Study of Relationship Between ICT and Economic Growth (Neural Network Approach)

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Abstract: In this paper we aim to evaluate the relationship between ICT and economic growths in world. In this study we used Panel data method as an instrument for complicated linear trends and the GMDH-neural network method as an instrument for complicated non- linear trends especially with the limited observations. is it gained that there is a significant relationship between investment in information and communication technology (ICT) and economic growth and from none-linear modeling we discovered that its effect is very strong and important.

Key-Words: - Information and Communication Technologies - Economic growth - GMDH-neural network – Panel data.

1 Introduction

Computers are not fundamentally number crunchers. They are symbol processors. The same basic technologies can be used to store, retrieve, organize, transmit, and algorithmically transform any type of information that can be digitized numbers, text, video, music, speech, programs, and engineering drawings, to name a few. This is fortunate because most problems are not numerical problems. As computers become cheaper and more powerful, the business value of computers is limited less by computational capability, and more by the ability of managers to invent new processes, procedures and organizational structures that leverage this capability.

Therefore Information and communication technology (ICT) is increasingly referred to as an important engine of economic growth. ICT has a three type of equipment: computer hardware, software and communication equipment. Our estimates of ICT's contribution to growth are faced with well-known measurement problems: estimate of investment flows; breakdown of investment (in nominal terms) into prices and volumes;

estimate of capital stocks on the basis of investment flows. These problems are particularly acute as regards ICT equipment, because of a severe shortage, at least until now, of basic statistics and because of the extremely swift enhancement of equipment performance.

ICT have been compared to other important historical inventions like the steam engine or the electric motor (David and Wright, 1999). These inventions are interpreted as ‘general purpose technologies’ (GPT) with three main characteristics: they are pervasive, they carry an inherent potential for technical improvements and they lead to innovational complementarities and scale economies (Bresnahan and Trajtenberg, 1995). According to this view, GPT should be understood primarily as ‘enabling technologies’, “opening up new opportunities rather than offering complete, final solutions” (Bresnahan and Trajtenberg, 1995:84).

Indeed, ICT's impact on growth is largely related to its impact on the productivity of production factors. Such effects may alter the pace of potential growth, in other words of sustainable growth, without a parallel increase in inflationary pressures.

The information and communication technology in economy are impressed on both demand and supply sides. In side of demand is impressed on economical manner from functional utilitarian and in the other side of supply is impressed on producer manner.

In recent years the number of economical person try to introduce new information technology in form of internal growth with introduce pattern of internal growth.

Some of studies introduce information and communication technology in form of R&D pattern of internal growth and then long-run growth is a functional of the growth of information technology and some other people try to aside between human capital and technology. With this theory long-run growth production capitation (neo-classic pattern) is equal with the growth of technology and we can say that human capital can influence on per capita income level.

2 Literature Review

In pattern of internal growth that we mentioned before, the first of 1980 decade in Chicago university romer and lucas try to alight interest of economical person to growth of economy with enforce of thinking of economy and human capital. With new improvement in imperfect competition theory, romer try to introduce economical technology to macro economical. After this theoretical improvement, empirical studies begins with some economists such as Robert Barro from Harvard university in order to examine of growth theory and on 1990 decade theoretical works and empirical work to be continued in vast level in growth pattern of solow you can see that technology show outside level and it’s like a "mana from heaven" that to be continue their way without any regard to other adjustment communication between economical growth and mentality economy and internal growth pattern shows seriously on economical level.

In internal growth pattern, they try to nomination of technology in form of internal element that impressed on production and economical growth. These patterns try to introduce technology impressed with different way such as human resource, better quality of production and versatile productions. Lucas introduced his theory of internal growth pattern with human resource in form of neo-classic growth model. Aghion and hiowt in themselves theory enforce to better quality of production theory in form of new technology that can impress on produces of old technology and apply of shompiter thought. Of course Grossman and Helpman introduced internal growth pattern exactly as same as last theories.

Romer and Grossman and Helpman talked about the internal growth pattern with this new theory because they thought that research and development activities are affect on new knowledge and they can begin of growth.

In order to study about internal technology on growth pattern we can mention study of Quah and Pohjola axle of theses studies are utility in production functions and economical growth.

Product function is:

$$y = f(K, N, \tilde{a})$$

K= capital

N= labor

$\tilde{a}$ = the primary index of technology

In order to proceed the exact measure of technology and in order to special notice to human resource ,We can suppose $\tilde{a}$ has two sections: h is human resource for each person and a is proper technology.

Because of human resource is hidden in labor and with this notice that labor can suppose in a form of capital, h is specific for any economy. On the contrary we can not suppose "a" is a form of labor because its nature is global. It is possible to suppose that "a" is tacit knowledge but "h" is not tacit knowledge, so we suppose that:

$$\tilde{A} = (h,A) \qquad (1)$$

With replacing equity (1) in above equity:

y=F(K,N,h,A)

Thus estimation of economical growth and impact of other factors on it, we try to use growth theory with consideration of information and communication technology factor.

