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ICTs And Economic Growth: An Empirical Analysis With Panal Data

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ABSTRACT

In nowadays knowledge-based economy, ICTs play an important role in reaching its goal and contributing directly and indirectly in the growth process. Therefore, the purpose of this paper is to study the effects of ICTs on growth by development level. We use a panel data for a sample of 48 countries during 1995-2006. We present our empirical methodology to test and compare the effects of ICTs on the economic growth in the advanced and in LDCs. Our estimations allow us to release some policy recommendations.

Keywords: *ICTs, digital divides, economic growth.*

I. THE THEORETICAL RELATIONSHIP BETWEEN ICTs AND GROWTH.

ICTs are among the most important factors affecting the process of economic growth in all countries. In fact, there are several arguments to explain the positive effect of ICTs on the economic growth. Indeed, ICTs allow a direct access with less cost to information about various products and services (by more effective and concrete techniques: video, voices, movies, radio, publications, etc.). No doubt, this vital role improves the productivity, the efficiency, the qualifications and even the models and strategies of the user of ICTs. Furthermore, in a given country, ICTs increase and diversify the internal business connections and those with the rest of the world. ICTs allow receiving information on the international market to detect new suppliers and customers etc. …

In addition, the fact of equipping government services by ICTs (e-government) facilitates the access to public services, reduces the dimensions and the costs of travel, improves the quality and the efficiency of the public services, decreases the discrimination and the degeneration in certain services such as customs, public health, calls for tenders, competition, etc.). ICTs improve also the transparency of the public information and endorse the equality between the citizens. These factors are important for the economic growth.

ICTs also constitute an opportunity and a fundamental source of job creation, economic and technological catching up, cost cutting of transactions and the informative distance, improvement of the gains of productivity, the quality of the services and decentralization of the powers and help achieve better coordination, etc. …

These positive effects on the economic growth justify the significant investments in ICTs made by different countries and reveal an increasing interest in these technologies. Indeed, at the international level, we witness a significant evolution in terms of access to these technologies and a liberalization of the ICTs market in most countries.

Empirically, several authors confirmed the positive effect of ICTs on productivity and economic growth. DEWAN S. and Kraemer K. (1998), studied the impact of ICTs diffusion on the productivity for a sample of 36 countries during 1985 – 1993. They explained the annual GDP by the stock of ICTs capital, the stock of capital other than ICTs and annual number of working hours.

To compare countries according to their level of development, the authors decomposed their sample into two sub-samples: one includes the LDCs and the other one the advanced countries. The results of the estimation for all countries and for each group are the following: for all countries, the physical capital contributes positively to the improvement of productivity. Indeed its coefficient is positive and significant. However, this coefficient is relatively low for the group of advanced countries. An unexpected result: the coefficient of the ICTs capital is negative but not significant for all the countries and for the sub-sample of LDCs. On the other hand, for industrialized countries, the ICTs capital contributes positively to the growth of productivity, its coefficient being positive and significant.

This study remains certainly limited and insufficient because it does not take into consideration the human resources which are a fundamental element and a vehicle in the use of ICTs. As a matter of fact, the negative effect of the ICTs capital on productivity in the case of the LDCs is understandable by the lack of human capital, and by a certain delay in investing in these new technologies.

To mitigate these limits, POHJOLA M (2000) expands the model of Solow by adding the human capital. The purpose of POHJOLA M is to estimate the effects of ICTs on economic growth. He used panel data relative to 39 countries (23 countries of the OECD) during 1980-1995. This sample was divided into two subgroups to distinguish between the advanced countries and the LDCs. Precisely; POHJOLA M adopted the following approach. At first, he estimated the standard model of Solow without human capital. The results showed a positive and significant effect for all countries and for the OECD countries. Then, the author added the human capital as the explanatory factor of economic growth. Human capital is measured by the average part of the working population having a secondary training. The results show that the human capital plays an important role in economic growth. Indeed, its estimated coefficient is positive and significant. However, its contribution is much more significant in the OECD countries than in the whole sample (0, 68 against 0, 3). This is understandable by the effort of these countries in education (as it is shown by the international statistics relative to the sciences and technologies (UNESCO, World Bank, etc.).

