Columbia Business School

Measuring socio-economic digitization: A paradigm shift (*)

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(*) 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.

Digitization is the capacity to use digital technologies to generate, process, share and transact information

- At the most basic level, digitization is the process of converting analogue information into a digital format
- In a broader context, digitization is defined as the 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
- 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)

To achieve a significant impact, digitization has to be widely diffused within the economic and social fabric of a given nation

- Adopted at three levels
  - Utilized by individuals, economic enterprises and societies
  - Embedded in processes of delivery of goods and services
  - Relied upon to deliver public services

- For this condition to occur, digitization has to fulfill several conditions
  - Affordable to allow scalable impact
  - Ubiquitous reaching most population of a national territory
  - Accessible by multiple fixed and mobile voice and data devices
  - Reliable, providing sufficient capacity to deliver vast amounts of information at speeds that do not hinder their effective use

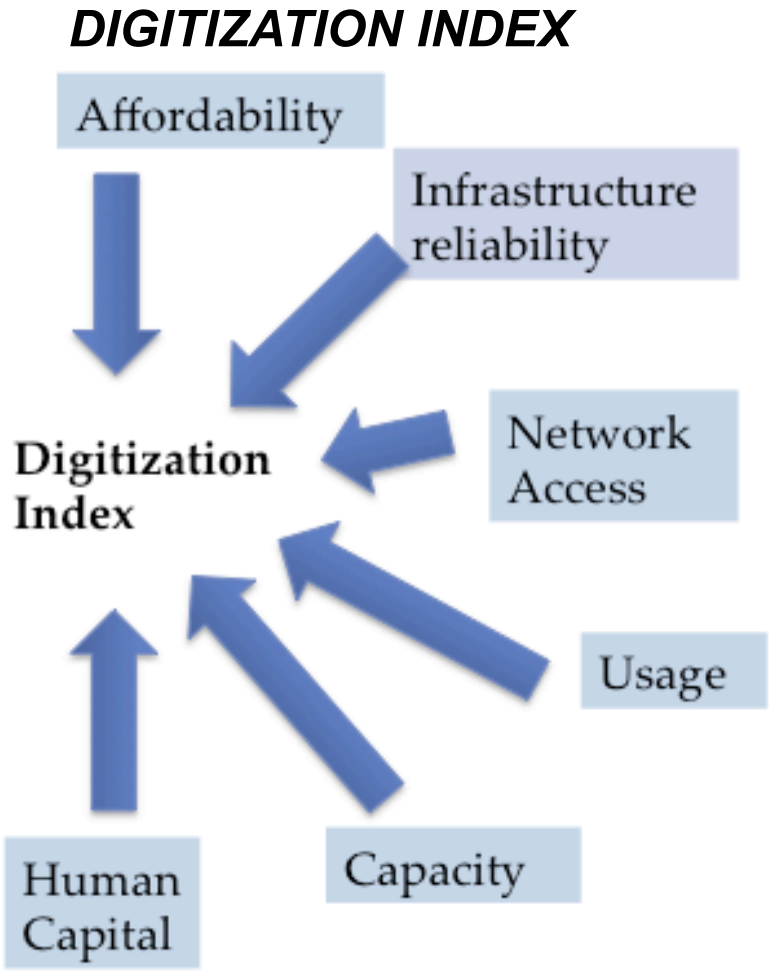
The purpose of this research was to develop a digitization index and measure its contribution to economic and social development

- Starting premise: most research measuring social and economic impact of ICT focuses on discrete technology platforms, such as mobile penetration, access to the Internet and broadband adoption

- Holistic adoption and usage of ICT results in enhanced effects that go beyond the contribution of specific platforms

- The transition to digitally-intensive societies should be assessed across a multiple set of metrics, capturing not only **penetration**, but also **usage** of these technologies in order to capture the full impact of digitization

A composite index comprising 23 indicators was developed to measure the level of digitization of a given country



Components	Subcomponents
Affordability	Residential fixed line tariff adjusted for GDP per capita
	Residential fixed line connection fee 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	Mobile investment per telecom subscriber
	Broadband investment per telecom subscriber
	Fixed line investment per telecom subscriber
Network Access	Fixed Broadband penetration
	Mobile Phone penetration
	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

Data to develop the index was compiled from multiple sources

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

The index was constructed following a typical methodology for composite index validity assessment

- Define the theoretical framework of the index and select variables
- Each sub-index was normalized, by using the mean and one standard deviation, and cropping the extremes
  - Affordability sub-index: the inverse of the maximum is used to cap it
  - Mobile penetration: was capped at a maximum of 100% to prevent over-weighting
- For each of the six components a minimum of subcomponents is assigned depending on the scarcity of the available information
- For the Index calculation, a minimum of four components is required
- Correlations were initially run between the digitization index and other technology indices to test its ranking value
  - Network Readiness Index (WEF)
  - ICT Opportunity Index (ITU)
  - Digital Opportunity Index (ITU)

