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Measuring digitization: A growth and welfare multiplier

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ABSTRACT

Digitization encapsulates the social transformation triggered by the mass adoption of digital technologies that generate, process and transfer information. The digitization index introduces a global measure of national performance reflecting ubiquity, affordability, reliability, speed, usability and skills. Output and welfare rise with the index while manifesting increasing returns to scale some implications for ICT public policy are drawn from these findings.

1. Introduction

Technological revolutions are marked with innovations that shape industrial production and drive long-term economic growth. These revolutions signify historic periods when their effects cut across all 'commonsense' criteria for social interactions and business behavior (Landes, 1969; Freeman and Perez, 1988; Nye, 1990). Digitization, per se is the process of converting analog 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 (mobile or fixed broadband networks) and semiconductor technologies (computers/laptops, wireless devices/tablets), software and computational 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).

There is a strong consensus in literature on the positive impact of computer use, mobile and fixed broadband networks adoption on economic growth, productivity and welfare. In particular broadband adoption has been found to boost growth and productivity (Qiang and Rossotto, 2009; Czernicz et al., 2011) while returns almost double once a critical mass of subscribers is achieved (Koutroumpis, 2009; Gruber and Koutroumpis, 2011). Productivity has also been found to increase with computer investments and network use (Varian et al., 2002; Brynjolfsson and Hitt, 2003) but firm level evidence on computerization points that it 'does not by itself transform a firm from being a poor performer to a top performer within its sector' (Grimes et al., 2011). Additionally the long term effects are considerably larger while the observed contribution of computerization is accompanied by relatively large and time-consuming investments in complementary inputs, such as organizational capital, that may be omitted in conventional calculations of productivity. On top of these findings, managerial culture and skills are critical for the return of the digitization infrastructure on the economy (Bloom et al., 2012) as well as the regulatory environment (Gust and Marquez, 2004; Van Reenen et al., 2010).

2. Digitization index

This research presents a measure of cross-country progress along the digitization development path. The digitization index consists of six elements and twenty-three indicators Table 1 and 2 measuring tangible parameters of perceived digitization metrics. Ubiquity refers to the adoption of mobile and fixed broadband networks accounting for broadband accessibility and ownership of data devices, such as PCs. Affordability is essential and derives from the relative access costs of providing such access. Reliability of networks depends on the annual network investment per subscriber and the faults reported per line. Speed is proxied by the performance of country level international links and the capacity of wireline 'last mile' offerings. Usage is a key component of digitization and includes the utilization and adoption of all commercial activities, government services, social media adoption and data usage. Skills contribute to digitization both in terms of development of local service offerings and usage capacities.

The index has been constructed following a typical methodology for composite index validity assessment (see Appendix A. 1). Data has been normalized to meet these criteria and allow for spatial and temporal comparisons. The sample includes 150 countries and spans from 2004 to 2010. Norway tops the charts Table 3, a consistent leader since 2004. A cluster of countries with similar scores follows: Iceland, Republic of Korea, Hong Kong and Switzerland. Excluding Korea, countries with less than 8 millions citizens populate the top spots indirectly alluding to a link between scale and the digitization progress. Close to the leaders are the United States, Canada, Denmark and Japan and other European countries follow.

3. Impact on economic output

Extending our analysis, 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 classic production function form $Y = A(t)K^{1-b}L^{b}$ where

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Table 1
Indicators, and sub-indicators of the digitization index.
Source: adapted from Sabbagh et al., 2012.

Components	Subcomponents	Sub-Subcomponents
Affordability	Residential fixed line cost adjusted for GDP/capita	Residential fixed line tariff adjusted for GDP/capita
		Residential fixed line connection fee adjusted for GDP/capita
	Mobile cellular cost adjusted for GDP/capita	Mobile cellular prepaid tariff adjusted for GDP/capita
		Mobile cellular prepaid connection fee adjusted for GDP/capita
	Fixed broadband Internet access cost adjusted for GDP/capita	
Infrastructure reliability	Investment per telecom subscriber (mobile, broadband and fixed)	Mobile investment/telecom subscriber
		Broadband investment/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/month /capita	
	SMS Usage	
Human capital	% Engineers in labor force	
	% Skilled labor	

$A(t)$ 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. 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 rather small and potentially insignificant. Additionally it is hard to find an instrument that could possibly control this effect. Given the relatively small effect, we expect, it has on GDP we extended the analysis controlling for country and year fixed effects Table 4 to help mitigate potential problems and account for the heterogeneity of our sample.