Finally, POHJOLA introduced the ICTs capital. He concluded that this new factor contributes to growth in the whole sample more than in OECD countries (0, 67 against 0,43). This result indicates that the ICTs capital is relatively low in the LDCs and its marginal productivity is relatively strong.

For both samples, this study shows that the contribution of the physical capital to growth decreases when we introduce a new type of capital. Indeed, for the whole sample, the coefficient of capital decreases from 0, 81 when we take into account only the physical capital to 0,68 if we add the human capital and to 0,36 if we add the ICT capital . For the OECD countries, this coefficient decreases from 0,48 to 0,43 and 0, 22 respectively. This result proves that the traditional analyses of growth, where empirical works talk only of physical capital, overestimate its contribution to growth.

In another study, POHJOLA P. (2002) estimated the same model but for a wider sample (42 countries) and for a longer period (1985-1999) than the previous study. The human capital in this new study is measured by the average number of years of studies and not by the average part of the working population having a secondary training. The results of this study are very similar to those of the previous one. Indeed, for the whole sample, the coefficient of physical capital is always higher in the absence of human capital and ICTs.

This proves the idea according to which the model of Solow, with an exogenous technical progress, overestimates the contribution of the physical capital. The estimation of Solow's model without physical capital showed a practically constant effect of the human capital. Indeed, the coefficient of this factor dropped from 0, 17 to 0, and 16.

Finally, taking development level into account, the author estimated the effects of the various forms of capital on growth for a sub-sample of 24 high-income countries. Compared with the whole sample, the ICTs capital has a more important effect on growth in the rich than in the poor countries. This result means that the positive effect of ICTs on growth in advanced countries is understandable in terms of their capacity to benefit from these technologies.

In conclusion, this study confirms the fact that ICTs, instead of reducing the distances in terms of growth and development, they led rather to a more located growth and thus to an obstinacy of the regional imbalance in development and in growth.

In the same course of thought, Me Neighed H. and METHAMEM R. (2003) studied empirically the link between the digital divide and the level of development for a sample of 45 countries during 1994-2000. These countries are classified in three groups according to their GNP per capita in the year 2000. These authors opted for the following classification.

- Developed Countries: GNP / inhabitant > 10000 $. ·
- Country with intermediate income: 5000 $ < GNP / inhabitant < 10000 $.
- Less advanced Countries: GNP / inhabitant< 5000 $.

The results of this study show a globally positive and significant correlation between GNP per capita and ICTs indicators. In addition, estimations by categories of countries show that for all ICTs indicators, least developed countries register the most low coefficients in comparison with the intermediate Developed countries. Hence, the disparities in terms of income are partially responsible for the uneven ICTs diffusion.

PAPAIOANNOU S. K. and DIMELIS S. P. (2007) studied the effect of ICTs by using panel data of 42 countries during 1993-2001. They use a Cobb Douglass's production function to estimate real GDP according to the stock of ICTs capital, stock of non-ICTs capital and labor force. The results show that the ICTs capital has a positive and significant effect on the growth of productivity for the whole sample. The authors found that the effect of the ICTs capital on growth is relatively more brought up than any other one. However, this impact is relatively low in LDCs in comparison to developed ones.

Recently, Lang G. and Hawash R. (2010) adopted the method of accounting growth to examine the impact of

ICTs on productivity in 33 LDCs during 2002-2006. The authors concluded that the adoption of ICTs and high education are the main factors which influence the evolution of the total productivity factor in these countries.