3 Production Function Framework

Total production function is considered, as a cobb-douglass production function:

$$Y = AC^{\alpha_c} K^{\alpha_k} H^{\alpha_h} N^{\alpha_n} R^{\alpha_r}$$

Y Total product function
C Information and communication Technology Expenditure
K Non information and communication technology expenditure
H Human capital
N Labor
A Level of technology
R Investment in Research & Development (R&D)

With logarithmic differentiation from both sides of foregoing function and then differentiation toward time; we will have

$$\dot{Y} = \dot{A} + \alpha_c \dot{C} + \alpha_k \dot{K} + \alpha_h \dot{H} + \alpha_n \dot{N} + \alpha_r \dot{R}$$

Above-mentioned equity is used to estimate impact of (ICT) on economic growth and , we will utilize intercountrys data for estimating this model.

4 Data and Variables

In this study, we have used data from fifty seven countries[1] of world in period of (2001-2005) and because of none existed data we have used some alternative parameters instead of some parameters.

Studies demonstrate that parameter that has most effect on economic growth is practiced and educated labor, hence instead of labor force growth rate we used rate of tertiary educated growth. And we used rate of researcher's growth toward labor parameter as a substitution for rate of R&D capital growth parameter.

1 Algeria, Argentina, Australia, Bangladesh, Belgium, Bolivia, Bulgaria, Cameroon, Canada, Chile, China, Colombia, Costa Rica, Czech Republic, Ecuador, Egypt, Arab Rep., Finland, France, Germany, Hong Kong, China, Hungary, India, Indonesia, Iran, Islamic Rep., Ireland, Jordan, Kenya, Korea, Rep., Kuwait, Malaysia, Mexico, Morocco, Netherlands, New Zealand, Nigeria, Pakistan, Panama, Peru, Philippines, Poland, Portugal, Romania, Russian Federation, Saudi Arabia, Senegal, South Africa, Spain, Sweden, Tunisia, Turkey, United Arab Emirates, United Kingdom, United States, Uruguay, Venezuela, RB, Vietnam, Zimbabwe

5 Introduction and estimation of Panel data model

We use the model within mentioned, In order to study impact of ICT on economic growth.

$$dY_{it} = \alpha_1 dKc_{it} + \alpha_2 dKnc_{it} + \alpha_3 dR_{it} + \alpha_4 dL_{it} + \lambda + U_{it}$$

dY rate of total production growth
dKc rate of ICT expenditure growth
dKnc rate of capital growth
dL rate of labor force growth
dR rate of researchers toward labor
λ index of technical progress
U random term

With gathering statistical information in order to estimate model, it is necessary to determine estimation technique (panel data).

Thus, we have used (F) statistic for determining if there is ordinate of origin for each one of country or not, and then we have used (Hausman test) for testing that witch technique(fix effect or random effect) is better to use for estimating model.

Therefore, concerning to the tests we have done, we used Pooling data for model estimation.

6 Empirical results

Variables	*Coefficient*	*t-statistic*	*p-value*
rate of ICT expenditure growth(dKc)	*0.009*	*1.52*	*88%*
rate of capital growth(dKnc)	*0.06*	*6.37*	*100%*
rate of labore force growth(dL)	*0.2*	*3.81*	*100%*
Rate of researchers toward labor growth(dR)	*0.004*	*0.17*	*15%*
index of technical progress(λ)	*0.27*	*18.39*	*100%*
F statistic			*100%*
R square			*74%*

As it is clear from result of above tables, coefficient of capital growth parameter on ICT in level of %95 is positive and significant.

According to the estimated model in period of (2001-2005), above mentioned coefficient is gained 0.009. the result demonstrate that investment on ICT has a significant effect on countries growth but the gained coefficient is very low and for justifying this problem we tried to estimate non-linear model.

Since investment on ICT can effect other sectors of economy hence Linear none-Explained is normal.

7 MODELLING USING GMDH NEURAL NETWORKS

By means of GMDH algorithm a model can be represented as set of neurons in which different pairs of them in each layer are connected through a quadratic polynomial and thus produce new neurons in the next layer. Such representation can be used in modelling to map inputs to outputs. The formal definition of the identification problem is to find a function $\hat{f}$ so that can be approximately used instead of actual one, f in order to predict output $\hat{y}$ for a given input vector $X = (x_1, x_2, x_3, ..., x_n)$ as close as possible to its actual output y. Therefore, given M observation of multi-input-single-output data pairs so that

$y_i = f(x_{i1}, x_{i2}, x_{i3}, ..., x_{in})$ (i=1, 2, …,M)

It is now possible to train a GMDH-type neural network to predict the output values $\hat{y}_i$ for any given input vector $X = (x_{i1}, x_{i2}, x_{i3}, ..., x_{in})$, that is

$\hat{y}_i = \hat{f}(x_{i1}, x_{i2}, x_{i3}, ..., x_{in})$ (i=1, 2, M).