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

The results suggest that a 10 point increase in the index has approximately a 3% impact on GDP Fig. 1 for the period 2004–2010 resulting in an annualized effect of 0.50%. We use as a base case an 'average' country whose digitization index increased by 10 points. Annual Growth Rate (CAGR) attributed to digitization is derived from the formula

$$CAGR = \left[\left(\frac{(digitization_{2010})/(100 - digitization_{2010}) - (digitization_{2004})/(100 - digitization_{2004})}{(digitization_{2010})/(100 - digitization_{2010})} \right) \hat{a}_3 + 1 \right]^{1/6} \quad (2)$$

These effects are higher compared tothose of broadband only impact studies. Koutroumpis (2009) estimated an annualized effect of 0.7%–1% on GDP growth for a 10 points increase in broadband adoption for a European sample between 2002 and 2007, while Czernich et al. (2011) found a contribution of 0.9–1.5% for the period 1996–2007, and Quiang et al. (2009) a 1.21–1.38% for broadband and a global sample 1980–2002. We believe that the higher impact results from the fact that Digitization is a rather holistic proxy compared to previous works, as it allows estimation of the actual contribution on GDP from a combined infrastructure, capacity, skill, quality and usage point. In a monetary equivalent, the impact of a 10 points increase is a €1.8 trillion added output on the world economy. Subsequently we break our sample into four clusters depending on the relative national scores: the advanced cluster (> 40), the transitional (30–40), the emerging (25–30) and the constrained (0–25). Testing the relevance of returns to scale we modify our model to account for different clusters and estimate the corresponding coefficients:

$$\ln(GDP_{it}) = a_1 \ln(K_{it}) + a_2 \ln(L_{it}) + a_{VLOW} \ln(D_{it}) + a_{LOW} \ln(D_{it}) + a_{MED} \ln(D_{it}) + a_{HIGH} \ln(D_{it}) + \varepsilon_{it} \quad (3)$$

An identical 10-point increase in the index has increasing en masse effects across clusters: 3.1% Fig. 2 for the advanced (0.51% annually), 3% for the transitional (0.5% annually), 2.5% for the constrained (0.42% annually) and 2.5% for the emerging (0.41% annually).

While the economic impact of digitization is measured on the aggregate through digitization index, the relation between each of the index components and the economy is worth expanding on. In particular, the ubiquity component, which measures the construction of networks, and reliability, which is captured through aggregate investment in infrastructure have a fairly straightforward "construction effect" (Katz and Suter, 2009, 2010). On the other hand, the usage component which measures the utilization of digital networks, is directly linked to numerous spillover effects on the economy. For example, the increase in e-commerce as a percentage of retail commerce significantly contributes to the efficiency in the transaction of goods and services. Finally, some first results on the 'returns to speed' hypothesis have already been confirmed (Rohman and Bohlin, 2012).

4. Impact on welfare

One of the most interesting and yet unexplored parameters of digitization is the link with overall societal welfare. The theory behind this link derives from reported life satisfaction that may arise as a result of digital service use. A classic counter-argument stems from the reverse causal link, manifesting that people might self-select to reside in places with better infrastructures, though

Table 2
Data sources of the indicators of the digitization index and analysis.

Name of Indicator	Source
Residential fixed line tariff adjusted for GDP/capita	ITU
Residential fixed line connection fee adjusted for GDP/capita	ITU
Mobile cellular prepaid tariff adjusted for GDP/capita	ITU
Mobile cellular prepaid connection fee adjusted for GDP/capita	ITU
Fixed broadband Internet access tariff adjusted for GDP/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/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
Gross Domestic Product (current USD)	World Bank
Gross Fixed Capital Formation (current USD)	World Bank
Labor force % (15–64)	World Bank

Table 3
Top 20 countries of the digitization index.