Finally, the Kaiser-Meyer-Olkin measure of sampling adequacy was ran, indicating that the index is statistically sound

```
Test scale = mean(unstandardized items)
Reversed items:  a1 a2 a3 a4 a5

Average interitem covariance:     234.5332
Number of items in the scale:           23
Scale reliability coefficient:     0.9416
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```
Test scale = mean(unstandardized items)
Reversed item:  affordability

Average interitem covariance:     198.3664
Number of items in the scale:            6
Scale reliability coefficient:     0.8640
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Kaiser-Meyer-Olkin measure of sampling adequacy

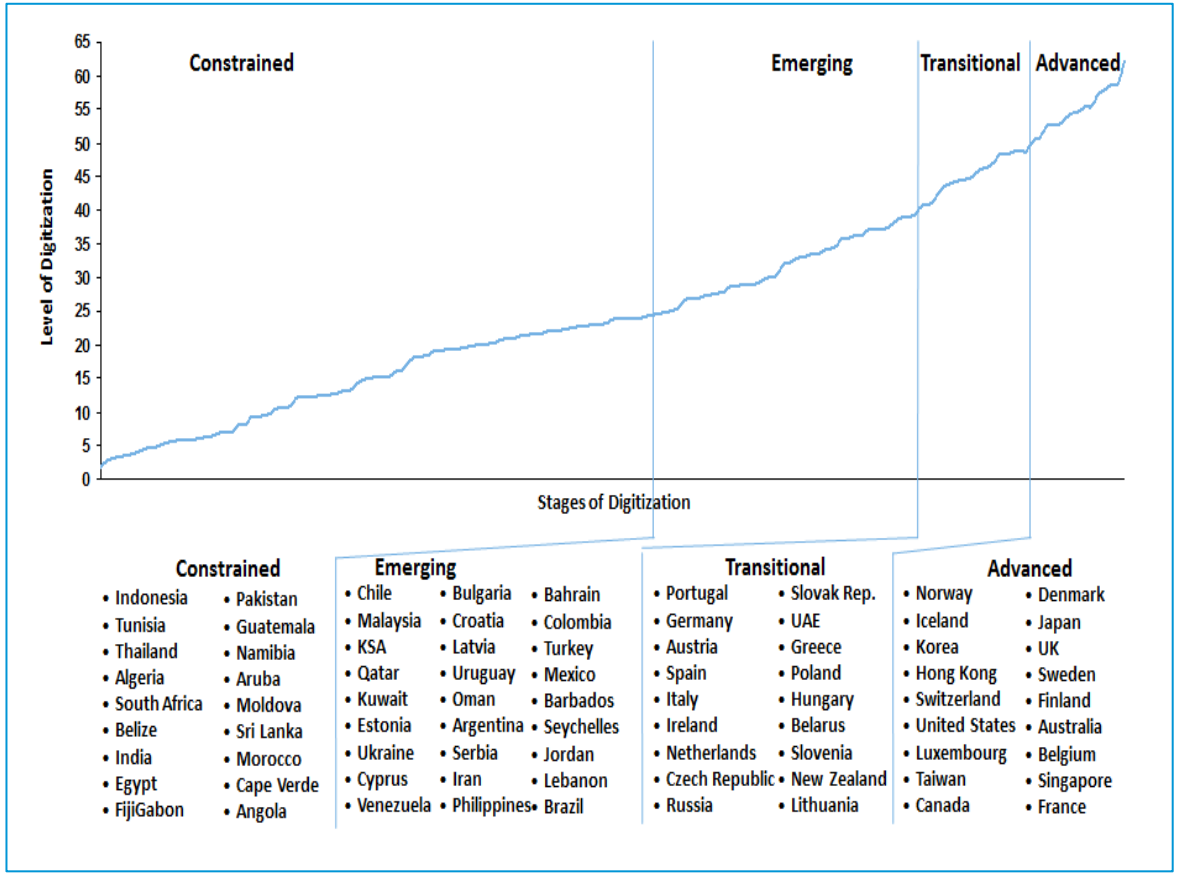
Variable	kmo
affordabil~y	0.8854
infrastruc~e	0.8741
networkacc~s	0.7530
capacity	0.8154
usage	0.8394
human	0.8311
Overall	0.8202

The estimated statistics derive from factor analysis:

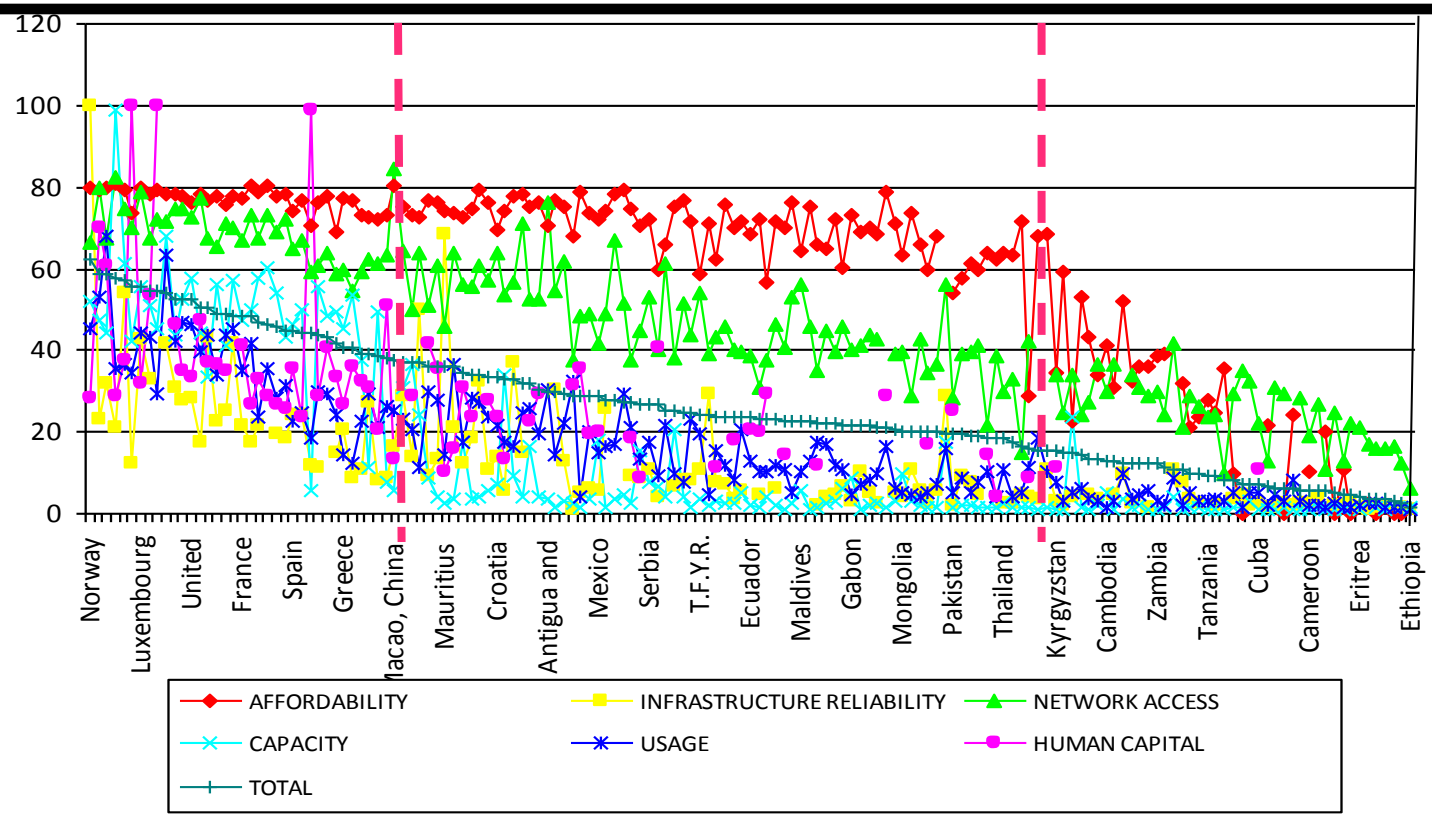
- KMO measures how distinct the factors (components of the index) are so that they do not over-identify latent phenomena. All factor estimates need to be higher than 0.60 and the overall KMO>0.8
