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# The Influence of Information and Communication Technologies on Economic Growth: A Test of Reverse Causation in the European Union Countries Context

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## Abstract

*This paper investigates convergence and causality between network readiness and gross domestic product (GDP). The research is based on data from the 27 European Union member-states. The results of this study indicate that both network readiness and GDP converge between the EU member-states, with the convergence of network readiness being faster than the convergence of GDP. Furthermore, the study shows that although there exists bilateral causality between network readiness and GDP, the influence of GDP on network readiness is much stronger than the influence of network readiness on GDP.*

**Keywords**: Granger test, network readiness, convergence, causality, pooled estimation.

## Introduction

This paper is the final of a series of four papers that investigates the influence of determinants of information and communication technologies (ICT), on important economic variables. The first paper in this series, referring to the 27 European Union member-states, concluded that the relationship between economic system and global national competitiveness is positively and partially mediated through information and communication technologies (Katos, 2009a). The second paper in the series, referring to 16 non-European Union Eastern Europe and Central Asia countries, concluded that the relationship between economic system and global national competitiveness is positively and fully mediated through information and communication technologies (Katos, 2009b). The third paper in the series, referring to 121 countries worldwide, concluded that the relationship between network readiness and enabling trade is positively and fully mediated through economic environment (Katos, 2010).

Over the last years authors tried to investigate the productivity performance in European Union in order to detect sources of convergence between the EU member-states. Furthermore, it was assumed that information and communication technologies contributed to labor productivity growth (Ark & Piatkowski, 2004). However, although it was argued that information and communication technologies constitute an important source of growth and probably a source of convergence between the EU member-states (Ark & Piatkowski, 2004), the actual influence of information and communication technologies on GDP and vise versa is still under empirical investigation because important underlying methodological and measurement problems have not yet been resolved (Brynjolfsson & Kahin, 2002). Accordingly, this study is aiming to fill this gap by empirically investigating whether information and communication technologies influence economic growth in the European Union.

Therefore, given the importance of information and communication technologies, expressed by network readiness of nations (Kirkman, Osorio, & Sachs, 2001), on economic development, the primary questions examined in this research are:

1. Is both network readiness and economic development converging overtime in the EU member-states?
2. What is the cause and effect activity in the relationship between network readiness and economic development?

Section two investigates convergence of both network readiness and gross domestic product between the 27 EU member-states. Section three investigates causality between network readiness and gross domestic product. Finally, section four presents the conclusions of the study.

## Investigating convergence

The most common method for testing convergence of economic variables of various countries refers to the estimation of the following equation (Baumol, 1986; Barro & Sala-i-Martin, 1991, 1992; Durlauf & Johnson, 1992):

$$\Delta X_{it} = \alpha + \beta X_{i,t-j} + \varepsilon_i \qquad (1)$$

where, X = the variable to be investigated for convergence, Δ = first difference, t = time, i = country, j = time lag, α = constant, β = slope, and ε = disturbance term.

Convergence of variable X between the countries is being accepted in case that parameter β in model (1) is negative. This means that given level $X_{i,t-j}$ (or more lags) of variable X, the difference $\Delta X_{it}$ should progressively be decreasing over time.

In this section we will investigate convergence for the variables of network readiness (NR) and gross domestic product (GDP) per capita in purchasing power standards (PPS). Network readiness refers to the capacity of a country to exploit the opportunities offered by information and communication technologies (ICT). Network readiness is measured by the network readiness index (NRI) that is constituted of two components: '*network use*' (variables related to the quantity and quality of ICT use), and '*enabling factors*' (network access, network policy, network society, networked economy) (Kirkman et al., 2001).

GDP is an indicator for a nation's economic situation. It reflects the total value of all goods and services produced less the value of goods and services used for intermediate consumption in their production. Expressing GDP in PPS eliminates differences in price levels between countries, and calculations on a per capita basis allows for the comparison of economies significantly different in absolute size (Eurostat, 2010).

Table 1 presents the means and standard deviations of the two variables of the 27 EU member-states to be investigated for convergence. It is seen that the countries with the smallest score of the NRI are Bulgaria (3.43), Romania (3.48), and Poland (3.51), and the countries with the largest score of the NRI are Finland (4.46), Sweden (4.47), Denmark (5.50). The question that it is raised is whether there is a tendency for convergence of the NRI among the 27 EU member-states.