	2004	2010
Norway	47.93	63.73
Iceland	32.40[a]	59.99
Republic of Korea	38.25[a]	59.82
Hong Kong	30.38[a]	58.88
Switzerland	33.88	58.59
United States	37.66[a]	57.94
Luxembourg	25.81[b]	57.85
Taiwan	N/A	56.41
Canada	31.37[a]	56.34
Israel	43.80	56.29[a]
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[a]	52.03
Belgium	23.71[a]	51.25
Singapore	32.48[b]	50.81
France	29.59	50.16
Portugal	28.19	49.28
Germany	31.79	47.86

[a] Computed out of 5 components.
[b] Computed out of 4 components.

Table 4
Estimating the effect of digitization index on GDP.

GDP (***GDP***$_{it}$)	(1)	(3)
Fixed capital stock (K_{it})	0.009[b]	0.010[b]
Labor (L_{it})	0.048[a]	0.050[a]
Digitization (D_{it})	0.060[b]	
High (high)		0.062[b]
Medium (med)		0.059[b]
Low (low)		0.051[a]
Very low (vlow)		0.050[a]
Constant	–	–
Year effects	Yes	Yes
Country effects	Yes	Yes
Observations	242	242
Adj-R^2	0.90	0.90

Columns (1) and (2) refer to the models in the text.
[a] Denotes statistical significance at the 10% level.
[b] Denotes statistical significance at the 5% level.

one would infer that migration for an abundance of such deliverables is rather rare. For this purpose we highlight this relationship in a correlative approach. We purposely construct a sample of life satisfaction observations for a cluster of 48 countries Figs. 3 and 4 from published reports from the World Database of Happiness repository. Contrary to the economic growth observation, welfare exhibits a quasi-exponential link to digitization suggesting that only after a certain score–necessarily reflecting usage–the local population realizes this transformation.

5. Public policy

The digitization index represents a powerful instrument to begin measuring not only the deployment and adoption of information technologies in a discrete fashion, but also to incorporate usage processes, representing the holistic dimension of impact.

Second, 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 fully understand the links between digitization and specific policies. An early analysis of these findings for Latin America (Katz et al., 2013) indicates that specific policies can be directly linked to dramatic improvements in the digitization index. For example, the focused set of pro-digitization policies tend to result in an acceleration of the index driven by device and service penetration, as well as the speed of broadband access. In other cases, countries achieve a substantial improvement in the affordability component due to a strong decline of wireless prices as a result of pro-competition policies. Moreover, countries tend to also benefit from the deployment of an international data transmission link that reduces transit prices and data latency.

Third, digitization appears to have a higher contribution to economic growth thanthose of discrete and isolated technologies. This points out to a multiplying factor that captures the enhanced impact of a developed technology ecosystem. Lastly, digitization

