Measuring socio-economic digitization: A paradigm shift

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ABSTRACT

Digitization is defined as the social transformation triggered by the massive adoption of digital technologies to generate, process, share and transact information. Unlike other technological innovations, digitization builds on the evolution of network access technologies, semiconductor technologies, software engineering and the spillover effects resulting from their use. This paper presents a methodology followed to calculate the Digitization Index, a measure of country level of digitization, a concept originally developed by Booz & Company, the global management consulting firm. This index consists of six elements capturing Ubiquity, Affordability, Reliability, Speed, Usability and Skill and 23 sub-indicators measuring tangible parameters of perceived digitization metrics. The sample spans across 150 countries from 2004 to 2010. Countries are clustered as Digitally Constrained, Emerging, Transitional or Advanced. Once the index is defined, hypotheses regarding the contribution of digitization to economic growth, job creation and welfare are tested. In addition, a critical mass hypothesis is also tested as additional returns might derive from network externalities and spillover effects. The results provide strong support for the effect of digitization across all growth generating metrics.

Keywords: digitization, economic growth, unemployment, welfare

JEL: L96, L52, O38

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1. Introduction

Technological revolutions are marked with innovations that shape industrial production and drive long-term economic growth. These revolutions signify a new era when their effects cut across all 'commonsense' criteria for social and business behavior and operations. The dynamic nature of the 'great waves of new technologies' has profoundly modified the world that we live in (Landes, 1969; Freeman and Perez, 1988; Nye, 1990). Societies have recognized their influence and referenced these periods as the Industrial Revolution, the Railway Era, the Age of Electricity and the Age of the Automobile (Perez, 2004). The ongoing revolution, often called Digital Era, builds on the advancements of information and communications technologies and shares common characteristics with other major leaps in recent history.

Until now, most indices that measure progress towards this new era have focused primarily 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).

Digitization *per se*, is the process of converting analogue information to a digital format. Digitization, as a social process, refers to the transformation of the techno-economic environment and socio-institutional operations through digital communications and applications. Unlike other technological innovations, digitization builds on the evolution of network access technologies (mobile or fixed broadband networks), semiconductor technologies (computers/laptops, wireless devices/tablets), software engineering (increased functionality of operating systems) and the spillover effects resulting from their use (common platforms for application development, electronic delivery of government services, electronic commerce, social networks, and availability of online information in fora, blogs and portals).

The aim of this paper is to create a first consistent attempt to quantitatively measure cross-country progress along the digitization development path. This index consists of six elements and 23 indicators measuring tangible parameters of perceived Digitization metrics, namely

Ubiquity, Affordability, Reliability, Speed, Usability and Skill. The sample consists of 150 countries and spans from 2004 to 2010. This index allows for an initial ranking and subsequently a more meaningful clustering of national economies into different categories. Based on the total index score and the elements' scores, countries are labeled as digitally Constrained, Emerging, Transitional or Advanced. The key identifiers of each category are explained in detail resulting in a suggestive policy approach on the necessary changes required for the advancement from one category to another.

As the Digitization process reflects a paradigm shift in the socio-economic status quo, this orchestrated transition is examined for its returns on economic growth, job creation and welfare. Besides, significant creation and substitution effects might also occur during this change. For this purpose, the Digitization Index is tested against different hypotheses. First, the economic impact hypothesis tests whether the evolution of this process has a measurable effect on country-level economic growth. Additionally, unemployment rates are tested against a job creation hypothesis; finally, subjective wellbeing and happiness are used as proxies of social welfare. Methodologically, an endogenous growth model is used that controls for the common parameters that affect economic growth. Unemployment and welfare effects are tested based on models that have been used widely in the relevant literature. Other econometric tests and controls are also put in place to account for the vast heterogeneity of the sample.

As Digitization is essentially built upon network technologies that frequently experience returns to scale, the index is also tested against the increasing returns to economic growth hypothesis. Along those lines, the initial stages of the digitization process do not affect socio-economic activities extensively. However, as the process matures with wider adoption and reaches a *critical mass*, additional returns might derive from the network externalities and spillover effects. The results provide strong support for the increasing returns hypothesis and illustrate the effects from the different index classifications of the countries in the sample.

In section 2, the background on technological revolutions is discussed and in section 3 the concept of digitization is introduced and detailed in terms of methodology followed for the construction of an index. In section 4, the results of economic impact analysis, both in terms of contribution to GDP growth, employment and welfare are presented. In section 5, we conclude with some policy suggestions stemming from the results.

2. Background

Modeling social adaptation to technological change and - process or product - innovation has been done extensively in the past. The diffusion path of each innovation may differ substantially for reasons related or unrelated to the breakthrough alone. For this purpose, disruptive technologies in several occurrences have 'initiated' new eras allowing incremental improvements or other disruptive changes prolong their effects for decades. Perez (2004) has set out the main periods of each of these technical change and adaptation periods.

First an irruption period guarantees that the technology and its capacities are tested. During this time traditional thinking is challenged pushing the capacity frontier of each innovation to answer everyday needs. Gradual improvements and wider industrial engagement help this process too. This incubation period allows for experimentation and technical improvements while socio-economic activities are still unaffected by the disruptive potential of the new findings.

At least in five cases during the past three centuries, an irrational adoption pattern or *frenzy* followed. In light of the impressive technological improvements investments on the new technologies and their prospects flourish. By and large, this investment euphoria did not meet expectations and ended in a bust. The end of these periods marks a turning point after having reached the peak of *inflated* expectations.

Naturally skepticism and disillusionment follow allowing time and experience to affect this relationship. Synergies are formed and opportunism subsides both in the political and the industrial arenas. A sustainable future appears collaterally beneficial and this is when these innovations actually reach maturity.

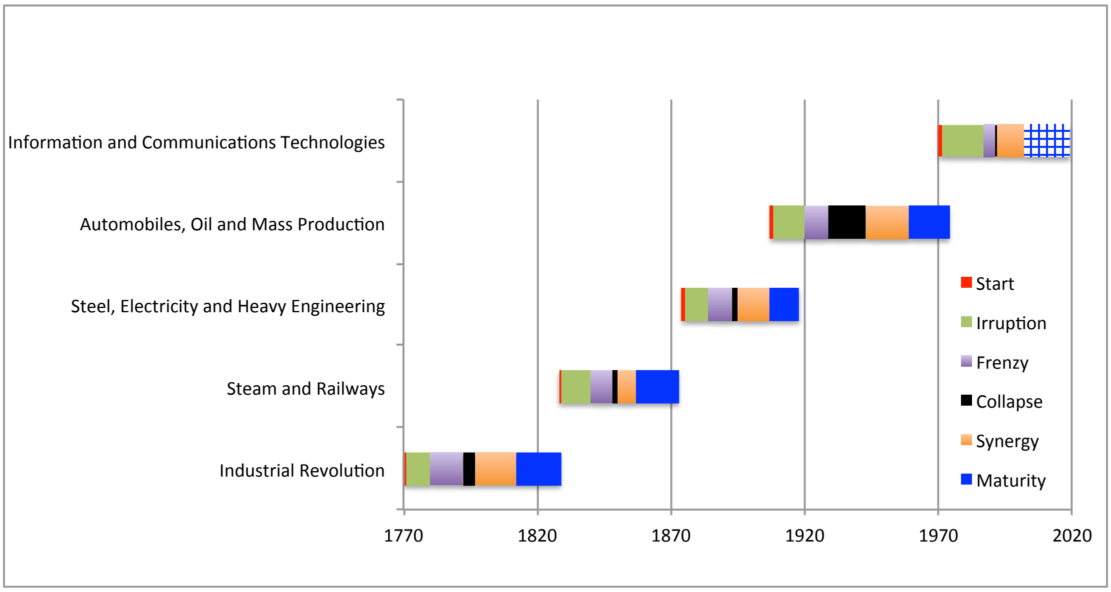

Figure 1: Technological revolutions since 1770 for the five different technology disruptions. (Source: C. Perez (2004) and authors' calculations)

In the case of the ICT or Digital era, one could suggest that after the 'dot com' bubble and its repercussions on the world economy new synergies have started to take shape. There is a trend towards standardization in the ICT equipment and network access industries. Household penetration of network access continues to grow and the majority of population – regardless of income or other socio-demographic characteristics - owns a mobile phone (see figure 2). Personal computers are still getting cheaper (per unit of computation) and gradually transform to meet the location-specific needs of the indigenous population (lighter, more energy efficient, not requiring constant power charge, ruggedized, easy to carry, connecting to different network protocols). The introduction of a holistic measure of these effects could help identify interesting links between infrastructure existence, use and returns of the new techno-economic framework across the world.

