, China's digitization levels consistently improved beginning in the late 1990 s as a result of infrastructure deployment plans across all telecommunications technologies, combined with an increase in living standards. On the other hand, while India experienced a sustained rise in digitization since 2002, its improvement has been relatively slow and the country continues to lag behind most emerging countries. One could attribute this effect to limits in the policies put in place to enhance the performance of the telecommunications sector (for example, excessive fragmentation in the allocation of wireless spectrum).

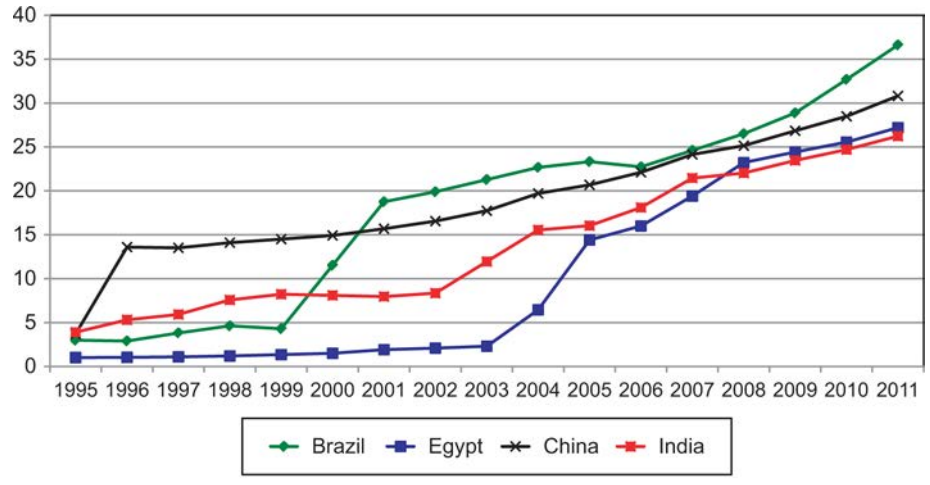
In sum, the data indicate that different development paths could result in increased digitization. More mature countries tend to follow a gradual progression toward digitization, although active government intervention can accelerate development, as seen in the cases of Korea and Norway. Specific policy initiatives can trigger quantum leap changes (25 points in five years) in digitization in some emerging countries. These policies may include liberalization of the telecommunications market, which can have a spillover impact on the ICT eco-system, or centralized state planning. A combination of active government involvement and private sector participation has also yielded an increase in digitization.

Figure 2 Digitization index for selected industrialized countries (1995-2011)



Source: Compiled by the authors

Figure 3 Digitization index for selected emerging countries (1995-2011)



Source: Compiled by the authors

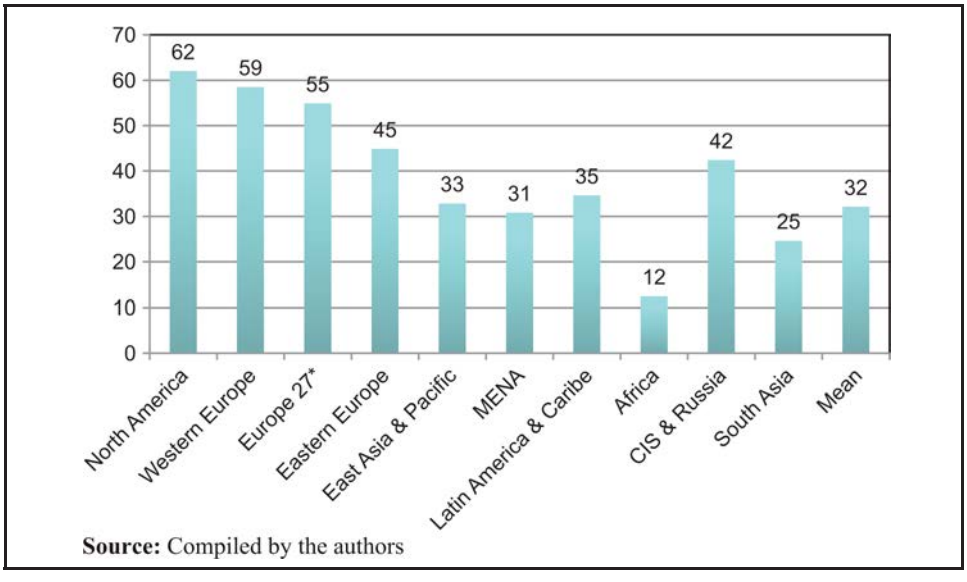
The state of digitization in Europe

A more in-depth look at the 27 European countries[2] found that they were, in aggregate, at an advanced digitization stage behind only North America (see Figure 4).

