DO SCIENTIFIC PRODUCTS CONTRIBUTE TO THE LEVEL OF OUTPUT? EMPIRICAL EVIDENCE FROM THE EUROPEAN UNION COUNTRIES

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Abstract

The relationship between scientific products and the level of productivity or output has become a hotly debated issue in recent years. However, the number of existing studies which examine this relationship is very low and hence more analyses are needed in order to reach conclusive results. This paper investigates the effect of scientific products on the level of gross domestic product (GDP) per capita for 15 European Union coutries over the period 1981-2011 by using Autoregressive Distributed Lag (ARDL) methodology to cointegration developed by Pesaran (1997), Pesaran and Smith (1998), Pesaran and Shin (1999) and Pesaran et al. (2001). According to the results of the empirical analysis, scientific publications have a statistically significant effect on the level of GDP per capita only in France and Sweden. In France the effect of scientific publications on the level of GDP per capita is negative in the short-run and this effect becomes positive in the long-run. However, in Sweden scientific publications have a positive impact on the level of GDP per capita both in the short-run and the long-run.

Keywords: Scientific and technical journal articles, GDP per capita, European Union countries, ARDL methodology.
JEL Codes: C22, O30, O31, O47, O52,

1. INTRODUCTION

The accumulation of knowledge is one of the main elements that determine the productivity and international competitiveness of a country (Inglesi-Lots and Pouris, 2013: 129). Theoretically, the significance of knowledge has been emphasized in the literature since the 1980s (Romer, 1986; Lucas, 1988). In parallel with these theoretical developments, the relationship between the knowledge stock of a country and its productivity or output level has been investigated by many researchers.

In the existing empirical literature, although there are quite a few studies which examine the relationship between the knowledge stock and productivity or output level by drawing on input indicators such as research and development expenditures the number of analyses which evaluate this

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relationship by using output indicators such as scientific publications is very low. Moreover, most of the existing studies which employ scientific publications to represent the knowledge stock of a country either calculate a basic correlation coefficient or apply causality analysis. Unlike most of the previous analyses, this study investigates the relationship between scientific publications and the output level by using ARDL methodology to cointegration developed by Pesaran (1997), Pesaran and Smith (1998), Pesaran and Shin (1999) and Pesaran et al. (2001) for the 15 European Union countries over the period 1981-2011. To the best of our knowledge, this is the first empirical study which analyses the linkage between scientific publications and the level of GDP per capita in the 15 European Union countries by applying the ARDL methodology to cointegration. Thus, the contribution of this study to the existing literature is two fold: First, the effect of scientific publications on the level of output is examined by using the most comprehensive data set available for the European Union countries; second, unlike most of the earlier analyses ARDL methodology to cointegration developed by Pesaran (1997), Pesaran and Smith (1998), Pesaran and Shin (1999) and Pesaran et al. (2001) is employed to shed light on the short-run and the long-run impacts of scientific publications on the level of output.

The remainder of the paper is as follows: in section 2 the existing empirical literature which focuses on the scientific publications-output level or economic growth nexus is summarized, in section 3 the model which provides the basis for the empirical analysis is discussed, in section 4 empirical methodology and the data is presented, in section 5 the results of the empirical analysis are explained and finally in section 6, the findings of the empirical analysis and policy suggestions are discussed.

2. LITERATURE REVIEW

In the existing literature, although there are many studies which use input indicators such as research and development expenditure to investigate the relationship between knowledge and economic growth the number of studies which draw on output indicators of knowledge such as scientific publications is very low. Here, the results of the papers which employ output indicators of knowledge in their empirical analyses are summarized.

Moya-Anegon and Herrero-Solana (1999) analyze the relationship between scientific publications and GDP by calculating the correlation between GDP in 1995 and the number of articles in Science Citation Indexed (SCI) journals in 1996 for the Latin American countries. According to the calculations, Moya-Anegon and Herrero-Solana state that there is a positive relationship between GDP level of the countries under investigation and their scientific publications.