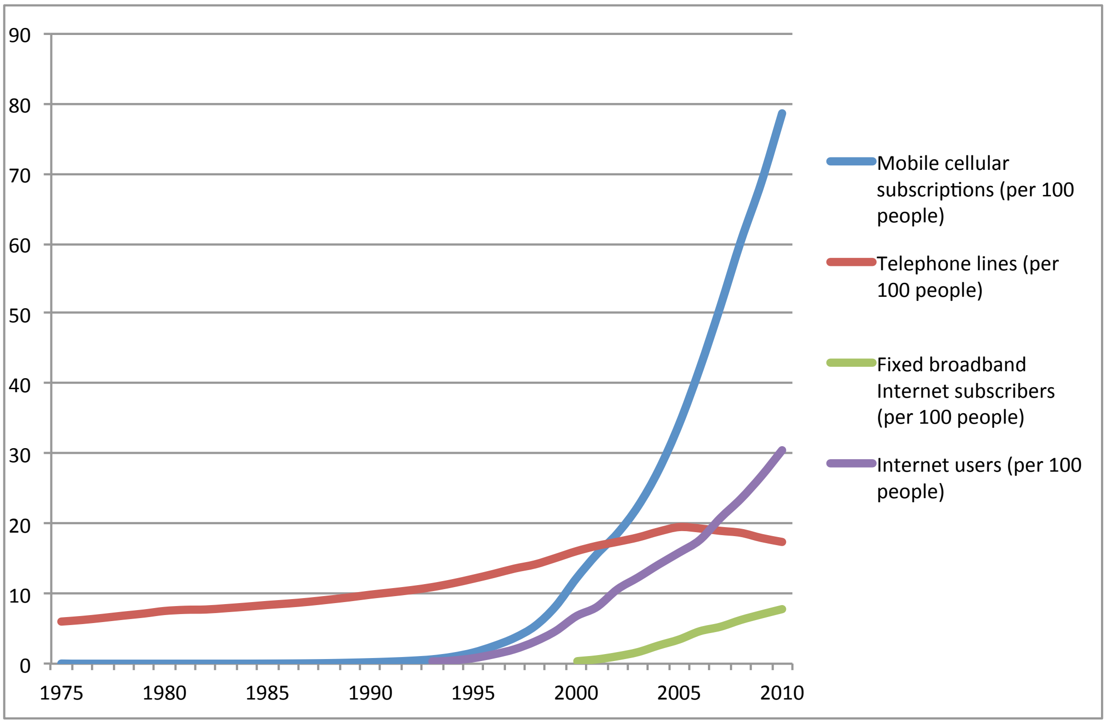

Figure 2: The current Digital Age and its characteristics. Worldwide adoption of ICT (Source: ITU, 2012)

3. The Digitization Index

The concept of digitization has principally been pioneered by Booz & Company, the global management consulting firm, through a number of research pieces (Friedrich et al., 2011a; Friedrich et al, 2011b; Raad, 2011). Digitization metrics try to quantify the cumulative effect of adoption and usage of information and communication technologies. While most of the research literature measuring the social and economic impact of ICT focuses on discrete technology platforms, we posit that the holistic adoption and usage of information technology results in enhanced effects that go beyond the contribution of specific platforms. Perhaps a good analogy to this hypothesis is the case of the first and second Industrial Revolutions, where dramatic productivity improvements resulted from the combined effects of deployment of transportation infrastructure (roads, canals), the introduction of first steam and then internal combustion engines, the commoditization of energy, and changes in manufacturing processes.

Furthermore, to achieve a significant impact, digitization has to be widely adopted in the economic and social fabric of a given country. As such, they have to be widely utilized by individuals, economic enterprises and societies, embedded in processes of delivery of goods and services (e.g. eCommerce), and relied upon to deliver public services (e.g. eHealth, eGovernment).

While the digitization process and the relevant policies are rarely orchestrated through a holistic framework (Republic of Korea represents a classic case where ex-ante pro-digitization policy outgrew local demand for these services), there are several milestones identified that accelerate or impede its progress. In particular, network access and the ubiquity of access media is perhaps, the first step towards achieving a basic level of digital infrastructure in a country. The existence of network equipment without wireless or wired infrastructure has limited meaning and use. Therefore *ubiquity* is the first component that allows individuals and enterprises to have universal access to digital services and applications.

Beyond the deployment of networks, subscribers never adopt a technology immediately. Mass adoption starts to appear once the technologies mature and access prices fall. This is frequently accelerated by mandates for network sharing, deployment of alternative platforms or the auctioning of spectrum bands. The concept of *affordability* is therefore crucial for the digitization process. The existence of affordable network links is the basis for launching new applications, services and pervasive information exchange.

Internet and mobile networks have been developed based on a series of protocols that guarantee a level of quality in the services provided on the application layer. Nevertheless most access media require vast investments to perform reliably. In terms of broadband access, national network links (undersea/transoceanic cables, city-level/country-level internet exchanges and backbone infrastructure) and 'last mile' connections are crucial for the overall network performance. For mobile access, population and land coverage as well as the quality of links between the base stations critically affect the service delivery. The concept of network *reliability* is considered a key element of the digitization process as it may hinder adoption and prevent the use of applications that depend on isochronicity, latency and lag.

Network throughput, or as usually mentioned, *speed* is by definition important for network access. Simple applications like voice and email usage require basic access speeds but others (multimedia and video applications, cloud services, etc) depend on higher speeds. Effectively digitization is measured upon network speeds as well.

Once the technical requirements are in place, affordable, ubiquitous, reliable and high-speed networks serve individuals and firms. The importance of this infrastructure derives from everyday activities and depends on the applications that people actually use. Services can provide information to active and passive users. For example, the user reviews posted at information portals represent a passive mode of information retrieval. Other services require active engagement, like blogging, social media, online shopping or e-government applications. All these parameters of digitization form the concept of *usability*. Mere existence of the networks and terminals (mobiles, tablets, laptops, readers, computers or servers) is just not enough. Usability transforms the 'dummy binaries' into meaningful elements of our lives.

Lastly, people are key in shaping social transformations. The education level of each society, its beliefs and institutions have a significant effect on the online 'culture' that it will create. While parts of the online elements are globalized, the applications that affect people are usually location specific and target majorities. Technical *skill* is therefore a crucial metric of the ability of individuals to incorporate digital services in their lives and businesses.

These six elements combined shape the adoption path to social digitization. They are composed of several subcomponents that allow us to proxy their effects on each layer. A detailed analysis of the elements follows.

Components	**Subcomponents**	**Sub-Subcomponents**
Affordability	Residential fixed line cost adjusted for GDP per capita	Residential fixed line tariff 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 adjusted for GDP/capita
		Mobile cellular prepaid connection fee adjusted for GDP per capita
	Fixed broadband Internet access cost adjusted for GDP per capita	
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
		Mobile Phone penetration
	Coverage, Infrastructure and Investment	Mobile cellular network coverage
		PC population penetration
		3G Penetration
Capacity	International Internet bandwidth (kbps/user)	
	% Broadband connections higher than 2 Mbps	
Usage	Internet retail volume	
	E-government usage	
	% Individuals using the internet	
	Data as % of wireless ARPU	
	Dominant Social Network Unique Visitors per month Per Capita	
	SMS Usage	
Human Capital	% Engineers in labor force	
	% Skilled Labor	

Table 1: Indicators, and sub-indicators of
the Digitization Index (Source: adapted from Sabbagh et al., 2012)

Affordability is calculated by the relative costs of all underlying infrastructures. In this context fixed, mobile and broadband service charges are considered together with connection fees. Each of the components (fixed, mobile and broadband) is given equal weight to account for the sample heterogeneity and the varying adoption in different socio economic conditions.

Infrastructure reliability depends on the quality of the services provided. Initially two different metrics were utilized - faults per line and investment per telecom subscriber - as quality proxies. However, during the statistical validation of the index, the first component had to be eliminated[3] mainly because of the lack of adequate observations. Therefore this component is comprised of investment per telecom subscriber (in all types of networks). This metric is sensitive to front-loaded investment projects that materialize later in time; therefore it might exhibit higher values before societies actually receive the implied benefit.

Network access derives from the adoption of mobile and fixed broadband networks. While adoption is always lower than network coverage or access, telecommunications operators usually invest in areas where higher adoption is expected. Nevertheless, regulatory interventions may incentivize network coverage in rural or underutilized areas as a means of reducing the digital divide. To account for this phenomenon, overall mobile coverage is also used, coupled with PC ownership and mobile broadband penetration. These metrics correct the potential underestimation of mobile or fixed broadband adoption and reflect the actual network access in different socio-economic contexts[4].

The measurement of Network Capacity is based on two different sources: international network links and "last mile" network service offerings. International bandwidth is crucial in order to provide adequate throughput to remote sites. This metric controls for the common phenomenon of several emerging regions of the world that experience high connection speeds for local content and services only (usually through hybrid Ethernet networks), while access to remote sites is constrained by either economic or technology bottlenecks. Additionally, we account for the percent of connections that deliver higher than 2Mbps of service.