- The Cronbach coefficient alpha is the most common estimate of internal consistency of items in a model or survey. It assesses how well a set of sub-indicators measures a single one-dimensional object. Reliable A-threshold >0.8
- With KMO=0.82 and $Alpha_{23}$=0.94 $Alpha_{6}$=0.86 the Digitization Index is statistically sound

The 2010 Digitization Index was calculated for 150 countries, revealing four developmental stages

- Index computed for 150 countries and the period 2004-2010
- Four clusters identified:
  - **Advanced** (Index>40)
  - **Transitional** (Index>30&<40)
  - **Constrained** (Index>25&<30)
  - **Emerging** (Index<25)



When ranking countries for each of the six sub-components, we determined that access and affordability are less of a world problem



- For all countries, normalized usage sub-index never matches the levels of access sub-indices, which indicate a big challenge across the world
- For all OECD and middle income countries, the sub-indices affordability and network access tend to be consistently above the digitization index indicating that countries have addressed the access challenge
- The affordability and capacity sub-indices tend to rapidly drop at low GDP levels, indicating a big gap between mature and low income countries

In addition to assess digitization development paths, we tracked its evolution over time for selected countries

- Constructed a time series of digitization for 18 countries between 1995 and 2010

- Assessed the evolution of the index attempting to determine idiosyncratic country paths to digitization
  - Emerging countries undergo quantum leap changes in digitization triggered by key policy initiatives
  - Mature countries exhibit a consistent, yet gradual, change in digitization performance

- Analyzed changes in the index in an attempt to identify specific events or policies that have triggered a change at a specific point in time

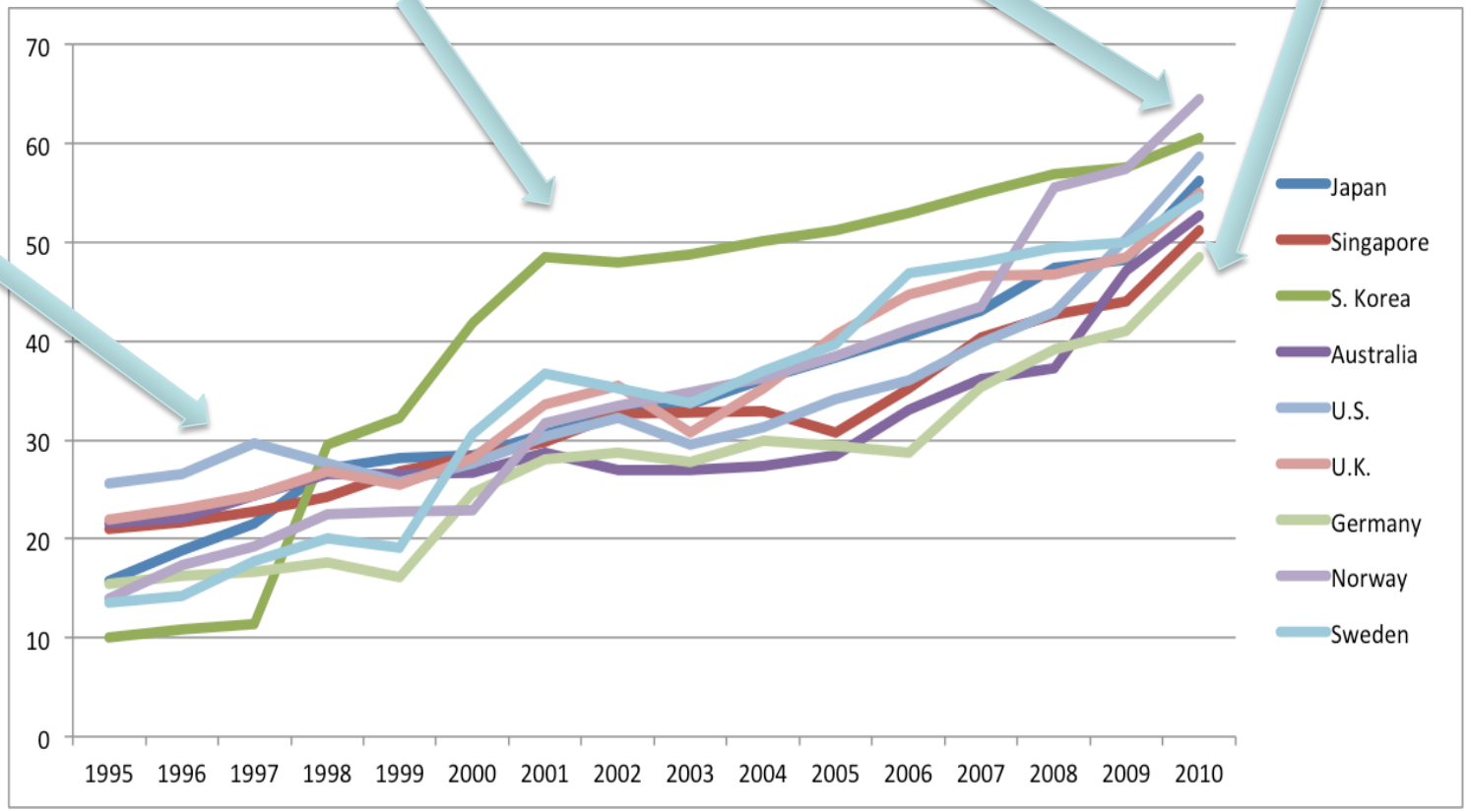
Most industrialized countries have consistently increased their digitization level over the past fifteen years, albeit at different rates

Norway leapfrogging through systematic adoption and timely launch of network access, skills and services

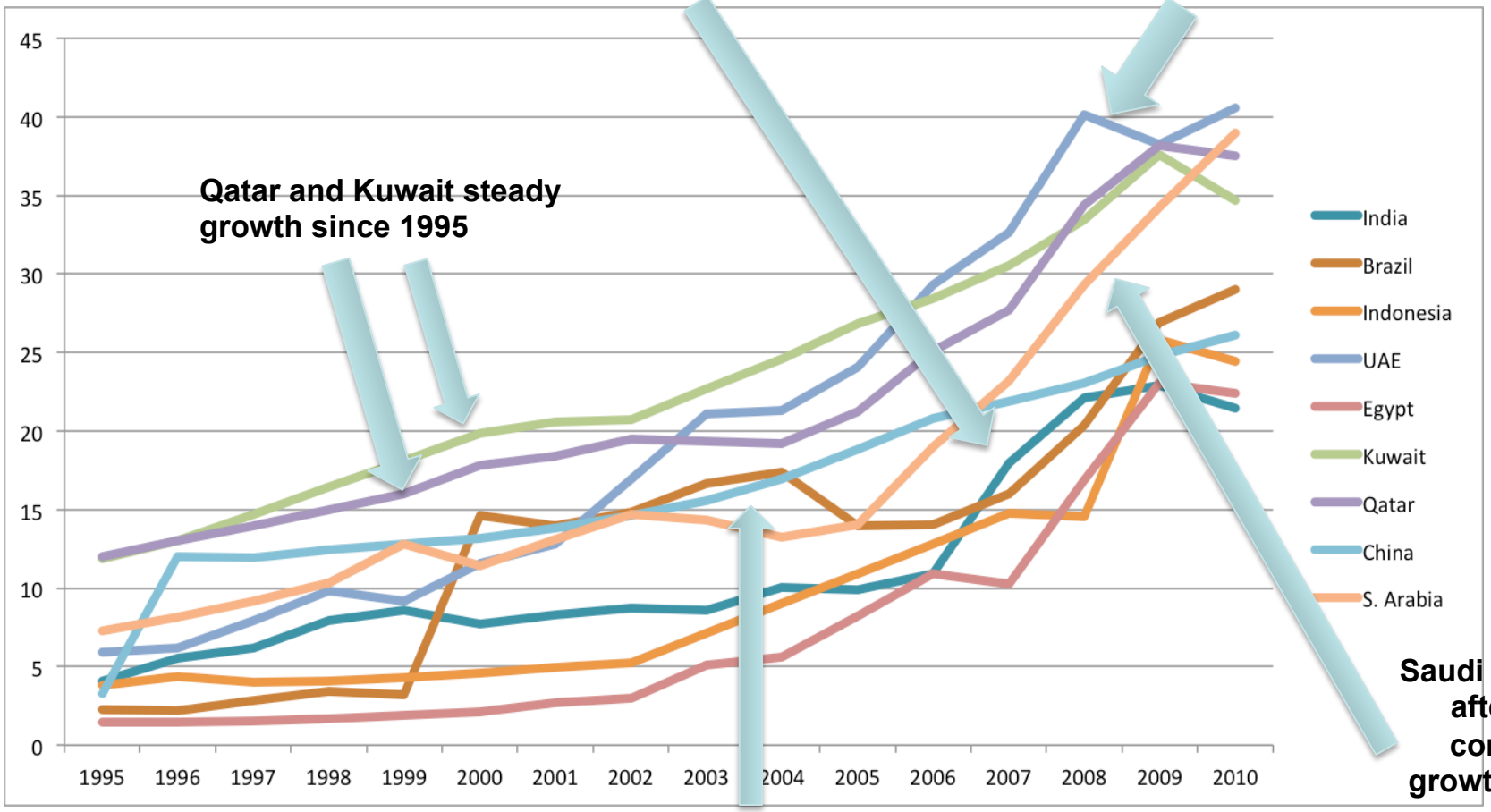
Germany trails other advanced countries

S. Korea government intervention for 100% (fiber?) broadband coverage

USA leading in 1997(pre dot com bubble) and now gradually making again its way to the top



The development path of emerging countries depends on their services and trade-intensity versus manufacturing