2. EMPIRICAL METHODOLOGY

Before making empirical tests, it is important to describe our empirical methodology by initially presenting the models and definitions of all used variables. Then, we present the results and their interpretations.

a. Model and variables

We want to estimate the following model:

$$Y_{it} = AK_{it}^{\alpha 1} L_{it}^{\alpha 2} ICT_{it}^{\alpha 3} Z_{it}^{\alpha 4} \quad (1)$$

Where:

Y_{it} is the GDP

A is the technical progress.

K_{it} is the capital stock

L_{it} is the labor force

ICT_{it} : indicators of Information and Communication Technologies.

Z_{it} is a vector of economic variables such as FDI and opening. The indications i and t indicate respectively the country i and the year t. The logarithmic transformation of the previous equation is the following:

$$\log Y_{it} = \alpha_0 + \alpha_1 \log K_{it} + \alpha_2 \log L_{it} + \alpha_3 \log ICT_{it} + \alpha_4 \log open_{it} + \alpha_5 \log FDI_{it} + \varepsilon_{it} \quad (2)$$

This reserved specification ensues from previous theoretical and empirical works (Dewan S. and Kraemer K. (1998), Pohjola M (2000), Papaioannou S. K. and Dimelis S. P. (2007). Opened and FDI represent respectively the opening and foreign direct investments.

b. Measures of variables

Variables used in our estimations are the following ones:

Y_{it} : It is an indicator of growth, measured by the GDP at constant price in $ USA (year 2000).

Open: indicates the opening and is measured by the rate of import (Imports / GDP). The choice of this indicator can be attributed to the fact that a high number of countries of our sample are importers of ICTs. Thus, for these countries, the effects of ICTs on growth depend on their efforts of import and adoption of ICTs produced by the advanced and leading ones.

FDI is the foreign direct investment, measured by the flows of the FDI that we calculated by multiplying the percentage of FDI with regard to the GDP by the GDP in dollars (USA)

This data is taken from the database of the World Bank (WDI (2009), basic year 2000).

K_{it} is he stock of physical capital. The data relative to this stock is not completely available for all countries. For this raison, we calculated this stock using the method of the permanent inventory. According to this method, the stock of physical capital (K_t) of year t is equal to the sum of this stock of the year t-1, corrected by a rate of depreciation (δ) more the investment of the year t (I_t).

$$K_t = I_t + (1 \quad \delta) K_{t\ 1} \quad (3)$$

Where I_t is the Gross Fixed Capital Formation (GFCF) of year t and δ is the rate capital depreciation.

By referring to certain empirical works (Daveri, F. (on 2002), Papaioannou S. K. and Dimelis S. P. (on 2007)) which adopted the same method, we retained 7 % as value of δ. This rate is equivalent to an average use of capital equal to 15 years. The initial capital stock corresponds to the ratio of the initial investment I_0 and the sum of the annual average growth rate g of the investment (I_t) during the period of estimation and the rate of depreciation δ.

$$K_0 = \frac{I_0}{(g + \delta)} \quad (4)$$

GFCF data at constant price in $ USA (basic year 2000) are from World Bank database (WDI 2009)).

L_{it} is the labour force (WDI 2009))

TIC_{it} Is the indicator of ICTs which represents a key variable in our estimations? In reality, to estimate the effects of ICTs on growth, the ideal method consists in using the stock of ICTs capital as explanatory variable. Unfortunately, the data are not available either to use this stock or to calculate it. Indeed, no database offers the stock of ICTs capital or the flows of investment in ICTs for all the countries of our sample. However, the data relative to telecommunications investment are available for 35

countries. For that reason, we used the previous method of the permanent inventory to calculate the stock of telecommunication capital. The rate of depreciation is supposed equal to 33 % (which is equivalent to three years of telecommunication capital use).We distinguished between the stock of telecommunication capital and the stock of capital other than telecommunication. The last one is the difference between the stock of total physical capital and the stock of telecommunication capital.