Usage is a key component of digitization. We utilize variables ranging from the percentage of online retail versus traditional retail commerce, e-Government services, the percent of individuals that report some kind of internet usage (especially for countries that connections are not necessarily dedicated), social media adoption and usage (a metric that reflects both the social and the economic benefits realized primarily by advertising campaigns), SMS usage (a simple data proxy) and the percent of total mobile connection revenues per user that are dedicated to data services only. All these variables shed light in different usage patterns and help understand how these values range across a wide variation of income, educational and social contexts.

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[3] The factor analysis is explained in the next section

[4] For example, in Senegal mobile penetration was almost 80% in 2011 and fixed broadband access less than 1%. Nevertheless, mobile broadband coverage exceeds 30%, almost 30 times higher than actual broadband usage. Therefore the network access is already there but the adoption metrics fail to reflect it. On the other hand, fixed broadband coverage is almost impossible to measure. This is why fixed broadband adoption is used as a proxy of this variable (See Katz and Koutroumpis, 2012).

Human capital contributes to digitization and is affected by it. However, existing conditions or country fixed effects, help shape the capacity, focus and speed of services that will be offered. This process depends both on the numbers of people that can offer them (proxied by technical staff or engineers) and by the qualities and skills of the people using them. Therefore in this metric we combine the impact of digitization on its suppliers and its target audience.

The various sources of data used to create the Digitization Index are included in Table 2.

Name of Indicator	**Source**
Residential fixed line tariff adjusted for GDP per capita	ITU
Residential fixed line connection fee adjusted for GDP per capita	ITU
Mobile cellular prepaid tariff adjusted for GDP/capita	ITU
Mobile cellular prepaid connection fee adjusted for GDP per capita	ITU
Fixed broadband Internet access tariff adjusted for GDP per capita	ITU
Investment per telecom subscriber (mobile, broadband and fixed)	World Bank
Fixed Broadband penetration	ITU
Mobile Phone penetration (2010)	ITU
Population covered by mobile cellular network	ITU
Percentage of population using a PC (2010)	ITU
3G Penetration (2Q 11)	Wireless Intelligence
International Internet bandwidth (bits/second/internet user)	ITU
Broadband speeds (% above 2 Mbps)	Akamai
Internet retail (Retail internet as percentage of total retail)	Euromonitor
E-government Web measure index	UN
Percentage of individuals (users) using the internet (2010)`	ITU
Data as a percentage of wireless ARPU (4Q10)	Wireless Intelligence
Dominant Social Network Unique Visitors per month Per Capita	Internet World Stats
SMS Usage (Average SMS sent by consumers)	Wireless Intelligence
Engineers (Engineers as a percentage of total population)	World Bank
Skilled Labor (Labor force with more than a secondary education as a percentage of the total labor force)	World Bank

Table 2: Data sources of the indicators of the Digitization Index

The Digitization Index has been constructed following a typical methodology for composite index validity assessment[5]. First the theoretical framework of the index is set up and the variables are selected. This includes all six components that describe the digitization process. Then a multivariate analysis is performed in order to analyze the underlying structure of the data'. In particular the process helps choose the statistically valid sub-indicators in each component that are both adequately different from each other and measure accurately the latent phenomenon. This process includes the principal components' and factor analysis of all

[5] See the OECD Handbook for constructing composite indicators by Nardo et al. (2005)

components[6]. Data has been normalized to meet these criteria and allow for spatial and temporal comparisons. At this point, the second component of infrastructure reliability had to be dropped as it failed the factor analysis thresholds[7].

The Digitization Index has been calculated for 150 countries and all years between 2004-2010. The top 20 country scores are included in Table 3 (ranked for year 2010). Norway tops the charts, a consistent leader since 2004. A cluster of countries with similar scores follows: Iceland, Republic of Korea, Hong Kong and Switzerland. It is interesting to note that, when excluding the Republic of Korea, countries with less than 8 millions of population appear in the top-5. Then the United States, Luxembourg, Taiwan, Canada, Israel, Denmark and Japan make another closely ranked cluster. Luxembourg has made a remarkable progress in this period whereas the United States is found to have slowed down (given the underestimate of their performance in 2004). A mostly European cluster with the United Kingdom, Sweden, Finland, Belgium, France, Portugal and Germany follows with Australia and Singapore in between. The United Kingdom leads this cluster and retains its distance with Germany although they seem to have evolved on an almost parallel path. To the contrary, France, Portugal and Australia have significantly changed paths during this period, which is evident in the formulation of their national Broadband Agendas. The complete index scores are included in the Appendix.

	2004	**2010**
Norway	47.93	63.73
Iceland	32.40*	59.99
Republic of Korea	38.25*	59.82
Hong Kong	30.38*	58.88
Switzerland	33.88	58.59
United States	37.66*	57.94
Luxembourg	25.81**	57.85
Taiwan	N/A	56.41
Canada	31.37*	56.34

[6] Kaiser criterion and Cronbach coefficient alpha

[7] Two tests were performed to assess the adequacy of the sample: the Cronbach Alpha is 0.74 and the KMO statistic 0.75 (all subcomponents above 0.71), allowing us to proceed with the subsequent analysis of the index. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy is a statistic for comparing the magnitudes of the observed correlation coefficients to the magnitudes of the partial correlation coefficients. The concept is that the partial correlations should not be very large if one is to expect distinct factors to emerge from the factor analysis. A KMO statistic is computed for each individual sub-indicator, and their sum is the overall KMO statistic. This statistic varies from 0 to 1.0, and should be 0.60 or higher to proceed with factor analysis though realistically it should exceed 0.80 if the results of the principal component analysis are to be reliable. If not, it is recommended to drop the sub-indicators with the lowest individual KMO statistic values, until results rise above 0.60.

Israel	43.80	56.29*
Denmark	39.63	56.08
Japan	40.78	55.61
United Kingdom	38.93	54.35
Sweden	37.97	53.79
Finland	37.46	52.18
Australia	32.03*	52.03
Belgium	23.71*	51.25
Singapore	32.48**	50.81
France	29.59	50.16
Portugal	28.19	49.28
Germany	31.79	47.86

* Computed out of 5 components

** Computed out of 4 components

Table 3: Top-20 countries of the Digitization Index

4. The Digitization Ranking

The calculation of the Digitization Index for 150 countries in 2010 reveals that countries tend to follow four clearly development stages. The high cluster includes *Advanced* countries, the medium *Transitional*, the low *Emerging* and the very low *Constrained* (see figure 3).

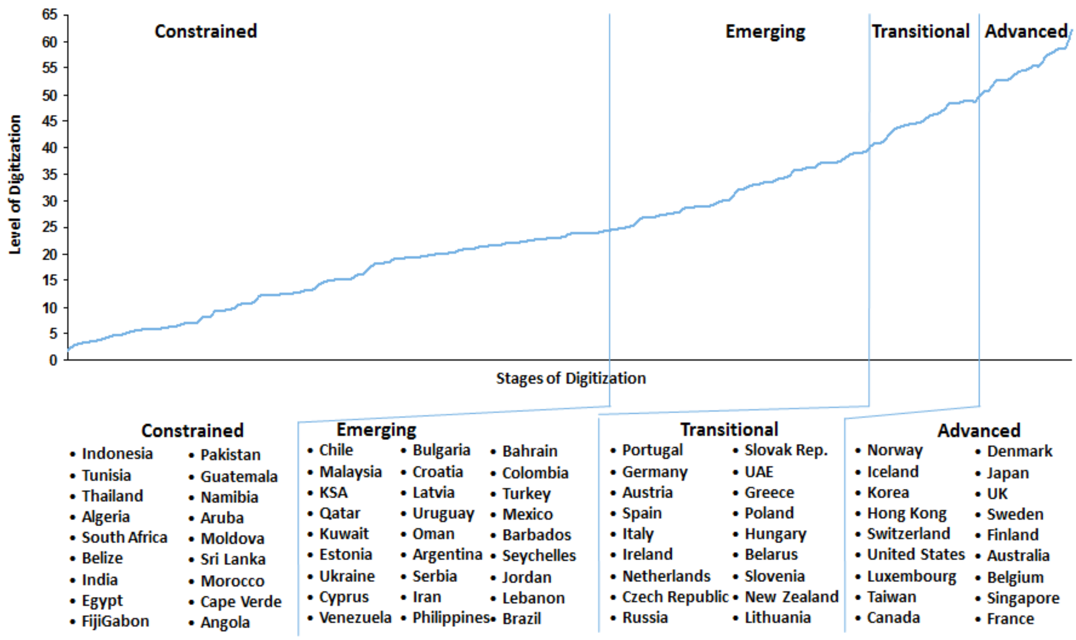

Figure 3: Four clusters of Digitization

(Source: Sabbagh et al. (2012)

Constrained economies—those with a digitization score below 25—face challenges in realizing basic digitization building blocks such as widespread access and affordability. In these nations, services remain expensive and limited in reach.