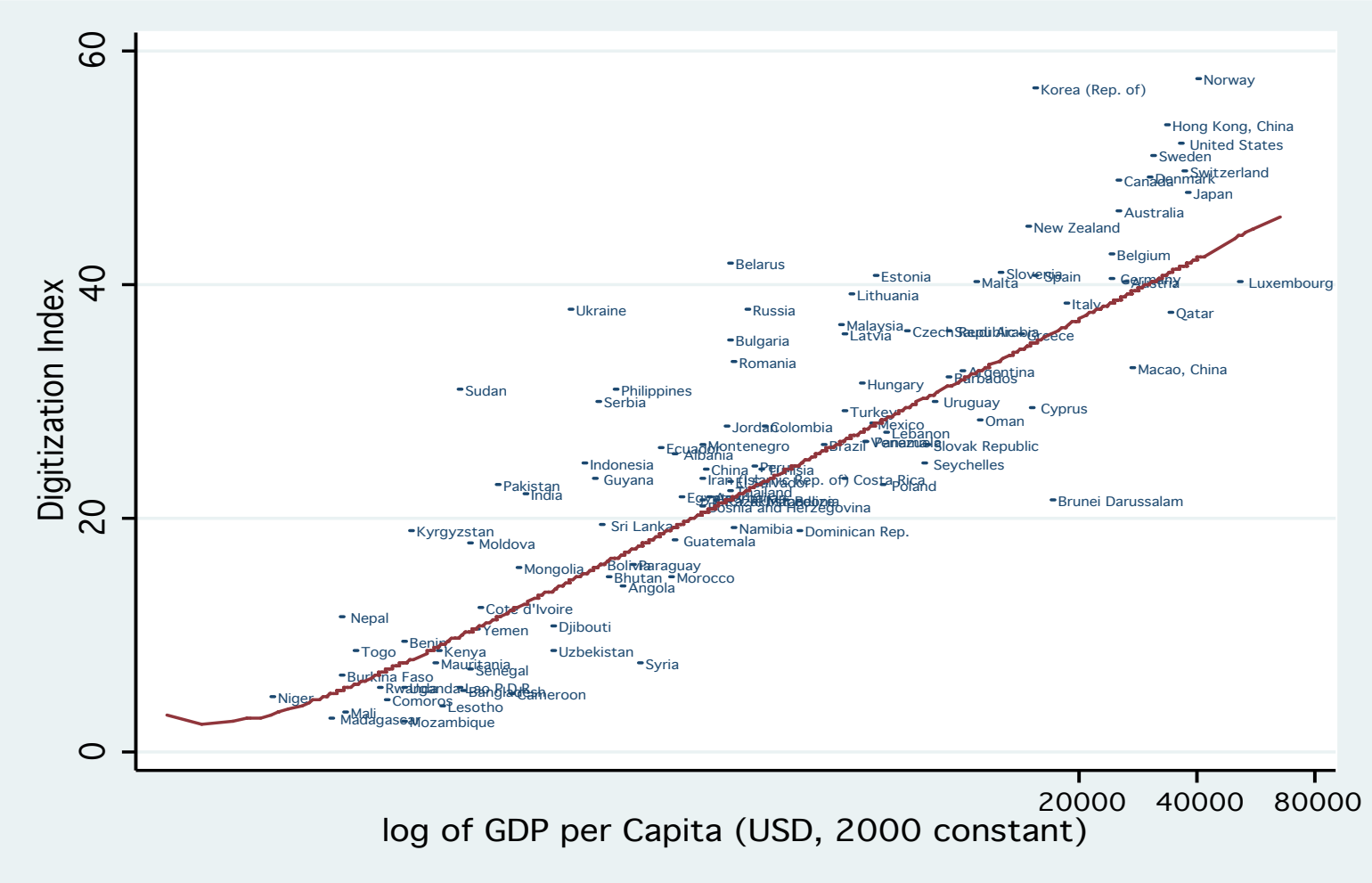


Data indicates different development paths towards digitization

- Mature countries follow a gradual progression towards digitization
  - Active government intervention accelerates development (Korea, Norway)

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

To understand the economic impact of digitization, a correlational view of the index and individual income was first developed



Extending this hypothesis, an econometric model was built to test the contribution of GDP to economic growth

- 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
- L to the labor force

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

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

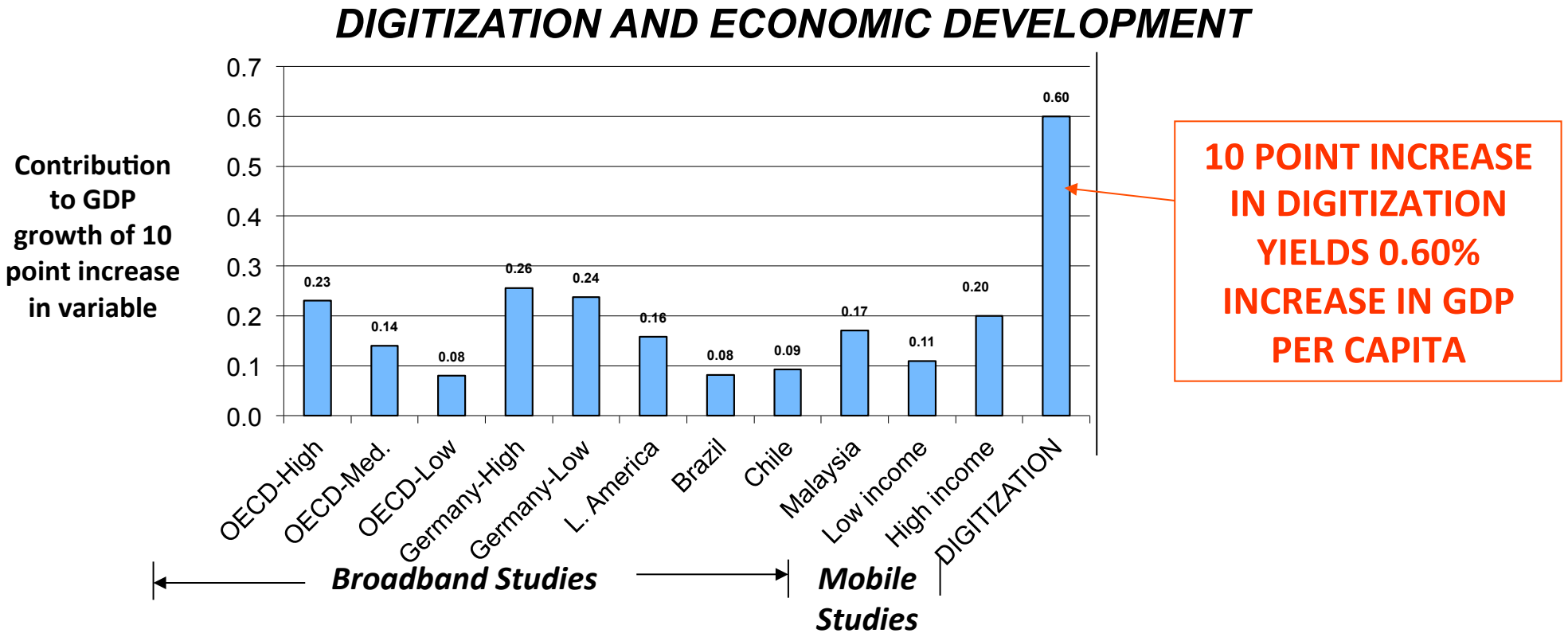
Digitization is found to have a positive and significant effect on economic output

- The model states that 10 point increase on digitization increases GDP per capita by 0.60%
- The index is a weighted average of different indicators that might be endongenous to GDP, like broadband and wireless penetration; however, given their overall impact of these on the metric is insignificant (5%)
- Furthermore, by controlling for country and year fixed effects, some potential endogeneity problems are mitigated