The problem is now to determine a GMDH-type neural network so that the square of difference between the actual output and the predicted one is minimised, that is

$$\sum_{i=1}^{M} [\hat{f}(x_{i1}, x_{i2}, x_{i3}, ..., x_{in}) - y_i]^2 \rightarrow \min.$$

General connection between inputs and output variables can be expressed by a complicated discrete form of the Volterra functional series in the form of

$$y = a_0 + \sum_{i=1}^{n} a_i x_i + \sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij} x_i x_j + \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{n} a_{ijk} x_i x_j x_k + ... \quad (1)$$

Which is known as the Kolmogorov-Gabor polynomial (Sanchez et al. 1997; Iba et al. 1996; Ivakhnenko 1971; Farlow 1984; Nariman-zadeh et al. 2003)? This full form of mathematical description can be represented by a system of partial quadratic polynomials consisting of only two variables (neurons) in the form of

$$\hat{y} = G(x_i, x_j) = a_0 + a_1 x_i + a_2 x_j + a_3 x_i x_j + a_4 x_i^2 + a_5 x_j^2 \quad (2)$$

In this way, such partial quadratic description is recursively used in a network of connected neurons to build the general mathematical relation of inputs and output variables given in equation (1). The coefficient a_i in equation (2) are calculated using regression techniques (Farlow 1984; Nariman-zadeh et al. 2003) so that the difference between actual output, y, and the calculated one, $\hat{y}$ for each pair of x_i, x_j as input variables is minimized. Indeed, it can be seen that a tree of polynomials is constructed using the quadratic form given in equation (2) whose coefficients are obtained in a least-squares sense. In this way, the coefficients of each quadratic function G_i are obtained to optimally fit the output in the whole set of input-output data pair, that is

$$E = \frac{\sum_{i=1}^{M} (y_i - G_i())^2}{M} \rightarrow \min \quad (3)$$

In the basic form of the GMDH algorithm, all the possibilities of two independent variables out of total n input variables are taken in order to construct the regression polynomial in the form of equation (2) that best fits the dependent observations (y_i, i=1, 2, …, M) in a least-squares sense. Consequently, $\binom{n}{2} = \frac{n(n-1)}{2}$ neurons will be built up in the first hidden layer of the feed forward network from the observations $\{(y_i, x_{ip}, x_{iq});$ (i=1, 2, …, M)} for different $p, q \in \{1,2,..., n\}$. In other words, it is now possible to construct M data triples $\{(y_i, x_{ip}, x_{iq});$ (i=1, 2, …, M)} from observation using such $p, q \in \{1,2,..., n\}$ in the form

$$\left[\begin{array}{cc|c} x_{1p} & x_{1q} & y_1 \\ x_{2p} & x_{2q} & y_2 \\ \hline x_{Mp} & x_{Mq} & y_M \end{array}\right].$$

Using the quadratic sub-expression in the form of equation (2) for each row of M data triples, the following matrix equation can be readily obtained as

$A\mathbf{a} = Y$

where $\mathbf{a}$ is the vector of unknown coefficients of the quadratic polynomial in equation (2)

$$\mathbf{a} = \{a_0, a_1, a_2, a_3, a_4, a_5\} \quad (4)$$

And

$Y = \{y_1, y_2, y_3, ..., y_M\}^T$

is the vector of output's value from observation. It can be readily seen that

$$A = \left[\begin{array}{cccccc} 1 & x_{1p} & x_{1q} & x_{1p}x_{1q} & x_{1p}^2 & x_{1q}^2 \\ 1 & x_{2p} & x_{2q} & x_{2p}x_{2q} & x_{2p}^2 & x_{2q}^2 \\ \hline 1 & x_{Mp} & x_{Mq} & x_{Mp}x_{Mq} & x_{Mp}^2 & x_{Mq}^2 \end{array}\right]$$

The least-squares technique from multiple-regression analysis leads to the solution of the normal equations in the form of

$$\mathbf{a} = (A^T A)^{-1} A^T Y \quad (5)$$

Which determines the vector of the best coefficients of the quadratic equation (2) for the whole set of M data triples. It should be noted that this procedure is repeated for each neuron of the next hidden layer according to the connectivity topology of the network. However, such a solution directly from normal equations is rather susceptible to round off errors and, more importantly, to the singularity of these equations.

8 Estimation GMDH neural networks model

Variables	*dKc – dKnc – dL - dR*
Omitted variables	---------
Variables with double effect	*dKc – dR*
RMSE[2]	*0.025*

Results of above table show that, as we expected, parameter of investment in ICT has a double effect on countries economical growth.

9 Conclusion

In our study, is it gained that there is a significant relationship between investment in information and communication technology (ICT) and economic growth and from none-linear modeling we discovered that its effect is very strong and important. So we conclude that “if we pay attention to investment in ICT (with regards to its effect on other sectors of economy) it is possible to have a accelerated economic growth.

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1.Root Mean Square Error

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