c. Estimations

According to the availability of data, we estimated the following equation:

$$\log Y_{it} = \alpha_0 + \alpha_1 \log ICT_{it} + \alpha_2 \log L_{it} + \alpha_3 \log NICT_{it} + \alpha_4 \log\ open_{it} + \varepsilon_{it}$$

With ICT and NICT indicate respectively the stock of the ICTs capital, measured by the stock of telecommunication capital and the stock of capital other than ICTs (that is not telecommunication capital). The previous equation is estimated at first by using panel data relative to the whole sample. We divided then our sample into two subgroups of countries to distinguish between the Developed countries (19 countries of the OECD) and the LDCs (16 countries). The hypothesis taken is that of fixed effects. The results of the estimations appear in the following table.

According to this table, the stock of telecommunication capital has a positive effect on growth, but this effect is significant only for the OECD countries (column 2).

The insignificant effect of this factor for the case of the LDCs and the whole sample can be due to a problem of the data which can be unreliable. Indeed, the censorship of investment in telecommunication, especially in the LDCs cannot correspond to the exact values of these investments. Generally and for tax fraud reason, firms declare amounts lower than their real investment. This affects negatively the calculation of the aggregated stock of telecommunication capital.

Openness and labor force have positive and significant effects on growth as well for the whole sample as for both subgroups of countries.

In another series of estimations we examined the effect of the uneven ICTs diffusion on growth by using the following ICTs indicators: the Digital Opportunity Index (LDOI), the number of Personal Computers (lpercomp), the number of Internet users (lnetuser), the number of Mobile cellular telephone subscriptions per 100 inhabitants and the total number of the fixed and mobile phone subscriptions (lttelsub). All indicators are taken from the International Union of Telecommunications database (2007).

Table 1 : Effects of ICTs on Growth

Dependent variable : Log of GDP			
Explanatory variables	Whole sample	OECD	LDCs
	(1)	(2)	(3)
Constant	8.508 (11.95)	4.300 (3.05)	7.500 (6.80)
Ll	0.694 (11.92)	1.138 (9.41)	0.672 (7.90)
LICT	0.007 (0.71)	0.028 (2.41)	0.0022 (0.14)
LNICT	0.214 (12.07)	0.138 (6.42)	0.224 (6.05)
Open	0.003 (9.85)	0.004 (12.00)	0.003 (4.99)
R^2	0.76	0.89	0.69
N	(420)	228	192
Hausman test	Chi2(4)=56.72 (0.000)	Chi2(4)= 65.96 (0.000)	Chi2(4)= 214.48 (0.0000)
The values between brackets are t of Student for the estimated coefficients and the probability of chi2 for Hausman test. N: number of observations.			

The Digital Opportunity Index was built by the International telecommunication Union (ITU) in 2005 during the World Summit on Information Society organized in Tunis. This index constitutes a measure of the digital divide and refers to the digital access index (DAI) built in 2003. The DOI is a resultant of eleven ICTs components which integrates data relative to the access and the use of ICTs, infrastructure and qualifications in every country. It facilitates comparisons between countries in terms of ICTs.

In our estimations, ICTs indicators are noted as follows:

- lperscompt: number of personal computers,
- LDOI: Digital Opportunity Index,
- lmbtelsubs: number of Mobile cellular telephone subscriptions per 100 inhabitants.
- lnetuser: number of Internet users,
- lttelsub: total number of the subscribers in telephones (fixed and mobile).

The letter (l) at the beginning of every indicator indicates the logarithm. The purpose of using different indicators is to know if the choice of the ICTs variable influences or not the ICTs effect on growth. In these estimations, we used the total sample of 48 countries. About LDOI indicator, data are available only for 19 countries and during 2001-2006. Unlike previous estimations, we used total capital stock (K) because there is no multi co-linearity between this stock and other variables which do not intervene in the calculation of this stock.

The results, with the hypothesis of fixed effects, appear in the table 2 in which every column is relative to an ICTs indicator. These results show a positive correlation between all ICTs indicators and growth. The choice of ICTs indicator has no effect on the signs of the coefficients which are always positive and significant. These results mean that growth is important when investment in ICTs is also important.