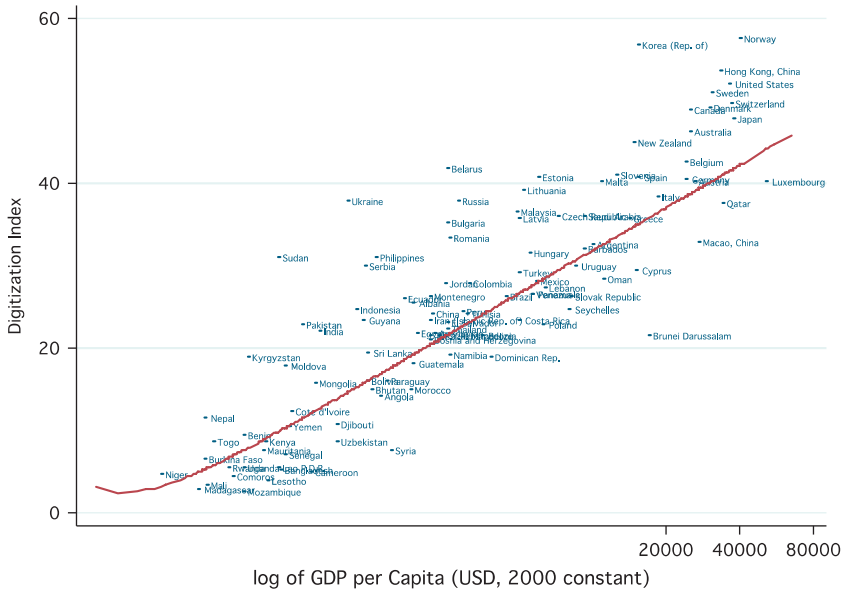

Fig. 1. Digitization index with log of GDP per capita in 2010.
Source: Authors calculations.

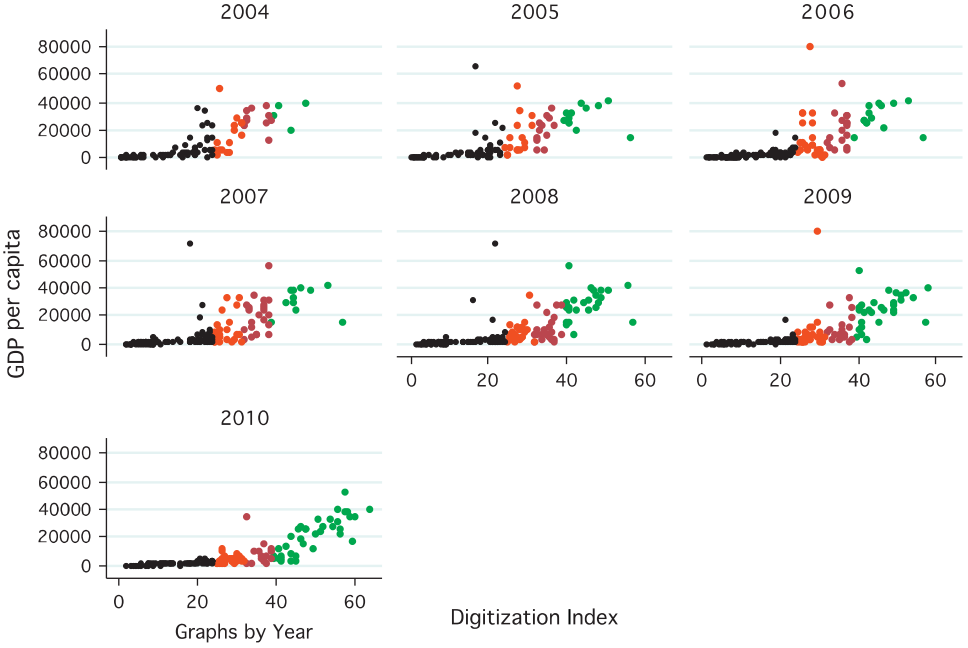

Fig. 2. GDP per capita and digitization index among the four stages of digitization (green is advanced, brown is transitional, red is emerging and black is constrained). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

also seems to be linked with self-reported well-being in line with recent findings (Graham and Nikolova, 2013; Kavetsos and Koutroumpis, 2011), although there are clear methodological limitations when trying to move 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-a-vis broadband requires tackling the formulation of ICT policies in a comprehensive and holistic manner, covering all areas of the ecosystem. This drives the need to insert broadband planning within the larger ICT infrastructure and usage context provided by digital agendas. Second, digitization policies need to initially focus on affordability–addressing country and region specific particularities–and access-stargeting a fixed or mobile critical mass of broadband subscribers depending on local socioeconomic conditions while adjacent policies can help with local content development and network usage. Countries that aim at achieving a quantum leap in digitization (in this case an increase of 20 points of the index in a period of 5 years or less) need to combine four levers: telecom market liberalization with spill-over impact on ecosystem, usage promotion policies, a combination of active government involvement and private sector participation, and centralized convergent state planning. Last, digitization promotion policies need to be combined with industrial sector related policies aimed at generating the spillover 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