Emerging economies – those with a score between 25 and 30 – largely have addressed the affordability challenge and have achieved significant progress in providing affordable and widespread access. However, the reliability of services in emerging digitization nations remains below par and capacity is limited. Usability remains low, with online commerce constituting less than 0.5 percent of the total retail market.

Transitional is the next digitization stage, encompassing those countries with a digitization score in the range of 30 to 40. Countries in the transitional stage have addressed the reliability challenge, providing citizens with access to ubiquitous, affordable and reasonably reliable services. Alongside, the jump in reliability, transitional countries show minor advances in the speed, usability and skill indices.

Advanced is the most mature stage of digitization, achieved with a score greater than 40. These countries have made significant strides in addressing ICT usability and developing a talent base to take advantage of available technologies, products, and services, while improving the speed and quality of digital services.

As expected, the average and range of level of digitization varies significantly by region (see table 4). It is also striking that index variation is often higher within each region than across regions (Africa, Asia/Pacific).

Region	**Number of Countries**	**Index (Average)**	**Minimum**	**Maximum**
North America	2	56.60	58.70	54.51
Western Europe	19	49.08	35.82	62.06
Eastern Europe	24	31.07	21.06	44.19
Asia Pacific	24	24.96	6.35	58.81
Middle East & N. Africa	17	23.74	5.81	37.06
Latin America	20	23.75	12.29	37.05
Sub-Saharan Africa	24	12.83	2.81	35.85

Table 4: Regional ranking of the Digitization Index

The cross-country comparison of the Digitization Index allows to draw several key findings. Countries follow four states: constrained, emerging, transitional, and advanced. Digitization development varies markedly by region of the world. All OECD and middle-income countries have successfully addressed the access and affordability challenge, indicating that the digital divide, especially for middle income countries relies in tackling reliability and usage. The affordability and capacity sub-indices tend to rapidly drop at low GDP levels, indicating a big gap between mature and low income countries.

5. Assessing different paths to Digitization

Testing the hypothesis of multilinear development path to digitization, we estimated the scores of the index for a subset of 18 countries and the period 1995-2010. This includes a time when mobile adoption was not yet mature, basic Internet access rather than broadband was offered and social networks were not massively used.

Data indicates that mature countries exhibit a consistent, yet gradual, change in levels of digitization (see figure 4).

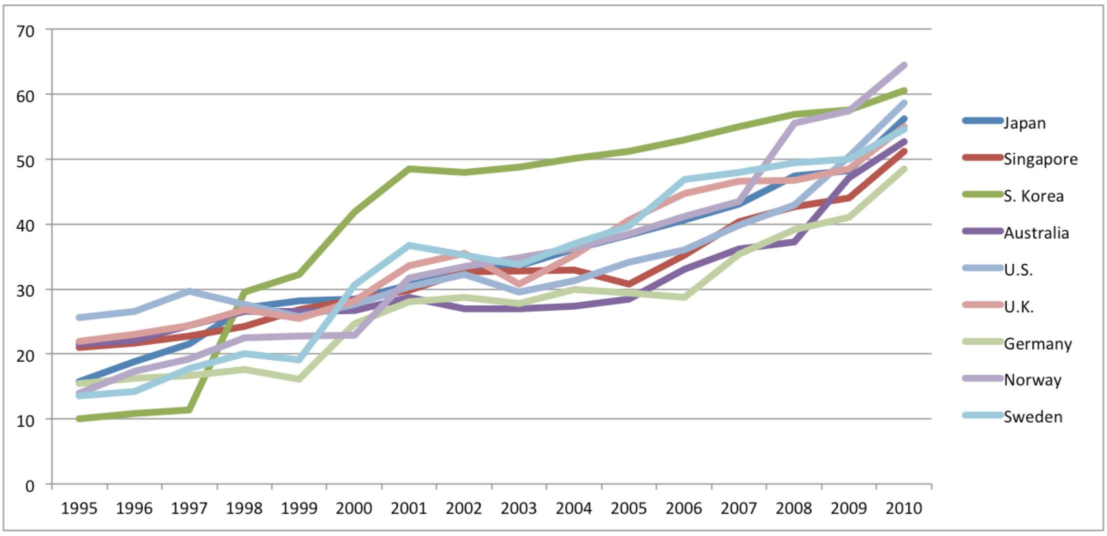

Figure 4. Mature Countries: Comparative Evolution of Digitization (1995-2010)

As figure 4 indicates, most industrialized countries have consistently increased their digitization level over the past fifteen years, albeit at different rates. On the other hand, emerging countries excel very quickly in digitization scores. (see figure 7).

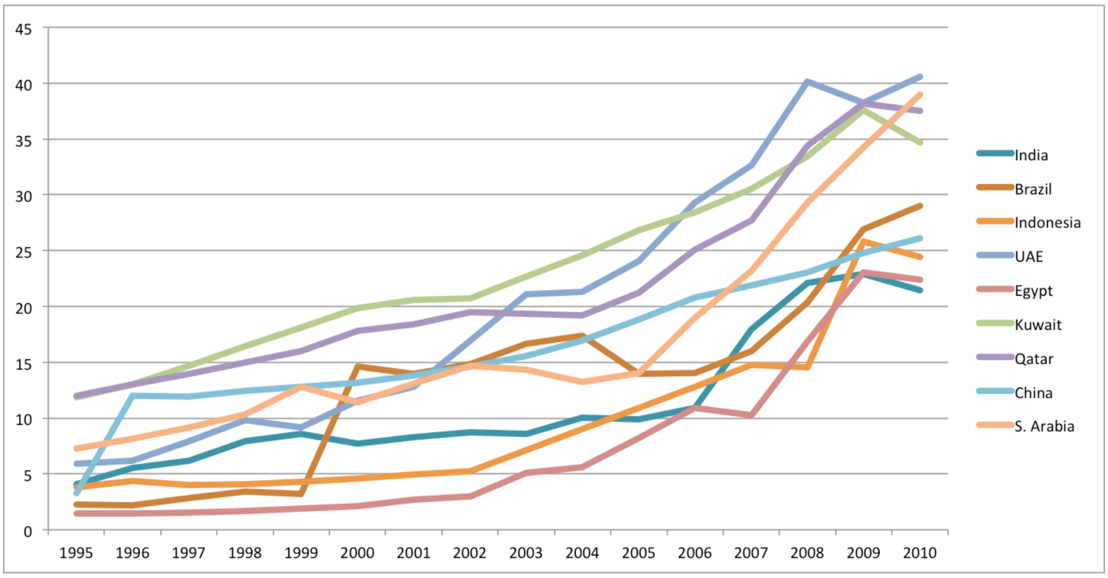

Figure 5. Emerging Countries: Comparative Evolution of Digitization (1995-2010)

According to the results in figure 5, some countries have led the transformation toward digitization. Their economies are typically based on commerce and services, which require digitization to render them more efficient. On the other hand, countries like Brazil, India, China and Egypt experienced an increase in digitization at a later stage, when the level of industrialization required higher ICT adoption and usage.

We also analyzed the changes in the index in an attempt to identify specific events or policies that have triggered a change at a specific point in time. The path for these countries is shown in Figure 6. One can clearly spot the drastic changes introduced by government intervention in the case of South Korea (Republic of Korea) back in 1998, Norway in the early 2000s, Australia in 2004 and 2010, Saudi Arabia in 2007, Kuwait in 2008, Japan in 1998 and 2004 and others. It is still striking to find that China is lagging compared to Brazil.

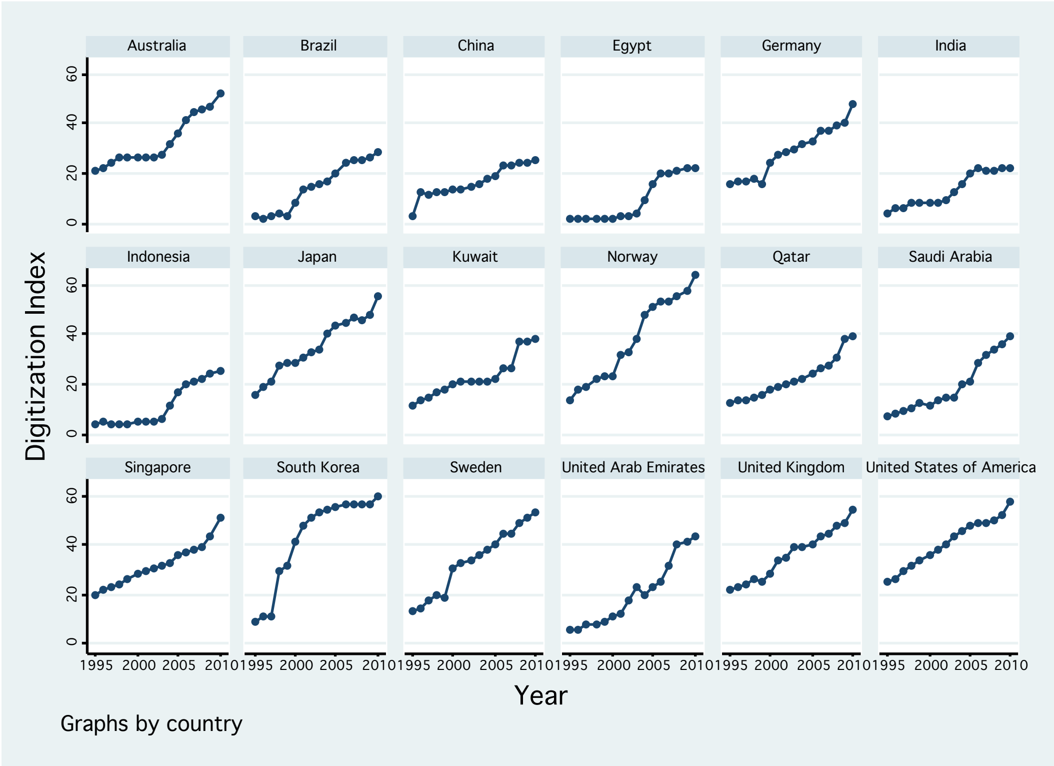

Figure 6: Digitization Index for a subset of 18 countries (Source: Authors calculations)