As indicated in Figure 4, Western Europe (comprising 20 countries) exhibits an average digitization index of 59, with the highest index pertaining to Norway (72) and the lowest to Greece (48). The calculation of Europe 27 (excluding Malta for lack of information but including the eastern European countries) brings down the index to 55. These scores, jointly with North America, are far ahead of the remaining regions of the world, revealing the disparity in digitization development.

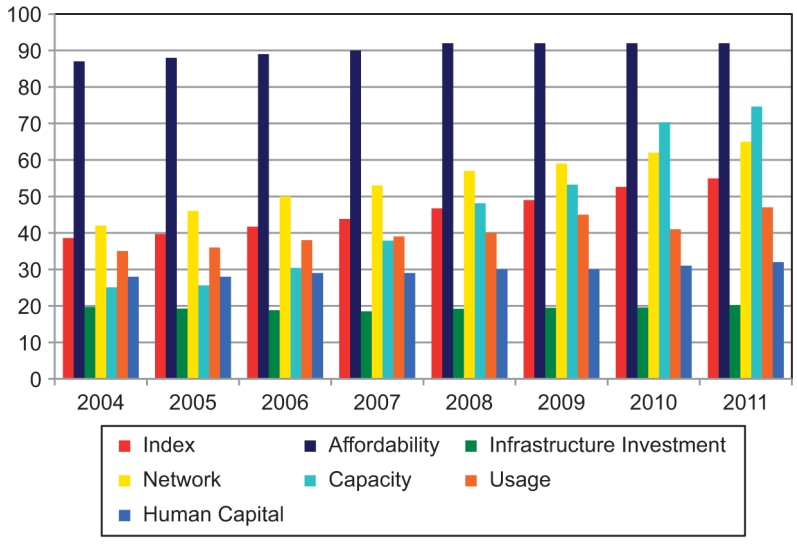
Beyond their advanced levels of digitization, the Europe 27 countries have made significant progress in terms of its specific digitization components over the course of the eight years between 2004 and 2011 (see Figure 5).

Figure 4 Digitization by regions (2011)



Source: Compiled by the authors

Figure 5 Europe 27: digitization index (2004-2011)



Source: Compiled by the authors

While the overall digitization index for Europe 27 increased at a compound annual growth rate of 5.16 percent since 2004, the highest rate of advancement at the sub-component level has been capacity (16.84 percent CAGR), which measures both international internet bandwidth and broadband speeds offered to users. This increase dwarfs growth in network access (6.44 percent CAGR), measuring fixed and mobile broadband penetration, as well as PCs, and usage (4.30 percent CAGR), covering adoption of the internet, eCommerce, eGovernment, and social networks. Interestingly enough, two sub-indicators have not grown at all after 2004: affordability (0.80 percent CAGR) and infrastructure reliability (CAGR: 0.38 percent). The interpretation of these results helps start understanding and confirming some assumptions about how digitization is proceeding in Western Europe.