King (2004) investigates the relationship between wealth intensity represented by GDP per capita and citations intensity represented by the ratio of the citations to all papers to the GDP in 31 countries

containing G8 group and 15 European Union countries (countries which were members of the European Union before 2004 accession) in 1995. King (2004) finds that Scadinavian countries, Israel, the Netherlands and Switzerland perfom very well with regard to this measure.
Vinkler (2008) estimates the correlation between GDP and the number of publications in 14 European Community member states, the US, Japan and 10 Central and Eastern European countries from 1975 to 2004 by using synchronized and asynchronized (examining consecutive time periods) longitudinal analyses. While the results of synchronized longitudinal analyses indicate that GDP and the number of publications move together the results of consecutive studies could not support that scientific publications may lead to economic growth. Hence, Vinkler (2008) suggests that it might be hazardous to assume a simple linear or exponential relationship between GDP and scientific products and more analyses are needed to shed light on the relationship between these variables.

Lee et al. (2011) examine the relationship between research output and economic productivity in a number of Asian and Western countries over the period 1981-2007. The authors draw on Granger Causality Analysis in their empirical evaluation and find a reciprocal relationship between research output and economic productivity in Asian countries while the relationship between these variables in Western countries is ambigious.

Meo et al. (2013) calculate the correlation between GDP per capita and research outcomes such as the number of published documents, citations per documents and H-index in 40 Asian countries between 1996 and 2011. According to the results of this analysis, the authors argue that there is no relationship between GDP per capita and research outcomes.

Inglesi-Lots and Pouris (2013) analyze the effect of research output on economic growth in South Africa over the period 1980-2008. By using ARDL methodology the authors conclude that while the research output affects economic growth in South Africa economic growth does not have an effect on research output. Hence, the results of this empirical analysis indicate a uniletaral relationship between knowledge and economic growth.

Kim and Lee (2015) investigate the impact of scientific and technological knowledge on economic growth in East Asian and Latin American countries between 1960 and 2005. In the empirical analysis, scientific and technological knowledge is represented by the number of Science Citation Indexed (SCI) articles per million residents and the number of corporate patents granted by the United States Patent and Trademark Office (USPTO) per million residents. Kim and Lee (2015) estimate the regression models by using OLS, fixed effects and Generalized Methods of Moments (GMM) estimators and come to the conclusion that whilst the number of SCI articles per million residents does not have a statistically significant effect on economic growth the number of corporate patents has a significant and positive effect on economic growth in the countries under investigation.

Inglesi-Lotz et al. (2015) examine the relationship between economic growth and research output in the BRICS countries (Brazil, Russia, India, China and South Africa) during the period 1981-2011. In the empirical analysis, Inglesi-Lotz et al. (2015) draw on panel causality analysis and take into account both cross-sectional dependency and heterogenity among the countries. The results of the empirical analysis indicate that there is a bidirectional relationship between economic growth and research output in India, whereas in Brazil, China and South Africa there is no relationship between these variables. Therefore, Inglesi-Lotz et al. (2015) conclude that the policies of the BRICS countries in relation to research and development are not similar although their economies show similar characteristics.

In a recent study, Kumar et al. (coming soon) assess the effect of scientific and technical research on economic growth in China and the USA over the period 1981-2012. The authors use ARDL methodology developed by Pesaran (1997), Pesaran and Smith (1998), Pesaran and Shin (1999) and Pesaran et al. (2001) and Toda and Yamamoto (1995) non-Granger causality tests. According to the results of the empirical analysis, Kumar et al. (coming soon) argue that research publications have a positive and statistically significant effect on economic growth both in the short-run and the long-run in China and the USA. Moreover, by taking into account the results of causality analysis the authors suggest that there is a bidirectional causality between output per worker and research publications per worker in China while in the USA this relationship is unidirectional which is from the research publications per worker to the output per worker.

In summary, although the empirical analyses which focus on the relationship between scientific publications and economic growth are on the rise in recent years the number of existing studies is still very low. Moreover, most of these studies calculate either a simple correlation coefficient between scientific publications and economic growth or apply basic causality analysis. Therefore, more analyses are needed to clarify the exact relationship between scientific publications and economic growth in different countries.