In conclusion, countries follow different paths to digitization. Mature countries follow a gradual progression towards digitization. It should be recognized, however, that developed countries tend to grow slower than emerging countries, but, as will be shown below, the economic contribution of digitization in countries with higher level of development is greater because of the structure of their economies.

Some emerging countries undergo quantum leap changes (25 points in five years) in digitization triggered by specific policy initiatives, such as telecom market liberalization with spill-over impact on the ICT eco-system, a combination of active government involvement and private sector participation, and centralized state planning.

Data analysis indicates that the pace of digitization and movement between stages is accelerating at a rapid pace. Developed countries such as Germany, the U.S., and the U.K. took nearly four years on average to move from the emerging to the transitional stage of digitization; now, developing countries, such as the UAE, Kuwait, and Estonia are making that progress in less than two years. Overall, between 2004 and 2007, countries registered 39 stage leaps; in the ensuing three-year period of 2007 through 2010, 65 countries progressed to the next level of digitization development. Not only has the pace quickened, the jump in development has been more marked. From 2004 to 2007, the average growth in the digitization score was seven points. From 2007 through 2010, the average jump was 10 points. At the same period, six countries have experienced two stage jumps, progressing from the emerging to the advanced stage; one of those countries, Romania, spent only one year in the emerging stage.

The acceleration stems from a number of factors. Emerging countries now can follow the path that developed nations already blazed, learning from their best practices. They also can take advantage of mature technologies and markets, and the resulting price reductions. Furthermore, the acceleration between stages may derive from increased market liberalization, growing affordability of technologies, growing availability of skills, and the widespread availability of high-speed broadband networks, which accelerates the implementation and usage of new technologies and the deployment of supporting infrastructure. In sum, the world is moving toward an advanced stage of digitization at an ever increasing pace.

6. Socio-economic Impact of Digitization

The socio-economic impact of digitization was assessed both, in terms of its contribution to economic growth and reduction of unemployment.

A. Impact on Economic Growth

As the process of digitization affects the way people work, communicate, shop, travel and live, one would expect to find a link between the index and the basic macro economic parameters in each society. The examples of mobile and broadband adoption in several recent studies help point towards this direction (Czernich et al; 2011, Koutroumpis 2009; Gruber and Koutroumpis 2011; Katz 2012; Katz and Koutroumpis, 2012). The first analysis was geared to see whether the Digitization Index is correlated with individual income on an international basis. Plotting the index scores for 2010 in Figure 7, we see an almost linear link to the logarithm of individual income indicating a logarithmic rather than a linear link. This observation suggests that 10 points of index score increase in the lower ranks is associated with a smaller effect on GDP per capita rather than the same change on the higher ranks. Reverse causality may appear here too, but strong income dependency is continuously decreasing, as devices and services become commodities in almost all socioeconomic contexts. An obvious exception to this rule includes countries with limited or no access to basic needs and adequate living conditions.

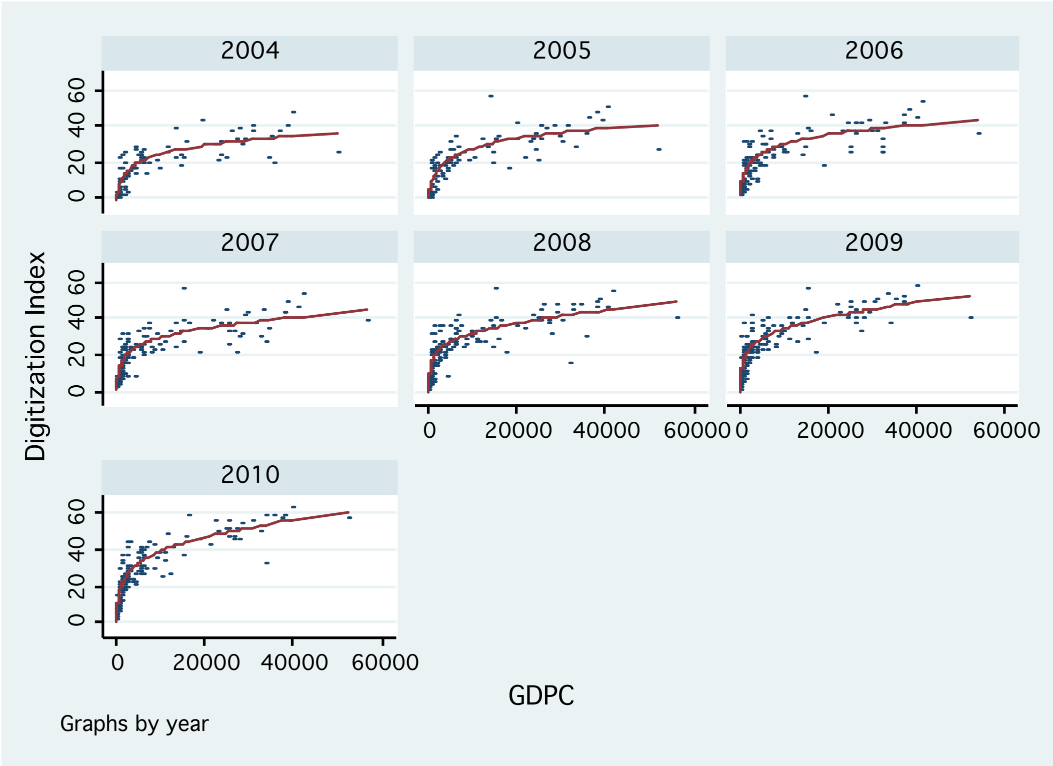

Figure 7: Digitization index with GDP per capita by year (Source: Authors calculations)

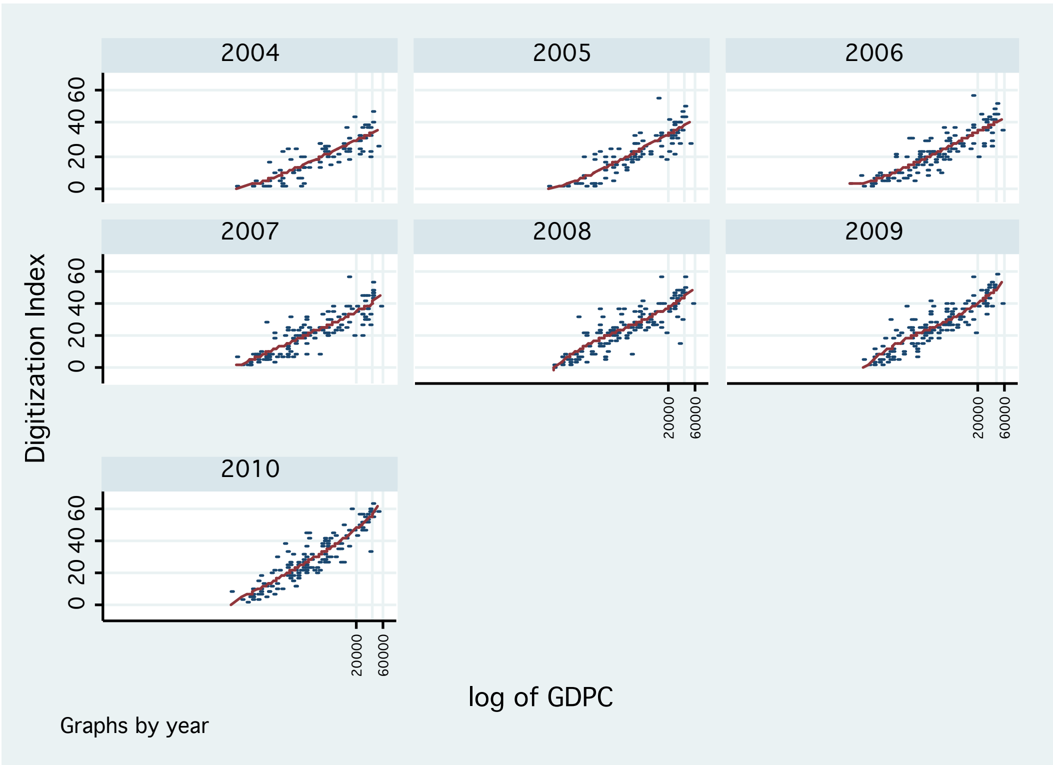

Figure 8: Digitization index with log GDP per capita by year (Source: Authors calculations)