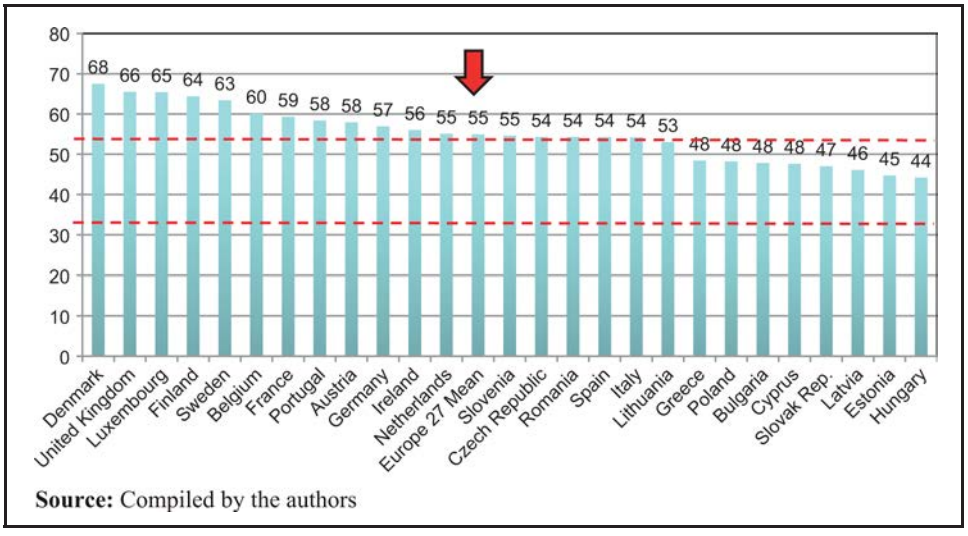
In the first place, growth in digitization metrics has primarily been achieved in the enabling infrastructure of internet access. While affordability (which measures wireless, wireline, and broadband tariffs) has not improved, this is because major price reductions occurred in the period prior to 2004. On the other hand, use of digital infrastructure is growing at a slower pace, revealing the challenges ahead in terms of furthering the assimilation of digital technologies in the European social and economic fabric. Finally, the stalling growth rate of infrastructure reliability (measured by investment levels) indicates one of the glaring challenges in implementing the digital agenda. While the penetration of digital technologies (such as broadband) has grown at an impressive rate, that has been achieved by means of regulatory frameworks that have constrained investment flows.

When disaggregated, the data showed another challenge for the future of the European digital agenda (see Figure 6).

While the Europe 27 countries have achieved a higher index in the aggregate (55), still a third of the countries are in a transitional stage of digitization (index between 35 and 50). These countries included Lithuania, Greece, Poland, Bulgaria, Cyprus, Slovak Republic, Latvia, Estonia, and Hungary.

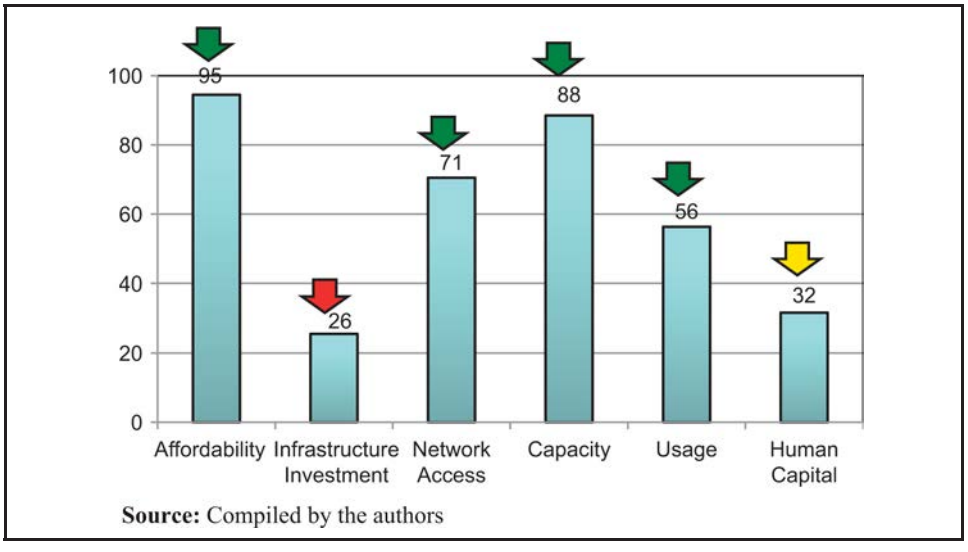
Further, an analysis at the component level indicates that each group of countries exhibited different sub-indices and challenges. For example, the policy challenges for the advanced countries appear to cluster around fostering investment in technology and the development of human capital. The sub-indicator also shows that policies emphasizing either affordability (price reductions[3]) or network capacity are not that critical in relative terms, while human capital development and infrastructure investment are moderately important (see Figure 7)[4].