3. MODEL

In the empirical analysis, the modelling framework which is used by Kumar et al. (coming soon) to investigate the relationship between research output and economic growth in China and the USA is applied. This modelling framework which is introduced by Sturm et al. (1998) and Rao (2010) pertains to the Augmented Solow Growth Model (Solow, 1956). In this modelling framework, production function is described as follows (Kumar et al., coming soon):

$$Y_t = A_t SP_t^{\sigma} K_t^{\alpha} L_t^{\beta} \tag{1}$$

In this equation Y represents GDP level, A is the stock of technology, SP is the number of scientific publications, K is the capital stock, L is the labor stock, σ, α and β is the share of scientific publications, the share of capital stock and the share of labor stock in the production function respectively and t is the time subscript. If this equation is divided by the labor stock the following equation is obtained:

$$y_t = A_t sp_t^{\sigma} k_t^{\alpha} \tag{2}$$

where y, sp and k is the GDP, the number of scientific publications and capital per worker respectively. In order to have a testable equation Kumar et al. (coming soon) assume $A_t = A_0 e^{g^T}$ and get:

$$y_t = A_0 e^{g^T} sp_t^{\sigma} k_t^{\alpha} \tag{3}$$

Kumar et al. (coming soon) attain the equation below which is estimated in the empirical analysis by taking the logarithm of equation 3:

$$\ln y_t = \theta + \alpha \ln k_t + \sigma \ln sp_t + \varepsilon_t \tag{4}$$

where θ is the constant term, α is the share of capital, σ is the share of scientific publications which measures the production elasticity of this variable and ε is the error term.

4. EMPIRICAL METHODOLOGY AND DATA

Similar to the Kumar et al. (coming soon)'s study, the Autoregressive Distributed Lag (ARDL) approach to cointegration introduced by Pesaran (1997), Pesaran and Smith (1998), Pesaran and Shin (1999) and Pesaran et al. (2001) is employed in order to estimate equation 4. As it is very well known, there are a number of different methods such as residual based test of Engle and Granger (1987) and the maximum likelihood based tests of Johansen (1991, 1995) and Johansen and Juselius (1990) for cointegration analysis in the existing literature. However, the ARDL methodology to cointegration (Pesaran et al., 2001) has several advantages in comparison to the other methods. First, ARDL methodology can be applied to the variables which are stationary (i.e. I(0)), integrated of order one (i.e. I(1)) or integrated fractionally (Ghosh, 2009: 700). Second, ARDL methodology circumvents the problems of serial correlation and endogeneity by proper augmentation (Ghatak and Siddiki, 2001: 574). Third, by applying a simple linear transformation the Error Correction Model (ECM) which combines short run adjustments and long-run equilibrium can be obtained from the ARDL model (Jalil and Mahmud, 2009: 5168, 5169). Last but not least, ARDL methodology provides more reliable results than the other methods when the sample size is small (Pesaran and Shin, 1999). The last characteristics of the ARDL methodology is especially important in this empirical analysis since the data for the scientific publications is not available for a long period of time.

By taking into account equation 4, the ARDL model which is estimated can be stated as follows:

$$\Delta \mathrm{lny}_t = \alpha_{10} + \alpha_{11}\mathrm{lny}_{t-1} + \alpha_{12}\mathrm{lnk}_{t-1} + \alpha_{13}\mathrm{lnsp}_{t-1} + \alpha_{14}\mathrm{crisis}_t + \alpha_{15}\mathrm{trend}_t + \sum_{i=1}^{m}\beta_{11i}\,\Delta \mathrm{lny}_{t-i} + \sum_{i=0}^{m}\beta_{12i}\Delta \mathrm{lnk}_{t-i} + \sum_{i=0}^{m}\beta_{13i}\Delta \mathrm{lnsp}_{t-i} + \varepsilon_{1t} \quad (5)$$

Equation 5 has the same variables with equation 4 and two additional variables. The first additional variable is the crisis which represents 2008 Global Economic Crisis and the second additional variable is the trend term which represents the time trend in the regressions.

The steps of the ARDL model are as follows (Jalil and Mahmud, 2009: 5169): At first, equation 5 is estimated by using Ordinary Least Squares (OLS) estimator and then, F-test is calculated to test whether there is a long-run relationship between the variables. The null hypothesis of this test is H_0: $\alpha_{11}=\alpha_{12}=\alpha_{13}=\alpha_{14}=\alpha_{15}=0$ which means that there is no long-run relationship between the variables whilst the alternative is H_1: $\alpha_{11}\neq0$, $\alpha_{12}\neq0$, $\alpha_{13}\neq0$, $\alpha_{14}\neq0$, $\alpha_{15}\neq0$. The calculated F-statistics is compared with two critical values. If the F-statistics is higher than the upper value then the null hypothesis of no cointegration is rejected. Instead of this, if the F-statistics drops below the lower value then the null hypothesis cannot be rejected. Finally, if the F-statistics is between the lower and higher bounds then the result is inconclusive.