A comparison of the various columns shows light differences between elasticities of the GDP with regard to the various ICTs indicators with the exception of LDOI variable which implies the highest elasticity (0,23 in column5).

Our results validate the conclusions of previous theoretical and empirical works which found the same effects of ICTs on growth (Pohjola (on 2000, 2002), Papaioannou S. K. and Dimelis S. P. (on 2007), Lang G. and Hawash R. (on 2010),

In all columns, the other explanatory variables play their awaited role in economic growth. Indeed, coefficients of the traditional factors (capital and labor) are in every case positive and significant. In addition, FDI and openness affect positively the growth process. The positive effect of FDI on growth is due to several reasons. Indeed, FDI is an important channel of ICTs diffusion which increases productivity in host countries. Besides, FDI generates positive spillovers by their competitive pressure, by the effects of imitation and by movement of workers to domestic firms which can improve their productivity and consequently the economic growth.

The positive effect of the openness is explicable by the fact that it is the first means to be equipped with ICTs. In LDCs capacities of innovation are very restricted and these countries remain dependent on foreign technologies.

Openness permits to communicate and to benefit from foreign and advanced technologies of leading countries.

Table 2 : Effects of ICTs on Growth (whole sample)

Dependent variable : Log of GDP, period 1995-2006					
Explanatory variables	(1)	(2)	(3)	(4)	(5)
Constant.	11.996 (12.57)	12.692 (15.06)	13.317 (14.11)	12.290 (12.90)	10.906 (4.19)
Lk	0.112 (6.73)	0.115 (7.06)	0.118 (7.23)	0.111 (6.64)	0.135 (4.02)
Ll	0.580 (8.61)	0.500 (7.74)	0.453 (6.33)	0.563 (8.40)	0.648 (3.72)
LFDI	0.008 (3.44)	0.0100 (4.21)	0.009 (4.04)	0.007 (3.23)	0.010 (2.54)
Lopen	0.287 (12.72)	0.251 (10.85)	0.262 (11.49)	0.279 (12.24)	0.001 (2.78)
Lnetuser	0.013 (5.04)				
Lpercomp		0.0541 (7.02)			
Lttelsub			0.049 (6.74)		
Lmbtelsubs				0.016 (5.41)	
LDOI					0.239 (4.32)
R^2	0.82	0.82	0.82	0.82	0.75
N	576	576	576	576	204
The values between brackets are t of Student. N: number of observations.					

In order to take into account the differences in ICTs effect on growth between LDCs and advanced countries, we divided our sample into two sub-samples. The first one contains 23 OECD countries and the other one integrates the remaining 25 ones. Then, we estimated the equation 2 for both groups. The results appear in both the following tables.
In LDCs (table 3), we find the same results as those of global sample: all ICTs indicators help growth in these countries. Indeed, the coefficients of these indicators are always positive and significant. These effects are understandable by the great appeal LDCs have on ICTs in particular during the last decade to catch-up leaders.

Table 3 : Effects of ICTs on Growth in LDCs

Dependent variable : Log of GDP, period 1995-2006					
Explanatory variables	(1)	(2)	(3)	(4)	(5)
Constante.	13.421 (7.92)	14.716 (10.79)	16.802 (10.96)	16.032 (9.39)	12.794 (1.79)
Lk	0.200 (6.97)	0.179 (6.38)	0.176 (6.38)	0.172 (5.95)	0.130 (1.64)
Ll	0.306 (2.86)	0.221 (2.40)	0.090 (0.89)	0.182 (1.75)	0.474 (1.32)
Lopen	0.175 (5.51)	0.135 (4.27)	0.131 (4.21)	0.169 (5.43)	0.010 (5.53)
FDI	0.011 (2.72)	0.014 (3.54)	0.013 (3.41)	0.009 (2.32)	0.004 (0.52)
Lnetuser	0.015 (3.36)				
Lpercomp		0.070 (5.59)			
Lttelsub			0.072 (6.29)		
Lmbtelsubs				0.027 (5.02)	

Ldoi					0.237 (2.10)
R^2	0.72	0.74	0.75	0.74	0.84
N	300	300	300	300	78
The values between brackets are t of Student. N: Number of observations.					