Figure 6 Europe 27: digitization index (2004-2011)



Source: Compiled by the authors

Figure 7 Europe 27: components of the digitization index (2011). Advanced countries



Source: Compiled by the authors

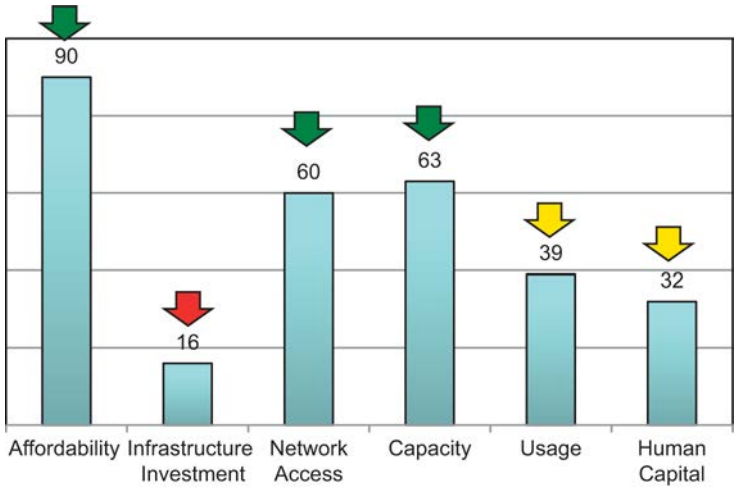
Conversely, Europe 27 countries with a digitization index at the transitional stage (between 35 and 50) have a more acute policy challenge in fostering investment, developing human capital, and promoting usage of digital infrastructure. Interestingly enough, no difference exists in the human capital sub-index between advanced and transitional countries, which might indicate a uniform challenge across Europe (see Figure 8).

The economic payback of digitization in Europe

The advances of digitization in the European continent have been able to generate substantial economic benefits. In order to estimate this impact, the econometric model developed in the context of digitization research was employed. This model is based on a simple Cobb-Douglas form:

$$Y = A_{(t)}K_1 + BL_1$$

Figure 8 Europe 27: components of the digitization index (2011). Transitional countries



Source: Compiled by the authors

Where:

- $A_{(t)}$ represents the level of technology progress (in our case the Digitization Index)
- K corresponds to the fixed capital formation
- L to the labor force

To measure the elasticity among variables, a log of each factor was considered:

$$\log(GDP_{it}) = a_1 \log(K_{it}) + a_2 \log(L_{it}) + a_3 \log(D_i) + \varepsilon_{it}$$

The causality tests[5] indicate that our estimates may be biased and for this purpose we use a lagged variable for Digitization[6]. The new formula is now:

$$\log(GDP_{it}) = a_1 \log(K_{it}) + a_2 \log(L_{it}) + a_3 \log(D_{it_{-1}}) + \varepsilon_{it}$$

The index is a weighted average of different indicators that might be endogenous to GDP, like broadband and mobile penetration. However their impact on the metric – these two metrics combined account for 5 percent of the index – seems insignificant. Additionally it is hard to find an instrument that could possibly control for this effect. Given the small effect it has on GDP, we extended the analysis controlling for country and year fixed effects to help mitigate potential problems and account for the heterogeneity of our sample (see Table II).

All variables in both models are significant at the 1 percent level. As expected, the capital formation is positive. Labor contribution to GDP is also consistent. The lagged Index is found to have a positive effect indicating a strong effect on economic output. The models suggest that there is a measureable input from digitization on country level growth both on a direct level and indirectly. This is captured by the different components of the metric that help measure the existence of network infrastructure and their affordability to the use of social media and online retail performance[7].

By relying on this model, the contribution of digitization to the growth of the Europe 27 GDP was estimated. In terms of its economic impact, digitization in the Europe 27 countries generated US$ 343 billion in new GDP over the course of 2004-2011 (see Table III).