- Capital formation and labor contribution are positive and significant, while digitization is found to have a positive and significant effect at the 5% level, indicating a strong effect on economic output, confirming the correlational view
- Annual Growth Rate (CAGR) attributed to digitization is derived from the following formula:

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

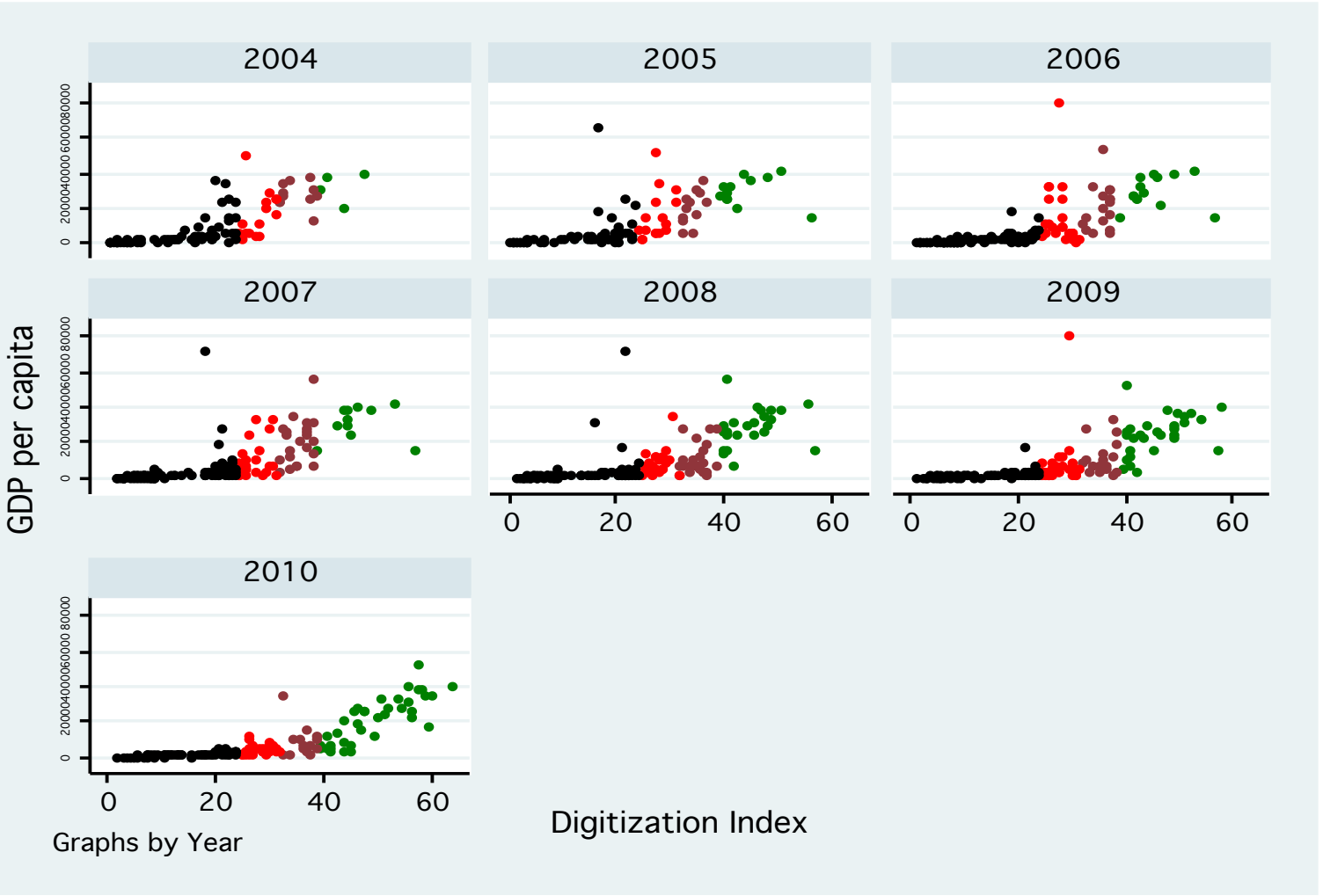
- A ten point increase in the Digitization Index has approximately a 3% impact on GDP for the period 2004-2010 resulting in an annualized effect of 0.50%

Furthermore, digitization has a larger contribution to GDP than stand-alone technologies



- This stipulates that full economic impact ICT is achieved through the 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

Additionally, digitization exhibits increasing returns to scale, where returns increase after an index score of 30



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

The increasing returns to scale hypothesis was also proven econometrically (*)

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

- 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%

(*) The sample is broken 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.