Data show that personal computers, subscribers, Internet users, etc. increase rapidly in LDCs. As an example and according to the World Bank (2009)), since 1998, the number of the new connections to the mobile telephony in LDCs is higher to that in advanced ones.

The results show that capital, openness and FDI play their expected roles on growth in this group of countries. These effects especially justify strategies and reforms implemented by these countries, in particular in the last ten years, to benefit from ICTs advantages and to attract FDI. In fact, a large number of LDCs has already adopted opening strategies since the 70s and 80s which resulted in a good environment to promote the process of growth and development. The result is that few LDCs achieved important rates of growth and that those rates were sometimes superior to those in developed countries. In the whole sample, results show that in LDCs, the elasticity of GDP, with regard to the DOI indicator, is always superior to that of the other ICTs indicators.

In OECD countries (table 4), the estimations prove the same effects of majority explanatory variables on growth. Indeed, coefficients of capital, ICTs indicators, openness and labor are always positive and significant.

Table 4 : Effects of ICTs on Growth in OECD

Dependent variable : Log of GDP, period 1995-2006				
Explanatory variables	(1)	(2)	(3)	(4)
Constant.	6.748 (4.97)	7.965 (5.93)	6.074 (4.49)	5.721 (4.23)
Lk	0.161 (8.03)	0.158 (8.26)	0.150 (6.90)	0.161 (7.60)
Ll	0.968 (8.45)	0.849 (7.43)	0.996 (8.61)	1.034 (8.96)
Open	0.002 (6.77)	0.002 (6.01)	0.0025 (6.33)	0.161 (7.60)
FDI	0.001 (0.60)	0.002 (0.93)	0.0022 (0.83)	0.002 (0.84)
Lnetuser	0.015 (4.62)			
Lpercomp		0.059 (6.30)		
Lttelsub			0.0443 (3.72)	
Lmbtelsubs				0.0133 (3.13)
R^2	0.91	0.91	0.90	0.90
N	276	276	276	276
The values between brackets are t of Student. N: Number of observations.				

Nonetheless, compared to previous estimations, we found no satisfying result using the LDOI indicator and the coefficient of FDI which is positive but still not significant. This does not allow asserting that FDI contributes directly to growth in OECD countries.

In the whole sample and in both sub-groups of countries, the modification of the ICTs indicator does not influence either the sign or the extent of ICTs effects on growth. Indeed, this effect is always positive and does not present very important differences between indicators.

3. CONCLUSION

International disparities of growth and performance are explicable by the digital gaps between countries. In this paper we studied empirically ICTs effects on growth by taking into account the development level of countries. The main conclusions of this work are the following ones: ICTs have positive and significant effects on growth in Developed countries and in LDCs. This confirms the idea according to which LDCs, mere consumers of ICTs, can benefit from these technologies. Yet, this profit is conditioned by the implementation of an absorption capacity and the adequate policies to make these technologies extremely useful.

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APPENDIX: Sample of country

Afrique	Europe	Asie	Amérique
Alegria, Cote d'Ivoire Egypt., Gabon, Kenya, Morocco, Senegal, South Africa Tunisia	Austria Belgium Denmark Finland France Germany Greece Ireland Iceland Italy Norway Portugal Czech Republic Spain Switzerland Turkey U K	Australia China India Indonesia N. Zealand Malaysia Pakistan Philippines Thailand. Japan Korea, south	Argentina Bolivia Brazil Costa Rica Ecuador Mexico Paraguay Peru Uruguay Venezuela USA