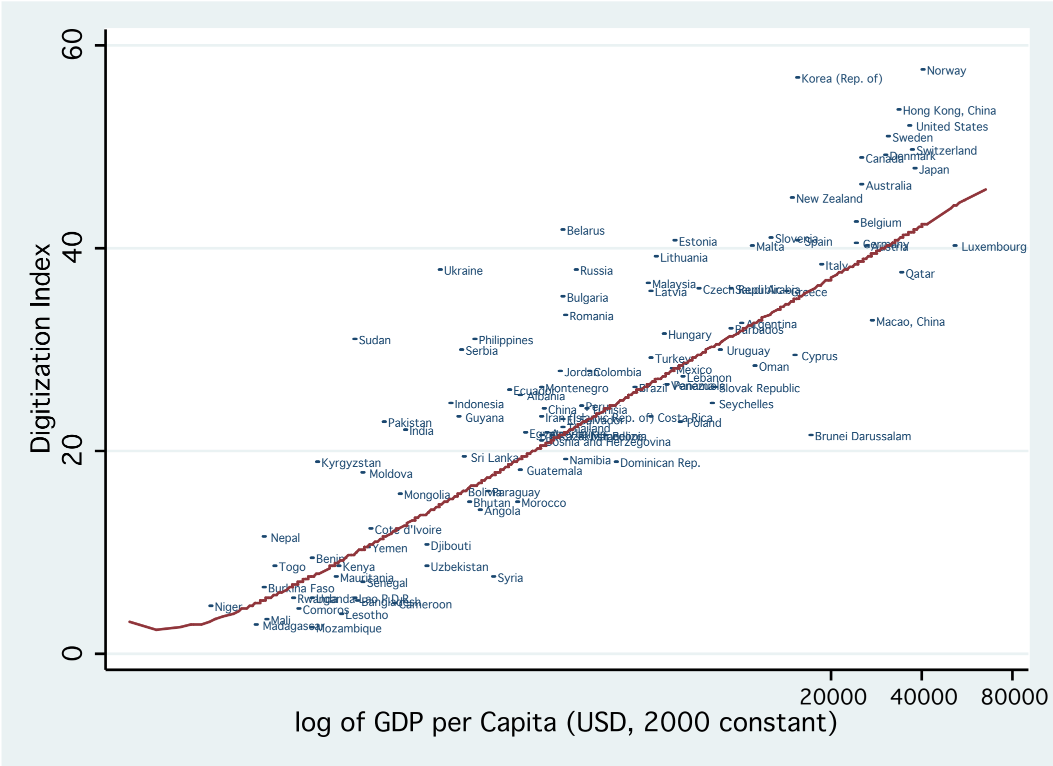

Figure 9: Digitization index with log GDP per capita in 2010 (Source: Authors calculations)

Extending this hypothesis, we tested the impact of digitization on economic growth. For this purpose we used an endogenous growth model that links Gross Domestic Product to the Fixed Stock of Capital, Labor Force and the Digitization index as a proxy of technology progress. This model for economic output stems from the simple Cobb-Douglas form: $Y = A(t)K^{1-b}L^{b}$ where *A(t)* represents the level of technology progress (in our case the Digitization Index), *K* corresponds to the fixed capital formation and *L* to the labor force.

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

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% of the index - seems insignificant. Additionally it is hard to find an instrument that could possibly control for this effect. Given the small effect we expect 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 (Table 4).

GDP ***(GDP$_{it}$)***	
Fixed Capital Stock (K_{it})	0.009**
Labor (L_{it})	0.048*
Digitization Index (D_{it})	0.060**

Constant	-
Year Effects	YES
Country Effects	YES
Observations	242
Adj-R^2	0.90

*,** denote statistical significance at the 10% and 5% level

Table 4: Economic Impact of Digitization

As expected, the capital formation is positive and significant although this metric varies considerably across different social, demographic and economic settings. Infrastructures have a disproportionately high effect for developed economies compared to the developing ones. Labor contribution to GDP is also consistent and significant; quality is often crucial in this case but the overarching concept is largely accepted.

The Digitization Index is found to have a positive and significant effect at the 5% level indicating a strong effect on economic output. Although this effect has been suggested by the earlier correlative approach, it is indeed supported by the econometric modeling too. Our calculations 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.

From a quantitative standpoint this estimate is also valuable. A ten point increase in the Digitization Index has approximately a 3% impact on GDP for the period 2004-2010 resulting on an annualized effect of 0.50%.[8][9] These effects are higher than the ones found in earlier works for broadband penetration. For example Koutroumpis (2009) estimated an annualized effect of 0.24% on GDP growth for a 10 point increase in broadband adoption for a European sample between 2002 – 2007, while Katz et a. (2010) found a contribution of 0.23% for Germany, and Gruber and Koutroumpis (2011) found a 0.2% for mobiles for the period 1990-2007. We believe the higher impact results from the fact that Digitization is a rather holistic approach compared to previous works, as it allows to estimate the actual contribution on GDP from a combined infrastructure, capacity, skill, quality and usage point. This significant finding stipulates that full economic impact ICT is achieved through the

[8] We use as a base case of an 'average' country whose Digitization Index increased by 10 points.
[9] Annual Growth Rate (CAGR) attributed to digitization derives from formula (1):

$$CAGR = \left[\left(\frac{\frac{Digitization_{2010}}{100-Digitization_{2010}} - \frac{Digitization_{2004}}{100-Digitization_{2004}}}{\frac{Digitization_{2010}}{100-Digitization_{2010}}}\right) * \hat{a}_3 + 1\right]^{1/6}$$

cumulative adoption of all technologies, in addition to the assimilation and usage in the production and social fabric. Achieving broadband penetration is only one aspect of required policies; maximization of economic impact can only be achieved through a holistic set of policies ranging from telecoms to computing to adoption of internet and eCommerce**. In a monetary equivalent, the impact of a 10 point increase is a €1.8 trillion added output on the world economy.**

Given this estimate, one would be interested to explore whether economic contribution is also related to the level of digitization. This relates to the hypothesis of increasing returns to scale in network technologies as the new markets and spillover effects contribute to this phenomenon. The initial idea is that countries with lower scores are often the ones that lack basic access, skills and usage that would prevent them from experiencing important effects on their economies. We therefore broke our sample into four different equally populated clusters. Four dummy variables are created (high, medium, low and very low) that take the value of 1 if the country is within the Digitization scores of interest or 0 if not. For the advanced cluster the threshold is 40, for the transitional 30-40, for the emerging 25-30 and for the constrained 0-25.

Returning to the model used in equation (1), it is now transformed to account for this scalable approach. The new model is:

(2) $$log(GDP_{it}) = a_1 log(K_{it}) + a_2 log(L_{it}) + high * log(D_{it}) + med * log(D_{it}) + low * log(D_{it}) + vlow * log(D_{it}) + \varepsilon_{it}$$

GDP (GDP$_{it}$)	
Fixed Capital Stock (K_{it})	0.010**
Labor (L_{it})	0.050*
Digitization (D_{it})	
High(high)	0.062**
Medium (med)	0.059**
Low (low)	0.051*
Very Low (vlow)	0.050*
Constant	-
Year Effects	YES
Country Effects	YES
Observations	242
Adj-R^2	0.90

*,** denote statistical significance at the 10% and 5% level

Table 5: Estimates on the scalable economic Impact of Digitization

The results presented in Table 5 are a confirmation of the increasing returns hypothesis. The advanced countries' cluster has a more pronounced effect on economic output compared to the rest of the groups. In particular, Advanced and Transitional stages are very closely tied and rather distinct from the Emerging and Constrained clusters. Evidently, there is still considerable heterogeneity within these clusters that might have an impact on the results. Nevertheless, the picture is quite clear from a macro perspective: there is indeed a scalable approach in this process and the returns appear to be largely increasing after a score in the region of 30 (Figure 6).