The F-statistics and the lower and higher critical values are based on the size of the sample, the model specification and the lag-length (Kumar et al., coming soon). Although there are some studies which provide critical values such as Pesaran et al. (2001) and Narayan (2005) these critical values are calculated for specific sample sizes and do not take into account structural breaks (Kumar et al., coming soon). There is a built in function in Microfit 5.0 developed by Pesaran and Pesaran (2009) which calculates F-statistics and the lower and upper critical values according to the features of the sample under investigation. This built in function in Microfit 5.0 is used in this empirical analysis.

As stated above, the ARDL model can be applied as long as the variables are either I(0) or I(1). However, Ouattara (2004) claims that if the variables are integrated of order two or higher then the F-statistics provided by Pesaran et al. (2001) is not valid. Thus, in order to ensure that the variables are either I(0) or I(1) the generalised least squares (GLS) detrended version of the conventional Dickey-Fuller test (DFGLS or ERS test) proposed by Elliott et al. (1996) and a modified version of the tests of

Phillips and Perron (1988) proposed by Ng and Perron (2001)[2] are applied before the ARDL estimation. Both of these tests perform better than the traditional unit root tests especially when the length of the series is short (Elliott et al., 1996; Ng and Perron, 2001), as is the case with this empirical analysis. After the unit root analysis, the ARDL methodology is applied to the countries whose variables are integrated of order zero or one.

The data covers 15 European Union countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom) over the period 1981-2011. The time period and the countries are chosen according to the data availability. Since labor force statistics are not available for most of the countries over the whole time period under investigation population statistics are used while calculating per capita series. GDP, net capital stock and population data are taken from the Annual Macro-economic Database (AMECO) of the European Commission's Directorate General for Economic and Financial Affairs (2015). Both GDP and net capital stock series are at 2010 prices. The data for the number of scientific and technical journal articles are taken from the World Bank-World Development Indicators Database (2015). The scientific and technical journal articles cover the fields of physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences and count the articles published in the journals classified by the Institute for Scientific Information's Science Citation Index (SCI) and Social Science Citation Index (SSCI) (World Bank, 2015). Since the number of scientific and technical articles data are missing for the years of 1982, 1983 and 1984 linear interpolation method is used in order to fill in these missing values. All variables (GDP, net capital stock and the number of scientific and technical articles) are stated as a percentage of total population and their natural logarithms are taken before the estimations.

5. EMPIRICAL RESULTS

Table 1 presents the results of the unit root tests. As it is clearly seen, except Ireland and Spain all series are either integrated of the order zero or one for all the countries under investigation. So, ARDL methodology can be applied to the 13 European Union countries excluding Ireland and Spain[3].

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[2] The modified Ng and Perron test is the M^{GLS} extension of the M tests developed by Perron and Ng (1996) that allows for GLS detrending.

[3] As it is very well known, the presence of structural breaks in the series may cause misleading results in the unit root analysis. As demonstrated by Perron (1989) when the structural breaks were taken into account many time series regarded as non-stationary according to the conventional unit root tests were in fact stationary. Because of this reason, Clemente, Montanes and Reyes (1998) unit root test which takes into account structural breaks in the series is also applied. The results of this test are similar to the DFGLS and Ng-Perron unit root test resuts. These results can be provided upon request.