Similarly, it is seen in Table 1 that the countries with the smallest GDP per capita in PPS are Bulgaria (7.8), Romania (8.0), and Latvia (10.8), and the countries with the largest GDP per capita in PPS are the Netherlands (29.4), Ireland (31.5), and Luxembourg (61.0). The question that it is also raised is whether there is a tendency for convergence of the GDP per capita in PPS among the 27 EU member-states.

*Table 1.* Means and standard deviations of network readiness and GDP per capita

| No. | Country | Network Readiness (NR) '1'=lowest to '7'=highest | | GDP per capita in PPS (GDP) (in thousand Euros) | |
|---|---|---|---|---|---|
| | | Mean | Standard Deviation | Mean | Standard Deviation |
| 1 | Sweden | 5.47 | 0.34 | 27.2 | 2.43 |
| 2 | Denmark | 5.50 | 0.28 | 27.7 | 1.96 |
| 3 | Finland | 5.46 | 0.31 | 25.8 | 2.61 |
| 4 | Netherlands | 5.21 | 0.40 | 29.4 | 2.79 |
| 5 | Austria | 4.96 | 0.33 | 27.9 | 2.29 |
| 6 | Germany | 5.02 | 0.25 | 26.0 | 2.31 |
| 7 | Luxembourg | 4.71 | 0.27 | 61.0 | 16.1 |
| 8 | France | 4.83 | 0.27 | 24.8 | 1.66 |
| 9 | UK | 5.13 | 0.30 | 26.8 | 2.07 |
| 10 | Belgium | 4.71 | 0.31 | 26.8 | 1.59 |
| 11 | Ireland | 4.80 | 0.24 | 31.5 | 3.56 |
| 12 | Estonia | 4.72 | 0.37 | 13.3 | 3.01 |
| 13 | Cyprus | 3.99 | 0.28 | 20.0 | 2.67 |
| 14 | Portugal | 4.31 | 0.31 | 17.0 | 1.46 |
| 15 | Slovenia | 4.20 | 0.28 | 19.2 | 2.54 |
| 16 | Czech Republic | 4.17 | 0.32 | 16.9 | 2.39 |
| 17 | Spain | 4.32 | 0.30 | 22.8 | 2.52 |
| 18 | Malta | 4.26 | 0.33 | 17.3 | 1.37 |
| 19 | Lithuania | 3.88 | 0.38 | 11.7 | 2.63 |
| 20 | Slovak Republic | 3.91 | 0.26 | 13.6 | 2.82 |
| 21 | Latvia | 3.81 | 0.32 | 10.8 | 2.51 |
| 22 | Hungary | 4.05 | 0.26 | 13.9 | 1.55 |
| 23 | Greece | 3.85 | 0.19 | 20.6 | 2.26 |
| 24 | Italy | 4.15 | 0.39 | 24.0 | 1.20 |
| 25 | Romania | 3.48 | 0.34 | 8.0 | 2.03 |
| 26 | Poland | 3.51 | 0.47 | 11.5 | 1.73 |
| 27 | Bulgaria | 3.43 | 0.34 | 7.8 | 1.59 |

Table 2 presents the regression results of applying model (1) to the variables of network readiness and gross domestic product expressed into logarithms. These results are acceptable although the coefficients of determination are very small in both regression equations due to the fact that the dependent variables are expressed into first differences. From the results with respect to network readiness it is seen in Table 2 that the slope coefficient, i.e. the coefficient of $\log(NR_{i,t-1})$ is negative and significant. This means that convergence of network readiness is taking place between the 27 EU member-states. Similarly, from the results with respect to gross domestic product it is seen in Table 2 that the slope coefficient, i.e. the coefficient of $\log(GDP_{i,t-1})$ is negative and significant. This means that convergence of gross domestic product per capita in PPS is taking place between the 27 EU member-states. However, comparing these two coefficients (i.e., elasticities) we see that the coefficient with respect to network readiness (-0.115) is much greater in absolute values than the coefficient with respect to gross domestic product (-0.029), thus indicating that convergence of network readiness is much faster than convergence of gross domestic product. Considering that convergence of these two variables is different in speed, what is then left is to investigate the type of causality between these two variables.