Table II Economic impact of digitization

GDP (GDP_{it})	*(1) Model without lags*	*(2) Model with lags*
Fixed Capital Stock (K_{it})	0.1632***	0.1598***
Labor (L_{it})	0.1406***	0.1471***
Digitization Index (D_{it-1})	0.0814***	0.0768***
Constant	18.23***	18.32***
Year effects	Yes	Yes
Country effects	Yes	Yes
Observations	783	652
R-squared	0.9051	0.9098

Note: *** denote statistical significance at the 1% level
Source: Katz *et al.* (2013a)

Table III Europe 27: economic impact of digitization (2004-2011)

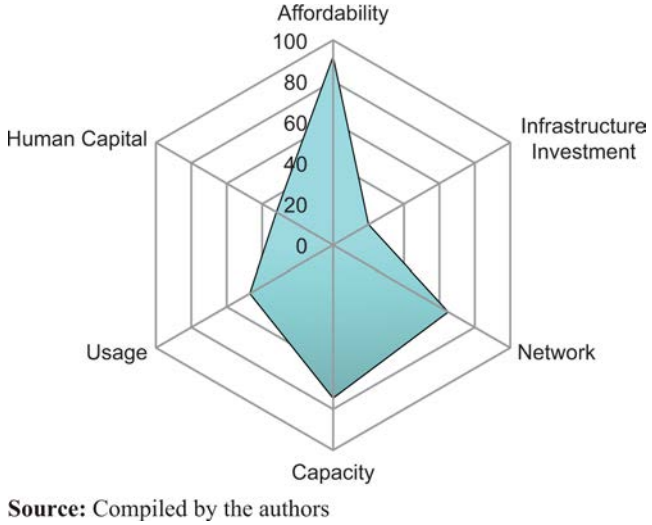
	2004	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*Total*
Digitization Index	38.6	39.7	41.7	43.8	46.7	49.0	52.6	54.9	–
GDP impact ('000'000'000))	–	$24.03	$46.53	$53.21	$67.21	$50.23	$61.48	$40.87	$343.57

The challenges ahead in the European Digital Agenda

While the payback is significant, Europe is facing a number of challenges in terms of its implementation of the Digital Agenda, which could put in jeopardy its achievement. As mentioned previously, the Europe 27 countries have progressed in terms of affordability, network access, and capacity components. However, they still face limitations in infrastructure investment and usage.

As mentioned in Figure 9, at the aggregate level, the Europe 27 countries are facing significant gaps in infrastructure investment and usage. However, a large portion of this gap is related to the uneven development of digitization across Europe 27 countries. The

Figure 9 Europe 27: analysis of the components of the digitization index (2011). Overall score = 54.9 Score



Source: Compiled by the authors

following table provides detail on the specific metrics that comprise the infrastructure and usage sub-indices, which help highlight the source of the digitization gaps (see Table IV).

As Table IV indicates, the drivers of the European gaps can be identified in key performance areas such as adoption of eCommerce, eGovernment applications, adoption of the internet and social network usage. Additionally, the gap in telecommunications investment is significant not only between leaders (Norway) and laggards (Greece), but also within higher ranked countries, such as the UK.

Analyzing the components identified the challenges faced by Europe's Digital Agenda. From 1994 to 2011, digitization in Europe improved 5.16 percent annually. While its affordability barely improved (0.80 percent), it was at the highest level of all industrialized countries. Europe saw the greatest improvement in the areas of capacity (international connectivity and broadband connections > 2mbps) (16.84 percent) and network access (broadband, mobile and PC penetration) (6.44 percent). At the same time, three areas continue to experience significant challenges: infrastructure (investment) (0.38 percent), usage (e-Commerce, e-Government, Data ARPU, social network usage) (4.30 percent), and human capital (1.93 percent) In sum, public policy should focus on investment promotion, demand stimulation through applications development, and human capital growth.

Table V indicates that if the Europe 27 countries were to reach the benchmark index set by Norway, they would experience significant economic results.