Table 1: Unit Root Test Results

Countries	Variables	DFGLS Test	Ng-Perron Test			
		t-Statistics	MZa	MZt	MSB	MPT
Austria	GDP	-2.40837	-15.7779*	-2.65932*	0.16855**	6.63055*
	Cap. Stock	-1.46620	-352.148***	-13.2164***	0.03753***	0.36833***
	Sci. Papers	-1.848055	-20.7196**	-3.16308**	0.15266**	4.72792**
	ΔGDP	-4.379364***	-14.0038***	-2.64069***	0.18857**	1.77004***
	ΔCap. Stock	-0.798482	---	---	---	---
	ΔSci. Papers	-1.912686*	---	---	---	---
Belgium	GDP	-1.729137	-10.2026	-2.01664	0.19766	9.96591
	Cap. Stock	-1.224949	-14.8788*	-2.51191*	0.16883*	7.32530*
	Sci. Papers	-1.384990	-4.33728	-1.27880	0.29484	19.2938
	ΔGDP	-4.154756***	-13.6012**	-2.59990***	0.19115**	1.83133**
	ΔCap. Stock	-1.900395*	-9.62383**	-2.02530**	0.21045**	3.16861**
	ΔSci. Papers	-5.238841***	-14.4577***	-2.67467***	0.18500**	1.74723***
Denmark	GDP	-1.787906	-11.3307	-2.13554	0.18847	9.21042
	Cap. Stock	-2.515187	-18.4526**	-2.96661**	0.16077**	5.35776**
	Sci. Papers	-3.103148*	-11.2960	-2.36090	0.20900	8.14533
	ΔGDP	-3.415115***	-11.7689**	-2.40414**	0.20428**	2.16500**
	ΔCap. Stock	-3.079734***	---	---	---	---
	ΔSci. Papers	-8.020864***	-11.8451**	-2.34630**	0.19808**	2.39951**
Finland	GDP	-2.840199	-18.0775**	-2.98269**	0.16499**	5.18234**
	Cap. Stock	-1.911926	-6.55501	-1.77537	0.27084	13.9066
	Sci. Papers	-1.147499	-44.7718***	-4.61989***	0.10319***	2.59401***
	ΔGDP	-3.353133***	---	---	---	---
	ΔCap. Stock	-2.876647***	-17.7909***	-2.94586***	0.16558***	1.50879***
	ΔSci. Papers	-2.506854**	---	---	---	---
France	GDP	-2.085413	-13.6185	-2.44711	0.17969	7.57630
	Cap. Stock	-1.333494	-5.64077	-1.50559	0.26691	15.7381
	Sci. Papers	-2.067474	-19.1592**	-3.02504**	0.15789**	5.17136**
	ΔGDP	-3.551732***	-12.3836**	-2.48834**	0.20094**	1.97842**
	ΔCap. Stock	-2.589636**	-16.2615***	-2.75356***	0.16933***	1.86157**
	ΔSci. Papers	-1.164957*	---	---	---	---
Germany	GDP	-1.486511	-4.09418	-1.35969	0.33210	21.4603
	Cap. Stock	-1.028283	-2.61075	-0.94499	0.36196	28.3104
	Sci. Papers	-1.663259	-5.09794	-1.52956	0.30004	17.5592
	ΔGDP	-4.634642***	-14.1069***	-2.63548***	0.18682***	1.81351**
	ΔCap. Stock	-4.927382***	-14.4317***	-2.67815***	0.18557***	1.72810***
	ΔSci. Papers	-4.745628***	-14.3045***	-2.67306***	0.18687**	1.71769***
Greece	GDP	-3.145254*	-5.33891	-1.42658	0.26720	16.3467
	Cap. Stock	-3.282129**	-124.619***	-7.89309***	0.06334***	0.73311***
	Sci. Papers	-2.695774	-108.299***	-7.20758***	0.06655***	1.37739***
	ΔGDP	-1.025322	-14.3263***	-2.41153**	0.16833***	2.66146**
	ΔCap. Stock	---	---	---	---	---
	ΔSci. Papers	-1.740885*	---	---	---	---
Ireland	GDP	-2.696462	0.65207	0.45991	0.70531	113.798
	Cap. Stock	-2.583557	-46.2432***	-4.79676***	0.10373***	2.02933***
	Sci. Papers	-3.074583*	-8.22973	-1.98487	0.24118	11.1986
	ΔGDP	-1.422151	-27.7876***	-3.72665***	0.13411***	0.88419***
	ΔCap. Stock	-2.023370**	---	---	---	---
	ΔSci. Papers	-1.633474*	-2.52584	-1.11464	0.44129	9.65213

Table 1: Unit Root Test Results (Continued)