*Table 2.* Regression results of model (1)

| Dependent Variable: $\Delta(\log(NR_{it}))$ | | Dependent Variable: $\Delta(\log(GDP_{it}))$ | |
|---|---|---|---|
| Variable | Coefficient | Variable | Coefficient |
| C | 0.176092 (0.0002) | C | 0.134300 (0.0000) |
| $\log(NR_{i,t-1})$ | -0.115243 (0.0003) | $\log(GDP_{i,t-1})$ | -0.028670 (0.0000) |
| R-squared | 0.067865 | | 0.095765 |
| Adjusted R-squared | 0.062880 | | 0.090930 |
| S.E. of regression | 0.067851 | | 0.042240 |
| F-statistic | 13.61469 | | 19.80473 |
| Prob(F-statistic) | 0.000294 | | 0.000015 |
| Durbin-Watson statistic | 2.001394 | | 1.567123 |

## Investigating Causality

The correlation coefficient between the mean values of the network readiness and GDP per capita in PPS variables reported in Table 1 is equal to 0.619 (p=0.001). This may mean that there is a positive association between these two variables. However, because in most cases the direction of causality is not known, various tests have been suggested to identify this direction. The most well known test is the one proposed by Grander (1969). This test being based on the premise that '*the future cannot cause the present or the past*' utilizes the concept of the VAR models (Seddighi, Lawler, & Katos, 2000). Let us therefore consider the two variable, $X_t$ and $Y_t$ VAR(k) model, where k = number of time lags:

$$Y_t = \alpha_{10} + \sum_{j=1}^{k} \alpha_{1j} X_{t-j} + \sum_{j=1}^{k} \beta_{1j} Y_{t-j} + \varepsilon_{1t} \quad (2)$$

$$X_t = \alpha_{20} + \sum_{j=1}^{k} \alpha_{2j} X_{t-j} + \sum_{j=1}^{k} \beta_{2j} Y_{t-j} + \varepsilon_{2t} \quad (3)$$

With respect to this model we can distinguish the following cases:

1. If $\{\alpha_{11}, \alpha_{12}, \ldots, \alpha_{1k}\} \neq 0$ and $\{\beta_{21}, \beta_{22}, \ldots, \beta_{2k}\} = 0$, there exists a unidirectional causality from $X_t$ to $Y_t$, denoted as $X \rightarrow Y$.
2. If $\{\alpha_{11}, \alpha_{12}, \ldots, \alpha_{1k}\} = 0$ and $\{\beta_{21}, \beta_{22}, \ldots, \beta_{2k}\} \neq 0$, there exists a unidirectional causality from $Y_t$ to $X_t$, denoted as $Y \rightarrow X$.
3. If $\{\alpha_{11}, \alpha_{12}, \ldots, \alpha_{1k}\} \neq 0$ and $\{\beta_{21}, \beta_{22}, \ldots, \beta_{2k}\} \neq 0$, there exists a bilateral causality between $X_t$ and $Y_t$, denoted as $X \leftrightarrow Y$.
4. If $\{\alpha_{11}, \alpha_{12}, \ldots, \alpha_{1k}\} =0$ and $\{\beta_{21}, \beta_{22}, \ldots, \beta_{2k}\} =0$, there is no causality between $X_t$ and $Y_t$, or the variables are independent.

In order to test the hypotheses referring to the significance or not of the sets of the coefficients of the VAR model of equations (2) and (3) the usual Wald F-statistic could be utilized (Seddighi et al., 2000).

Table 3 presents the results of the Granger causality tests between the variables of GDP per capita in PPS (GDP) and network readiness (NR) expressed in logarithms. We used logarithms to minimize any non-stationarity of the variables used in estimation. The figures reported in Table 3 refer to the probabilities of the Wald F-statistic. From these probabilities it is seen that:

- GDP causes NR according to Granger type in the following countries: Austria, UK, Cyprus, Greece, Bulgaria.
- NR causes GDP according to Granger type in the following countries: Sweden, Denmark, Germany, Luxemburg, Cyprus.

These results indicate that in the vast majority of the EU countries causality between GDP and NR is rather indeterminate. However, this inconclusive result may depend on the very small number of observations used in estimation. Thus, another method should be used for investigating the direction of causality.

*Table 3.* Results of Granger causality tests (F-statistic probabilities)