Conclusion

Digitization is a global concept, with significant heterogeneity within and across regions. Based on its six pillars – affordability, reliability, capacity, access, usage and skills, the Digitization Index was linked to higher growth and employment with increasing returns to scale. This finding bore significance, stipulating that full economic impact of ICT was achieved through the cumulative

Table IV Europe 27 vs specific countries: comparative digitization metrics

Component	*Indicator*	*Definition*	*Europe 27*	*Norway*	*The UK*	*Greece*
Infrastructure	Investment	Investment per telecom subscriber	$103.16	$549.97	$151.14	$109.48
Usage	Internet retail (%)	Retail internet as percentage of total retail	2.90	2.13	7.74	0.69
	E-government	Web measure index	0.69	0.86	0.97	0.58
	Internet usage (%)	Percentage of individuals using the internet	72.10	93.97	82.00	53.00
	Spend in data (%)	Data as a percentage of wireless ARPU	31	44	45	26
	Access to social networks	Dominant social network unique visitors per month per capita	25.34	49.80	44.60	14.68
	SMS usage	Average SMS sent by consumers	212	312	572	94

Sources: ITU; Wireless Intelligence; Euromonitor; Internet World Stats

Table V Europe 27: actual and simulated benchmark attainment

Index	*2011 actual (Europe 27)*	*2011 Norway scenario*
Digitization	54.9	72.3
Affordability (*)	92.0	96.0
Infrastructure investment	20.1	100.0
Network	65.0	67.0
Capacity	74.6	91.6
Usage	47.0	62.0
Human Capital	32.0	32.0
GDP Impact (2011) ('000'000'000 US$)	$40.87	$355.84

Note: *with the same level of human capital index of Europe 27
Source: Compiled by the authors

adoption of all technologies in addition to the assimilation and usage in the production and social fabric. From a policy perspective, high broadband penetration rates were only one aspect of required policies. Maximum economic impact could only be achieved through a holistic set of policies ranging from telecoms to computing to adoption of internet and Ecommerce.

These concepts were utilized to assess Europe's performance in terms of its digitization. Significant gaps were highlighted both in terms of its uneven development, but also in terms of lags in the areas of infrastructure investment and digital technology usage. The economic payback to be generated by pro-actively addressing these gaps promises to be significant. From a policy standpoint, the paper raises an interesting hypothesis to be explored in the European context: while the implementation of the Digital Agenda could be tackled in an overarching continental manner, particularities in each member country digitalization might raise the need for a more differentiated approach. In particular, European countries at the transitional stage should emphasize the creation of necessary incentives to accelerate investment in telecommunications networks. Additionally, demand promotion strategies focused on digital literacy and content development appear to be a critical lever to enhancing digitization. On the other hand, the policy challenges for the advanced countries appear to cluster around investment in infrastructure and the development of human capital. The sub-indicator analysis also shows that policies emphasizing either affordability or network capacity are not that critical in relative terms, while promoting usage of digital infrastructure is moderately important.

Notes

1. In fact, the index has been adopted by some emerging countries (such as Ecuador and Mexico) to measure progress on the digitization path, both at the aggregate and at the regional level.
2. Analysis excluded Malta due to lack of sufficient information.
3. Including efforts to promote adoption at the bottom of the socio-demographic pyramid.
4. Infrastructure reliability reflects the annual investment in telecommunications networks divided by the number of network users. This figure can be affected by large-scale deployments in particular countries during the normalization process (each value is divided by the highest value of that year). For this purpose we intend to revisit this metric with a new design covering a broader temporal dimension (three or five year average) that is less prone to construction effects.
5. To test for inverse causality, the model was rerun by switching GDP and the Digitization Index with the results indicating a potential reverse causality. In addition, the model was tested through a Granger Causality Test, which did not allow discarding the reverse causality.
6. This change does not completely address the problem but helps mitigate its consequencies on the estimated coefficients.
7. Given that the digitization index is a proxy for technological progress, and considering some of the indicators used to construct the digitization index, we tested for the presence of collinearity between the index and the other covariates, relying on the variance decomposition proportions in Belsey *et al.* (1990). The test for collinearity indicates that our sample lies well below the threshold suggested by the literature. In particular our model has a condition number of 20.44, whereas the concern levels, according to Belsey *et al.* (1990) start with condition numbers above 30.

References

Batzilis, D., Dinkelman, T., Oster, E., Thornton, R. and Zanera, D. (2010), *New Cellular Networks in Malawi: Correlates of Service Rollout And Network Performance*, National Bureau of Economic Research Working Paper No. 16616.