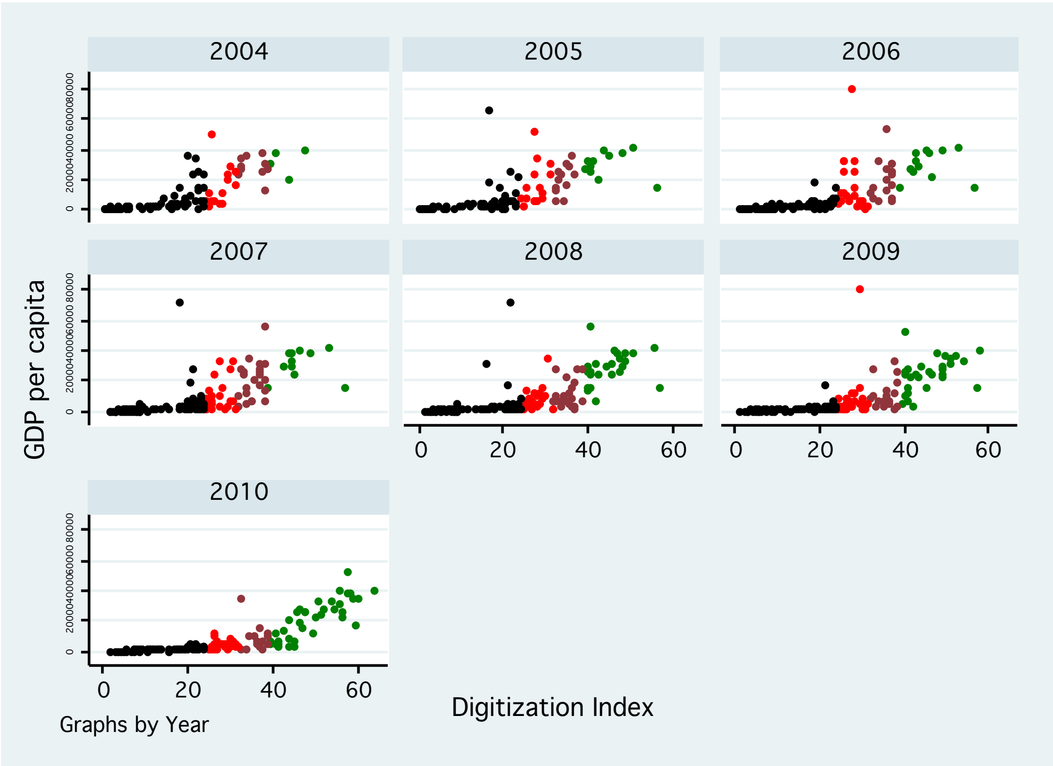

Figure 10: GDP per capita and Digitization Index among the four stages of Digitization (green is Advanced, brown is Transitional, red is Emerging and black is Constrained)

Again, from a quantitative standpoint this estimate is also valuable. A ten-point increase in the Digitization Index has the following impact:

- **Advanced** 3.1% compound impact on GDP for the period 2004-2010 resulting on an annualized effect of 0.51%
- **Transitional:** 3.0% compound impact on GDP for the period 2004-2010 resulting on an annualized effect of 0.50%

- **Constrained:** 2.5% compound impact on GDP for the period 2004-2010 resulting on an annualized effect of 0.42%
- **Emerging:** 2.5% compound impact on GDP for the period 2004-2010 resulting on an annualized effect of 0.41%

B. Impact on Unemployment

Turning to the other effects of Digitization, we attempt to measure its impact on job creation. For this purpose, we use a simple model that links unemployment rates with existing infrastructure, income, education levels, total exports as a percent of GDP and the credit performance. This model builds on the longer sample of the 18 countries that allows us for an assessment in a broader sample. Moreover, most of the employment statistics are unavailable in developing countries mainly due to a high percentage of undeclared employment and varying working conditions. Therefore the focus of this exercise is the sub sample presented in Figure 1. The model to measure the impact of Digitization on unemployment is the following (3):

(3) $$U_{it} = b_1 D_{it} + b_2 K_{it} + b_3 Edu_{it} + b_4 GDPC_{it} + b_5 Exp_{it} + b_6 Cr_{it} + \varepsilon_{it}$$

Unemployment (U $_{it}$)	
Digitization (D_{it})	-0.084**
Fixed Capital Stock (K_{it})	-0.265**
Education (Edu_{it})	0.006
GDPC ($GDPC_{it}$)	0.018
Exports (Exp_{it})	1.261**
Credit (Cr_{it})	-0.572
Constant	-
Year Effects	YES
Country Effects	YES
Observations	150
Adj-R^2	0.85

*,** denote statistical significance at the 10% and 5% level

Table 6: The impact of Digitization on Unemployment

The unemployment impact model controls for country and year fixed effects. Digitization is negative and significant relatively to the unemployment rate as Fixed Capital formation is. Education and GDP per capita do not seem to be significantly related to this metric whereas the percent of Exports seems to positively affect unemployment. **A 10% increase in the**

Digitization index leads to a 0.84% decrease in unemployment rate. Again, full deployment and assimilation of ICT has a much larger impact on employment because it contributes to more jobs in the ICT sector (software development, Business Process Outsourcing, equipment manufacturing and parts supplies). In addition, the impact of assimilation of ICT through enhanced usage has spill-over impact on other sectors of the economy (in particular, trade, financial services, health care).

C. Impact on Welfare

One of the most interesting and yet unexplored parameters of Digitization is the link to overall societal welfare. This suggests that Digitization has a direct effect on the overall happiness and life satisfaction that people earn from the capacities and capabilities of engaging in digital technology platforms. A classic counter-argument stems from the causal link between the life satisfaction and Digitization, manifesting that people might self-select to be in a country or regional context with higher provisions of digital services rather than being the subjects of various offerings. Nevertheless for the vast majority of population, one would infer that people would not migrate for an abundance of Digitization deliverables. For this purpose we choose not to model this relationship in a strict quantitative manner but prefer to highlight it in a correlative approach. Several indexes exist that measure Subjective Well Being, Happiness and Life Satisfaction. We purposely construct a sample of life satisfaction observations for a cluster of 48 countries from published reports from the World Database of Happiness repository. Plotting the annual observations and fitting a polynomial curve, we identify an almost linear relationship of life satisfaction and the degree of digitization. One reason for the kink in most curves is the fact that several observations underestimate Digitization score due to missing observations[10].

[10] The authors have chosen to penalize countries that fail to report one ore more components of the Digitization Index up to the limit of four out of six. This suggests that a country with three or lees elements will receive an N/A at the Digitization score.

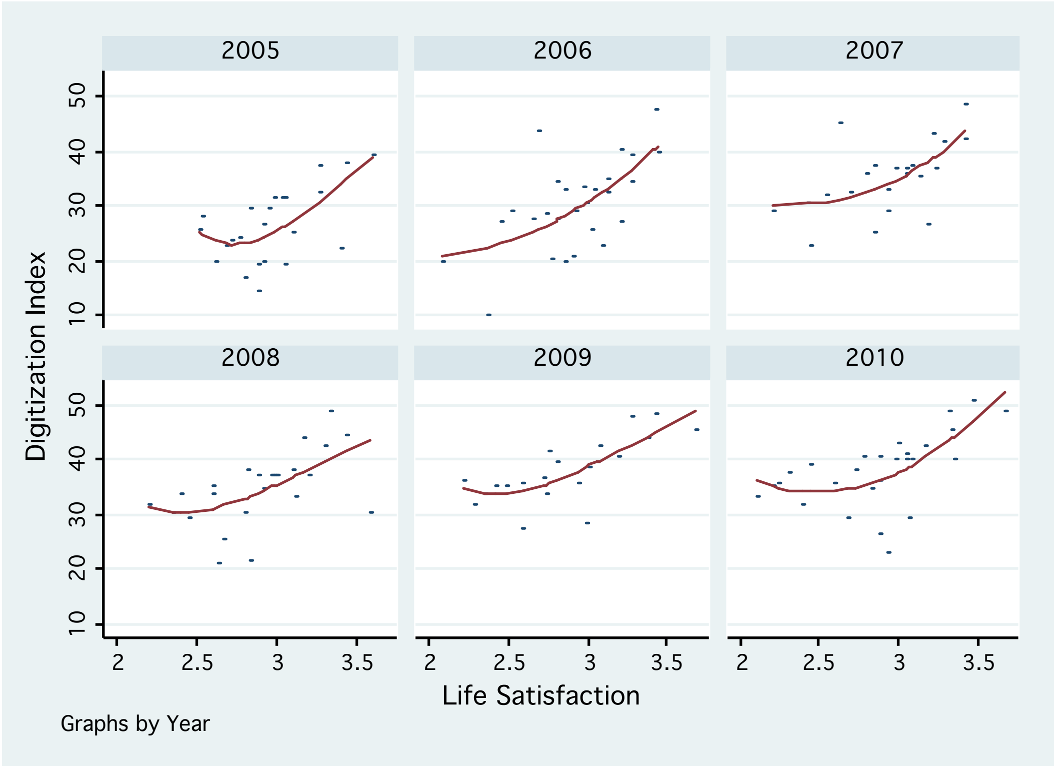

Figure 11: The Digitization Index and the Life Satisfaction for 48 countries in the sample

To account for potential discrepancies in the life satisfaction metrics we also utilize the Gallup Thriving Index that is available for 2010. Plotting this index (Figure 8) shows a slightly differentiated picture. Below a certain Digitization score (perhaps close to 25) the thriving Index is almost unrelated to Digitization. Nevertheless there is a clear link between higher levels of perceived accomplishment and overall country Digitization.