Countries	Variables	DFGLS Test	Ng-Perron Test			
		t-Statistics	MZa	MZt	MSB	MPT
Italy	GDP	-1.342392	-6.11861	-1.48092	0.24203	14.6494
	Cap. Stock	-1.225113	-88.0718***	-6.44570***	0.07319***	1.76928***
	Sci. Papers	-1.574347	-15.8275*	-2.61642*	0.16531**	6.87420
	ΔGDP	-3.198008***	-11.3365**	-2.37437**	0.20945**	2.18602**
	ΔCap. Stock	-1.558501	---	---	---	---
	ΔSci. Papers	-0.127229	-15.8275*	-2.61642*	0.16531**	6.87420
Luxembourg	GDP	-1.323114	-4.97763	-1.31500	0.26418	17.0023
	Cap. Stock	-2.395519	-9.97340	-2.20373	0.22096	9.26468
	Sci. Papers	-2.549846	-8.18066	-1.83945	0.22485	11.6390
	ΔGDP	-3.963092***	-13.3174**	-2.56547**	0.19264**	1.89673**
	ΔCap. Stock	-2.939558***	-10.5955**	-2.27039**	0.21428**	2.43262**
	ΔSci. Papers	-2.743093***	-3.61634	-1.27637	0.35295	6.77400
Netherlands	GDP	-2.469679	-14.5195	-2.53255	0.17442	7.17983
	Cap. Stock	-1.874049	-6.65938	-1.78153	0.26752	13.7000
	Sci. Papers	-2.642088	-3825.63***	-43.7334***	0.01143***	0.02535***
	ΔGDP	-2.794861***	-8.85923**	-2.10182**	0.23725**	2.77629**
	ΔCap. Stock	-3.693719***	-31.9427***	-3.96709***	0.12419***	0.85473***
	ΔSci. Papers	-1.484897	---	---	---	---
Portugal	GDP	-1.837332	-32.1459***	-3.90008***	0.12132***	3.43551***
	Cap. Stock	-0.421308	-26.0271***	-3.39580**	0.13047***	4.70056**
	Sci. Papers	-1.630129	-7.40560	-1.74435	0.23554	12.6128
	ΔGDP	-2.407225**	---	---	---	---
	ΔCap. Stock	-1.246638	---	---	---	---
	ΔSci. Papers	-3.872206***	-11.8934**	-2.43752**	0.20495**	2.06409**
Spain	GDP	-2.117402	-54.9136***	-5.06974***	0.09232***	2.45007***
	Cap. Stock	-1.430744	-14.9094	-2.56125	0.17179*	7.06247
	Sci. Papers	-2.467587	-1.63865	-0.67239	0.41033	36.9749
	ΔGDP	-1.955749**	---	---	---	---
	ΔCap. Stock	-2.675308***	-25.7279***	-3.48792***	0.13557***	1.26791***
	ΔSci. Papers	0.045437	-0.22208	-0.19734	0.88859	43.0836
Sweden	GDP	-2.247323	-10.6927	-2.30857	0.21590	8.53955
	Cap. Stock	-1.624405	-7.17305	-1.77273	0.24714	12.8683
	Sci. Papers	-1.179542	-18.1728**	-2.87158*	0.15802**	5.84847*
	ΔGDP	-4.002636***	-13.4094**	-2.58875***	0.19306**	1.82933**
	ΔCap. Stock	-2.258177**	-11.1624**	-2.30275**	0.20629**	2.42303**
	ΔSci. Papers	-1.518626	---	---	---	---
Uni. Kingdom	GDP	-2.506448	-24.7257***	-3.33251**	0.13478***	4.73766**
	Cap. Stock	-1.747057	-150.151***	-8.59425***	0.05724***	0.82403***
	Sci. Papers	-1.128176	-2.26721	-0.86244	0.38040	31.1971
	ΔGDP	-2.955662***	---	---	---	---
	ΔCap. Stock	-0.956099	---	---	---	---
	ΔSci. Papers	-5.976788***	-14.2737***	-2.66333***	0.18659**	1.74725***

Note: ***, **, * denotes the significance at 1%, 5% and 10% levels respectively. A constant and a trend term added to the models according to the examinations of the series' graphs.
Source: Author's estimations.