Belsey, D.A., Kuh, E. and Welsch, R. (1990), *Regression Diagnostics: Identifying Influential Data and Sources of Collinearity*, Wiley, New York, NY.

Crandall, R., Lehr, W. and Litan, R. (2007), ''The effects of broadband deployment on output and employment: a cross-sectional analysis of US data'', *Issues in Economic Policy*, Vol. 6, pp. 1-34.

Friedrich, R., LeMerle, M., Grone, F. and Koster, A. (2011), *Measuring Industry Digitization: Leaders and Laggards in the Digital Economy*, Booz & Co., London.

Gruber, H. and Koutroumpis, P. (2011), ''Mobile telecommunications and the impact on economic development'', Wiley-Blackwell, Hoboken, NJ, pp. 1-41, 52nd Panel Meeting of Economic Policy, July.

Holbling, K., Grone, F., Seelbach, F. and Maekelburger, B. (2011), *Advancing Digital Commerce Capabilities to Drive Financial Value: Perspective and Benchmarking Framework*, Booz & Co., London.

Jensen, R. (2007), ''The digital provide: information (technology), market performance and welfare in the South Indian fisheries sector'', *The Quarterly Journal of Economics*, Vol. 122 No. 3, pp. 879-924.

Katz, R.L., Vaterlaus, S., Zenhäusern, P. and Suter, S. (2010), ''The impact of broadband on jobs and the German economy'', *Intereconomics*, Vol. 45 No. 1, pp. 26-34.

Katz, R. and Koutroumpis, P. (2013), ''Measuring socio-economic digitization: a paradigm shift'', *Technovation*, (forthcoming).

Katz, R., Koutroumpis, P. and Callorda, F. (2013), ''The Latin American path to digitization'', *info*, Vol. 15 No. 3, pp. 6-24.

Klonner, S. and Nolen, P. (2010), ''Cell phones and rural labor markets: evidence from South Africa'', *Proceedings of the German Development Economics Conference, Hannover, 2010 56*, Verein für Socialpolitik, Research Committee Development Economics.

Koutroumpis, P. (2009), ''The economic impact of broadband on growth: a simultaneous approach'', *Telecommunications Policy*, Vol. 33 No. 9, pp. 471-485.

Muto (2008), ''The impact of mobile phone coverage expansion on market participation: panel data evidence from Uganda'', *World Development*, Vol. 37 No. 12, pp. 1887-1896.

Qiang, C.Z. and Rossotto, C.M. (2009), ''Economic impacts of broadband'', *Information and Communications for Development 2009: Extending Reach and Increasing Impact*, World Bank, Washington, DC, pp. 35-50.

Sabbagh, K., Friedrich, R., El-Darwiche, B., Singh, M., Ganediwalla, S. and Katz, R. (2012), ''Maximizing the impact of digitization'', in Dutta, S. and Bilbao-Osorio, B. (Eds), *The Global Information Technology Report*, World Economic Forum and Insead, Geneva.

Thompson, H. and Garbacz, C. (2008), ''Broadband impacts on state GDP: direct and indirect impacts'', paper presented at the International Telecommunications Society 17th Biennial Conference, Montreal, Canada.

Further reading

Czernich, N., Falck, O., Kretschmer, T. and Woessman, L. (2009), ''Broadband infrastructure and economic growth'', December, CESifo Working Paper No. 2861, available at: www.ifo.de/DocCIDL/cesifo1_wp2861.pdf

About the authors

Raul Katz is Director of Business Strategy Research at the Columbia Institute for Tele-Information in New York, and Adjunct Professor in the Finance and Economics Division at Columbia Business School. Raul Katz can be contacted at: rk2377@columbia.edu

Pantelis Koutroumpis is a Fellow at the Innovation and Entrepreneurship Group at Imperial College Business School in London, UK.

Fernando Martin Callorda is a Researcher at the Center of Technology and Society at the Universidad de San Andres (Argentina) and an Assistant Professor at the Business Administration Department, ESEADE, Buenos Aires, Argentina.

All three are affiliated with Telecom Advisory Services LLC.