| No. | Country | Granger Causality (Lags up to 1) | | Granger Causality (Lags up to 2) | |
|---|---|---|---|---|---|
| | | GDP→NR | NR→GDP | GDP→NR | NR→GDP |
| 1 | Sweden | 0.325 | 0.837 | 0.633 | **0.008** |
| 2 | Denmark | 0.202 | 0.378 | 0.318 | **0.069** |
| 3 | Finland | 0.507 | 0.411 | 0.979 | 0.913 |
| 4 | Netherlands | 0.701 | 0.226 | 0.550 | 0.275 |
| 5 | Austria | **0.024** | 0.353 | 0.124 | 0.635 |
| 6 | Germany | 0.113 | **0.007** | 0.725 | 0.311 |
| 7 | Luxembourg | 0.247 | **0.058** | 0.537 | **0.046** |
| 8 | France | 0.389 | 0.494 | 0.256 | 0.845 |
| 9 | UK | 0.820 | 0.442 | **0.101** | 0.500 |
| 10 | Belgium | 0.110 | 0.380 | 0.365 | 0.483 |
| 11 | Ireland | 0.427 | 0.485 | 0.196 | 0.221 |
| 12 | Estonia | 0.127 | 0.501 | 0.229 | 0.186 |
| 13 | Cyprus | 0.167 | **0.040** | **0.070** | 0.160 |
| 14 | Portugal | 0.582 | 0.708 | 0.445 | 0.991 |
| 15 | Slovenia | 0.241 | 0.460 | 0.575 | 0.598 |
| 16 | Czech Republic | 0.191 | 0.747 | 0.183 | 0.525 |
| 17 | Spain | 0.635 | 0.459 | 0.477 | 0.326 |
| 18 | Malta | 0.949 | 0.207 | 0.209 | 0.713 |
| 19 | Lithuania | 0.274 | 0.347 | 0.722 | 0.470 |
| 20 | Slovak Republic | 0.113 | 0.697 | 0.113 | 0.592 |
| 21 | Latvia | 0.376 | 0.672 | 0.215 | 0.486 |
| 22 | Hungary | 0.641 | 0.813 | 0.255 | 0.431 |
| 23 | Greece | 0.800 | 0.945 | **0.040** | 0.824 |
| 24 | Italy | 0.733 | 0.734 | 0.856 | 0.326 |
| 25 | Romania | 0.184 | 0.722 | 0.213 | 0.678 |
| 26 | Poland | 0.612 | 0.172 | 0.753 | 0.624 |
| 27 | Bulgaria | **0.049** | 0.213 | 0.378 | 0.823 |

*Note*: Bold figures indicate narrow and wider significance

In order to further investigate the direction of causality between GDP per capita in PPS and network readiness in the EU countries we used the 'pooled regression' methodology. This methodology is expressed in models (4) and (5) where the data are longitudinal (cross-section and time series)

$$Y_{it} = \alpha_{10} + \sum_{j=0}^{k} \alpha_{1j} X_{i,t-j} + \sum_{j=1}^{k} \beta_{1j} Y_{i,t-j} + \varepsilon_{it} \qquad (4)$$

$$X_{it} = \alpha_{20} + \sum_{j=1}^{k} \alpha_{2j} X_{i,t-j} + \sum_{j=0}^{k} \beta_{2j} Y_{i,t-j} + \varepsilon_{it} \qquad (5)$$

Tables 4 and 5 present the results of the pooled regression estimation for the dependent variables of network readiness (in $\log(NR_{it})$) and GDP per capita (in $\log(GDP_{it})$) respectively. In each table two types of results are presented. The first type refers to '*fixed effects'* where the constant term is decomposed into 27 individual levels, and the second type refers to '*common constant'* where the constant term is estimated as one. Although in both tables and in both types of estimation the results are acceptable according to the usual statistics, in what it follows we will concentrate on the fixed effects results because they look preferable in statistical terms compared to the common constant results.

From the results in Table 4 it is seen that network readiness positively depends on current GDP (elasticity = 0.289) and on network readiness of the previous year (elasticity = 0.401). From the results in Table 5 it is seen that GDP positively depends on current and last year network readiness (aggregate elasticity = 0.158 – 0.115 = 0.043) and on past GDP extended in two years (aggregate elasticity = 0.560 + 0.390 = 0.950). These results indicate that there exists '*bilateral causality'* between network readiness and GDP. However, according to the elasticities reported, the influence of GDP on network readiness is much stronger (0.289) than the influence of network readiness on GDP (0.043). This result may support the 'productivity paradox' stating that "you can see the computer age everywhere but in the productivity statistics" (Solow, 1987, p.36).

## Conclusions

The results of this study support the view that both information and communication technologies, expressed by the national network readiness index, and gross domestic product per capita, expressed in purchasing power parity standards, converge overtime in the 27 EU member-states. The convergence of ICT is much faster than the convergence of GDP. Furthermore, the results of this study indicate that although there exists bilateral causality between network readiness and GDP, the influence of GDP on network readiness is much stronger than the influence of network readiness on GDP.