Beyond its contribution to economic output, digitization also has a positive impact on employment creation

- Simple model links unemployment rates with existing infrastructure, income, education levels, total exports as a percent of GDP and the credit performance:

$$U_{it}=b_1D_{it}+b_2K_{it}+b_3Edu_{it}+b_4GDPC_{it}+b_5Exp_{it}+b_6Cr_{it}+\varepsilon_{it}$$

- Model controls for country and year fixed effects

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

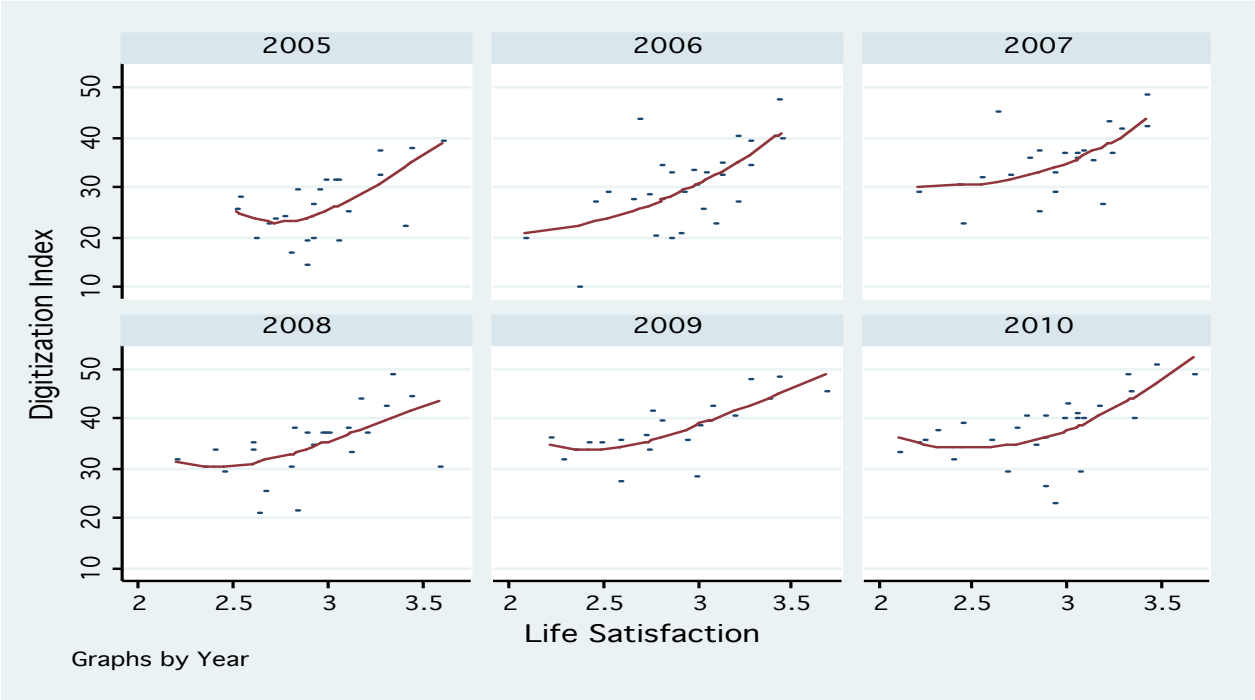
The econometric impact model on job creation is also quite robust

- All control variables have the right sign
- All canonical variables are statistically significant
- The model is very stable, meaning that signs and statistical significance of each of the coefficients are stable even when the specifications are changed
- By including GDP per capita in the variables, we negate the possibility that the index is working as a proxy for level of development
- As in the case of GDP growth, digitization has a higher impact on job creation than broadband
  - 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)

One of the most interesting and yet unexplored parameters of Digitization is the link to overall societal welfare

- This suggests a hypothesis 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 services and technologies
- For this purpose we choose not to model this relationship in a strict quantitative manner but prefer to highlight it in a correlative approach

Digitization appears to be correlated with life satisfaction and well being



- Digitization & Life satisfaction: limited effects from 20 to 40, consistent improvement from 40 to 60
- 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

Conclusion

- Digitization is a global concept, with significant heterogeneity within and across regions
- Digitization index builds on six pillars: affordability, reliability, capacity, access, usage and skills
- Index linked to higher growth, and employment with increasing returns to scale
  - Significant finding since it stipulates that full economic impact of ICT is achieved through the cumulative adoption of all technologies, in addition to the assimilation and usage in the production and social fabric
  - The policy implication is that 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
- At higher levels of its development, digitization contributes to welfare, thereby improving human development