After examining the order of integration of the series the optimal lag length is selected according to the Log Likelihood (LogL), Sequential Modified LR Test Statistic (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SC) and Hannan-Quinn Information Criterion (HQ). Table 2 shows these statistics. According to the results, the optimal lag lengh is: 1 for Luxembourg, 2 for Belgium, Denmark and the United Kingdom, 3 for France, Germany and Portugal, 4 for Finland, Italy and Sweden, 2 or 3 for Austria, 1 or 4 for Greece and 2 or 4 for the Netherlands. Hence, these lags are used while estimating the ARDL model[4].

Following the selection of optimal lag length F-statistics is calculated in order to decide whether there is a long-run relationship between the variables. Table 3 presents these results. As it is clearly seen, the long-run relationship between GDP, capital stock and scientific and technical articles per capita exists only for France, the Netherlands and Sweden. Thus, error-correction model (ECM) is estimated for these countries.

Table 4 and table 5 show the estimated long-run coefficients and the ECM respectively. According to the long-run coefficient estimates (table 4), scientific and technical journal articles are statistically significant and have a positive sign for France and Sweden. However, this variable is not statistically significant for the Netherlands. The results indicate that a 1% increase in scientific and technical journal articles per capita leads to 2.59 % and 2.34% increase in GDP per capita in France and Sweden respectively. Therefore, it can be suggested that while scientific and technical journal articles have a strong positive effect on GDP per capita in France and Sweden in the long-run this variable does not have an impact on GDP per capita in the Netherlands. When the results of the ECM are examined (table 5) it is seen that error-correction coefficient is statistically significant and has a negative sign for all of the countries under investigation. This result confirms the existence of a long-run relationship between the variables. With regard to the coefficient estimates, it can be stated that capital per capita and the crisis variables are statistically significant in all of the countries. While capital per capita has a positive effect crisis has a negative impact on GDP per capita in the short-run. When it comes to the scientific and technical journal articles per capita, it can be suggested that this variable is statistically significant in France and Sweden. In contrast to the long-run results, scientific and technical journal articles per capita has a negative effect on GDP per capita in France in the short-run. However, in Sweden the impact of scientific and technical journal articles on GDP per capita is positive. Therefore, it can be stated that although scientific products in France have a negative impact on GDP in the short-run this negative impact becomes positive in the long-run. Conversly, in Sweden scieintific products have a positive effect on GDP per capita both in the short-run and the long-run. This may stem from the fact that the transformation of scientific knowledge to marketable products

[4] For Austria, Greece and the Netherlands two ARDL models are estimated by using two different lag lengths selected according to the test statistics. The results of these models are very similar. Since the data set does not cover a long period of time here the results of the model which is estimated by using smaller lag length are presented.

takes a long time in France while in Sweden scientific knowledge can be turned into commercial products even in the short-run.