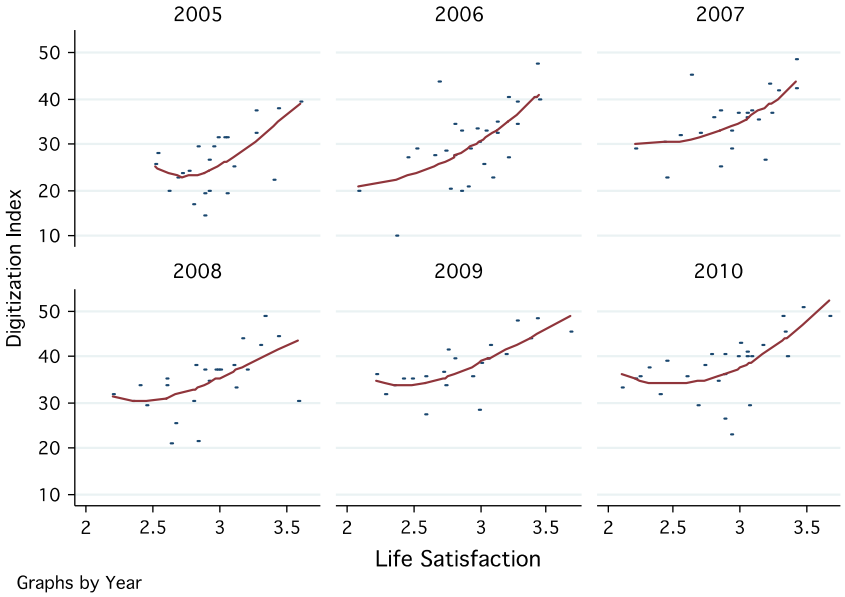

Fig. 3. The digitization index and the life satisfaction for 48 countries in the sample.

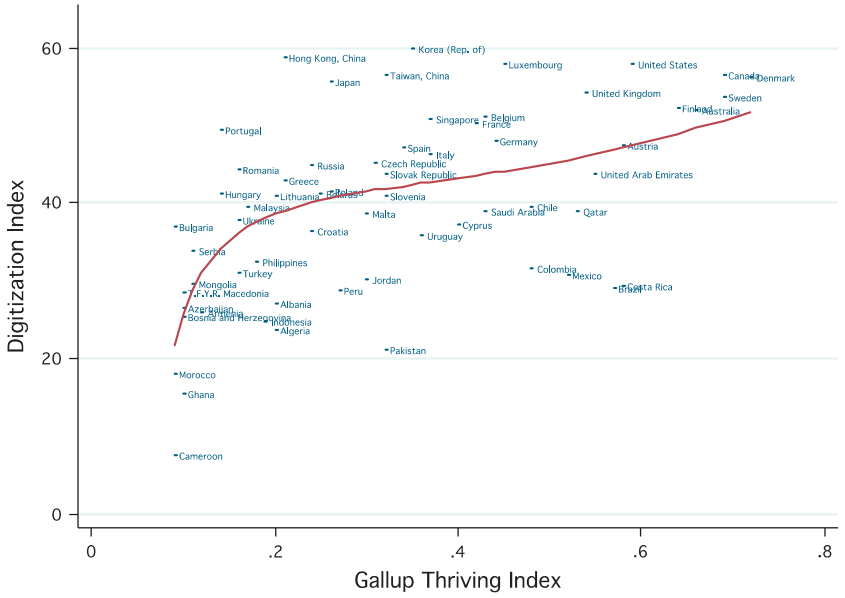

Fig. 4. The digitization index and the Gallup Thriving index.

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. Digitization is found to be critical but in no way a panacea for wider socio-economic development.

Appendix

A.1 First the theoretical framework of the index is set up and the variables–components and subcomponents–are selected. Statistically valid sub-indicators in each component are selected 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 components. 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.

A.2 This digitization index was originally developed by Booz & Co., the management consulting firm, and published in Sabbag et al. (2012).

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