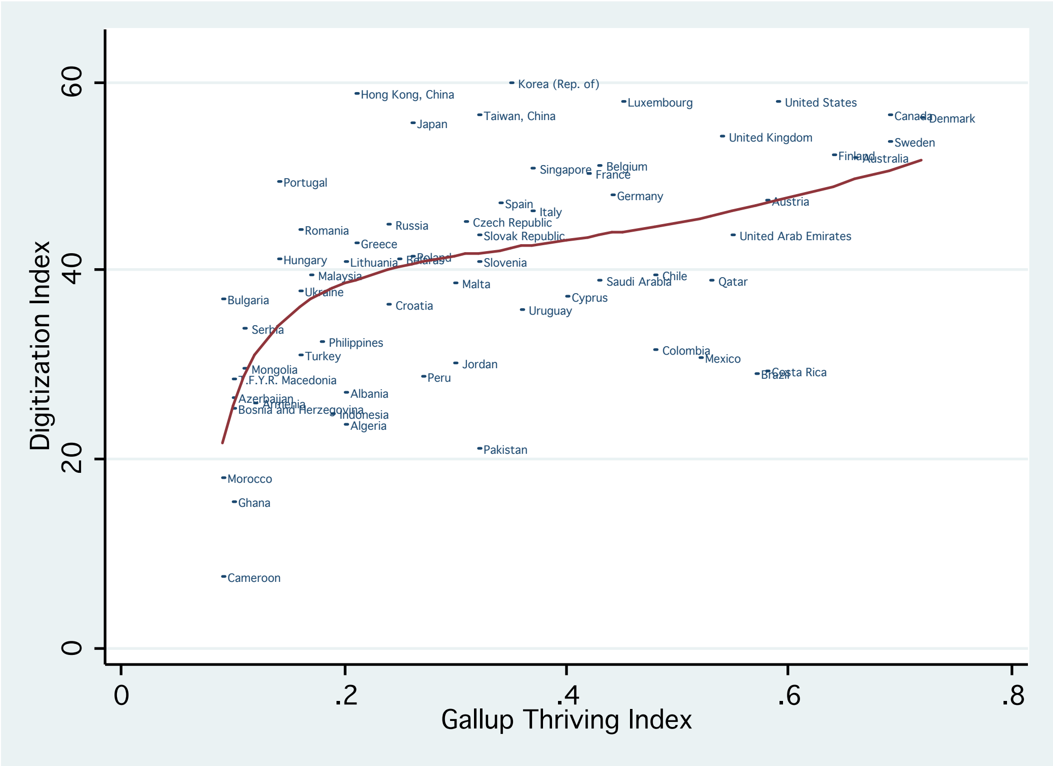

Figure 12: The Digitization Index and the Gallup Thriving Index

This might indicate that well-being at lower levels of development is more related to the satisfaction of basic needs (such as food and shelter in the Maslow Scale), while at higher levels of development, once these needs are addressed, digitization becomes more relevant.

7. Conclusion

To sum up, we have found that digitization index represents a powerful instrument to begin measuring not only the deployment and adoption of information technologies in a discrete fashion, but to incorporate usage processes, representing the holistic dimension of impact. Secondly, the index allows the identification of clusters of countries moving along a developmental path, linking it to the adoption of specific policies. However, more research has to be conducted to understand the causal link between digitization and specific policies. Thirdly, digitization appears to have a higher contribution to economic growth and job creation than discrete technologies. This points out to a multiplying factor that captures the enhanced impact of a developed technology eco-system. Lastly, digitization also appears to have an impact on well-being, although further analysis needs to be conducted beyond the descriptive and correlational statistics contained in this paper.

The public policy implications of these findings are several. First, the enhanced impact of digitization vis-à-vis broadband requires tackling the formulation of ICT policies in a comprehensive and holistic manner, covering all areas of the eco-system. Secondly, digitization policies need to initially focus on affordability (for example, achieve broadband monthly fee/GDP per capita <0.12), access (targeting, as minimum, 22 % broadband penetration, at least 70+% of population using a PC, and 40% penetration of broadband wireless). Third, complementing the deployment of networks, government policies need to emphasize usage, targeting to reach 15% of eCommerce transactions/retail, an eGovernment web measurement index higher than 30, and Internet adoption higher than 30%. Fourth, countries that aim at achieving a quantum leap in digitization (25 points rise of the index in five years) need to combine four levers: telecom market liberalization with spill-over impact on eco-system, usage promotion policies, a combination of active government involvement and private sector participation, and centralized convergent state planning. Fifth, digitization promotion policies need to be combined with industrial sector related policies aimed at generating the spill-over ICT impact on economic growth and job creation.

It is important to emphasize that the social impact of digitization is contingent upon a number of caveats. At lower levels of development, the contribution of digitization to the well-being of the population will be attenuated insofar that primary needs are not addressed. Once these are met, achieving high levels of digitization will contribute to social equality, human development, and access of basic services. As such, these goals will not be met unless digitization promotion is not complemented with traditional economic and social development policies.

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Appendix

Digitization Index Rankings for 2004 and 2010

COUNTRY	2004	2010
Norway	47.93	63.73
Iceland	32.40*	59.99
Korea (Rep. of)	38.25*	59.82
Hong Kong, China	30.38*	58.88
Switzerland	33.88	58.59
United States	37.66*	57.94
Luxembourg	25.81**	57.85
Taiwan, China	N/A	56.41
Canada	31.37*	56.34
Israel	43.80	56.29*
Denmark	39.63	56.08
Japan	40.78	55.61
United Kingdom	38.93	54.35
Sweden	37.97	53.79
Finland	37.46	52.18
Australia	32.03*	52.03
Belgium	23.71*	51.25
Singapore	32.48**	50.81
France	29.59	50.16
Portugal	28.19	49.28
Germany	31.79	47.86
Austria	31.40	47.44
Spain	31.59	47.15
Italy	29.72	46.35
Ireland	32.43	46.31*
Netherlands	22.32*	45.96*
Czech Republic	26.60	45.06
Russia	12.20**	44.87
Romania	19.71*	44.18
Slovak Republic	22.93	43.68
United Arab Emirates	20.06**	43.62
Greece	22.67	42.91
Poland	24.44	41.52

Hungary	25.61	41.18
Belarus	24.90*	41.14
Slovenia	24.97	40.91
New Zealand	22.52*	40.90*
Lithuania	27.31	40.79
Chile	22.09*	39.45
Malaysia	28.25*	39.38
Mauritius	13.53*	38.88
Saudi Arabia	20.47**	38.84
Qatar	21.96**	38.84
Malta	16.78**	38.74
Estonia	23.94*	37.85
Ukraine	22.26*	37.71
Cyprus	23.68*	37.11
Bulgaria	19.65**	36.85
Croatia	N/A	36.35
Latvia	19.66	36.10
Uruguay	14.27**	35.84
Oman	N/A	34.61
Argentina	19.59*	34.55*
Serbia	N/A	33.82
Macao, China	N/A	32.92*
Iran (Islamic Rep. of)	N/A	32.57
Philippines	23.63*	32.41
Bahrain	17.97**	32.37*
Colombia	13.25*	31.67
Turkey	19.14	31.04
Mexico	19.52	30.84
Barbados	N/A	30.44*
Seychelles	N/A	30.21*
Jordan	5.67**	30.11
Lebanon	N/A	29.95*
Mongolia	5.76*	29.75
Costa Rica	16.43**	29.21
Brazil	16.92	29.10
Peru	13.18*	28.84
T.F.Y.R. Macedonia	6.30**	28.54
Albania	N/A	27.13
Venezuela	19.97*	27.10
Panama	19.06**	26.91**
Azerbaijan	N/A	26.64
Botswana	N/A	26.21*
Trinidad and Tobago	N/A	26.08**
China	17.37*	25.88*
Ecuador	10.33*	25.86*
Bosnia and Herzegovina	N/A	25.46

Georgia	6.25*	25.30*
Tunisia	N/A	24.08*
Thailand	3.55*	23.87
Algeria	1.72**	23.80
Kazakhstan	10.96**	23.78*
Guyana	1.67**	23.74
India	16.22**	22.67*
Egypt	N/A	22.39*
El Salvador	N/A	21.78*
Paraguay	N/A	21.68*
Moldova	1.67*	19.64*
Cape Verde	N/A	17.73**
Syria	N/A	15.45*
Senegal	N/A	9.49*

* Missing 1 component

** Missing 2 components