These conclusions are important for policy purposes because it is believed that despite lower income levels in the various EU member-states, information and communication technologies is contributing to productivity growth in the EU (Ark & Piatkowski, 2004). Furthermore, although this contribution is overvalued in the relevant literature, the results of this study support the view that the 'productivity paradox' may still exist (Solow, 1987). This result is important considering the need for the less developed countries in the EU to employee convergence policies in the coming years.

The conclusions above, nonetheless, should be treated with caution. This is for two reasons. First, biases in estimating equations employing weighted average indexes may have distorted the results (Katsouli, 2006). Therefore, further research is needed using disaggregated variables. Second, the sample size for testing causality is rather small. Therefore, further research is needed using larger sample sizes.

*Table 4.* Results of pooled regressions (Dependent Variable: log($NR_{it}$))

| Variable | Coefficient | Coefficient |
|---|---|---|
| Constant | | 0.180760 |
| | | (0.0001) |
| log($GDP_{it}$) | 0.289318 | 0.061977 |
| | (0.0000) | (0.0000) |
| log($NR_{i,t-1}$) | 0.401173 | 0.755464 |
| | (0.0000) | (0.0000) |
| Fixed Effects | | |
| 1--C | 0.053344 | |
| 2--C | 0.057794 | |
| 3--C | 0.061379 | |
| 4--C | -0.004827 | |
| 5--C | -0.016662 | |
| 6--C | 0.018813 | |
| 7--C | -0.256237 | |
| 8--C | 0.017852 | |
| 9--C | 0.018587 | |
| 10--C | -0.030616 | |
| 11--C | -0.064780 | |
| 12--C | 0.176636 | |
| 13--C | -0.028848 | |
| 14--C | 0.044711 | |
| 15--C | 0.000862 | |
| 16--C | 0.026978 | |
| 17--C | -0.042652 | |
| 18--C | 0.053196 | |
| 19--C | 0.109274 | |
| 20--C | 0.054685 | |
| 21--C | 0.109959 | |
| 22--C | 0.067040 | |
| 23--C | -0.081206 | |
| 24--C | -0.088308 | |
| 25--C | 0.162102 | |
| 26--C | 0.026681 | |
| 27--C | 0.142004 | |
| R-squared | 0.892337 | 0.828173 |
| Adjusted R-squared | 0.873495 | 0.826325 |
| S.E. of regression | 0.055364 | 0.064870 |
| F-statistic | 1326.112 | 448.2408 |
| Prob(F-statistic) | 0.000000 | 0.000000 |
| Durbin-Watson stat | 2.246357 | 1.921950 |

*Table 5.* Results of pooled regressions (Dependent Variable: log($GDP_{it}$))

| Variable | Coefficient | Coefficient |
|---|---|---|
| Constant | | 0.165127 |
| | | (0.0000) |
| log($NR_{it}$) | 0.158241 | 0.160095 |
| | (0.0214) | (0.0108) |
| log($NR_{i,t-1}$) | -0.115282 | -0.118634 |
| | (0.0285) | (0.0004) |
| log($GDP_{i,t-1}$) | 0.589601 | 0.981277 |
| | (0.0000) | (0.0000) |
| log($GDP_{i,t-2}$) | 0.389822 | |
| | (0.0024) | |
| Fixed Effects | | |
| 1--C | 0.042734 | |
| 2--C | 0.028196 | |
| 3--C | 0.049606 | |
| 4--C | 0.047479 | |
| 5--C | 0.044098 | |
| 6--C | 0.047291 | |
| 7--C | 0.151505 | |
| 8--C | 0.030733 | |
| 9--C | 0.039116 | |
| 10--C | 0.031054 | |
| 11--C | 0.056505 | |
| 12--C | 0.108968 | |
| 13--C | 0.059906 | |
| 14--C | 0.038652 | |
| 15--C | 0.070484 | |
| 16--C | 0.076954 | |
| 17--C | 0.059792 | |
| 18--C | 0.032232 | |
| 19--C | 0.116560 | |
| 20--C | 0.106219 | |
| 21--C | 0.118328 | |
| 22--C | 0.055101 | |
| 23--C | 0.063651 | |
| 24--C | 0.033079 | |
| 25--C | 0.126047 | |
| 26--C | 0.080958 | |
| 27--C | 0.098714 | |
| R-squared | 0.994087 | 0.992384 |
| Adjusted R-squared | 0.992733 | 0.992260 |
| S.E. of regression | 0.038896 | 0.041030 |
| F-statistic | 7341.109 | 8035.302 |
| Prob(F-statistic) | 0.000000 | 0.000000 |
| Durbin-Watson stat | 1.943897 | 1.695686 |

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