Table 2: Lag Length Selection

Lag	LogL	LR	FPE	AIC	SC	HQ
Austria						
0	213.5031	---	5.31e-11	-15.14838	-14.71643	-15.01994
1	258.7484	70.38161	3.69e-12	-17.83322	-16.96933	-17.57634
2	275.6268	22.50448*	2.18e-12	-18.41680	-17.12096*	-18.03148
3	286.5597	12.14768	2.13e-12*	-18.55998	-16.83220	-18.04622*
4	296.7787	9.083554	2.44e-12	-18.65027*	-16.49055	-18.00807
Belgium						
0	205.8181	---	9.38e-11	-14.57912	-14.14717	-14.45068
1	263.6084	89.89609	2.58e-12	-18.19322	-17.32933	-17.93634
2	282.8034	25.59324*	1.28e-12*	-18.94840*	-17.65256*	-18.56308*
3	287.4038	5.111555	2.00e-12	-18.62250	-16.89472	-18.10874
4	298.2414	9.633499	2.19e-12	-18.75863	-16.59890	-18.11643
Denmark						
0	195.6290	---	1.99e-10	-13.82437	-13.39243	-13.69593
1	258.0556	97.10798	3.89e-12	-17.78190	-16.91800	-17.52502
2	277.8760	26.42722*	1.85e-12*	-18.58341*	-17.28757*	-18.19809*
3	283.8323	6.618053	2.61e-12	-18.35794	-16.63016	-17.84418
4	294.6155	9.585126	2.86e-12	-18.49004	-16.33031	-17.84784
Finland						
0	144.2952	---	8.94e-09	-10.02186	-9.589919	-9.893424
1	247.3855	160.3627	8.57e-12	-16.99152	-16.12763	-16.73464
2	266.7474	25.81595*	4.21e-12	-17.75907	-16.46323*	-17.37375
3	276.4990	10.83511	4.49e-12	-17.81474	-16.08696	-17.30098
4	292.0588	13.83090	3.46e-12*	-18.30065*	-16.14092	-17.65845*
France						
0	205.3292	---	9.72e-11	-14.54291	-14.11096	-14.41447
1	284.9822	123.9045	5.29e-13	-19.77646	-18.91257	-19.51958
2	310.5915	34.14584	1.64e-13	-21.00678	-19.71094	-20.62146
3	327.1631	18.41285*	1.05e-13*	-21.56764	-19.83985*	-21.05388*
4	337.8741	9.520850	1.16e-13	-21.69437*	-19.53465	-21.05217
Germany						
0	164.3353	---	2.03e-09	-11.50632	-11.07438	-11.37788
1	203.9147	61.56794	2.15e-10	-13.77146	-12.90757*	-13.51458
2	213.9882	13.43134	2.10e-10	-13.85098	-12.55514	-13.46566
3	231.5216	19.48155*	1.26e-10*	-14.48308	-12.75530	-13.96932*
4	241.3150	8.705232	1.48e-10	-14.54185*	-12.38212	-13.89965
Greece						
0	170.0570	---	1.33e-09	-11.93015	-11.49820	-11.80171
1	236.7876	103.8033*	1.88e-11	-16.20649	-15.34260*	-15.94961
2	249.1859	16.53097	1.55e-11*	-16.45821	-15.16237	-16.07289
3	258.9881	10.89138	1.64e-11	-16.51764	-14.78985	-16.00388
4	271.4388	11.06725	1.59e-11	-16.77324*	-14.61351	-16.13104*
Italy						
0	-221.0748	---	5073.124	17.04258	17.47452	17.17102
1	-141.7920	123.3289	28.37287	11.83644	12.70033*	12.09332
2	-133.0017	11.72035	30.50190	11.85198	13.14782	12.23730
3	-125.0616	8.822327	37.21554	11.93049	13.65827	12.44425
4	-104.9524	17.87482*	20.46902*	11.10759*	13.26732	11.74979*
Luxembourg						
0	136.7847	---	1.56e-08	-9.465530	-9.033585	-9.337090
1	180.9473	68.69743*	1.18e-09*	-12.07017	-11.20628*	-11.81329*
2	184.8799	5.243508	1.81e-09	-11.69481	-10.39897	-11.30949
3	194.0696	10.21076	2.02e-09	-11.70886	-9.981077	-11.19510
4	209.8640	14.03949	1.53e-09	-12.21215*	-10.05242	-11.56995

Table 2: Lag Length Selection (Continued)

Lag	LogL	LR	FPE	AIC	SC	HQ
Netherlands						
0	208.9446	---	7.44e-11	-14.81071	-14.37877	-14.68227
1	267.0846	90.43994	1.99e-12	-18.45071	-17.58682	-18.19383
2	289.8676	30.37738*	7.60e-13	-19.47167	-18.17584*	-19.08635
3	302.5337	14.07348	6.53e-13*	-19.74324	-18.01546	-19.22948
4	313.9293	10.12941	6.85e-13	-19.92069*	-17.76096	-19.27849*
Portugal						
0	160.1085	---	2.77e-09	-11.19323	-10.76128	-11.06478
1	233.8108	114.6480	2.34e-11	-15.98599	-15.12210	-15.72911
2	245.1735	15.15018	2.08e-11	-16.16100	-14.86516	-15.77568
3	265.0588	22.09484*	1.05e-11*	-16.96732	-15.23954*	-16.45356*
4	274.4580	8.354834	1.27e-11	-16.99689*	-14.83716	-16.35469
Sweden						
0	179.4483	---	6.61e-10	-12.62580	-12.19386	-12.49736
1	267.4947	136.9609	1.93e-12	-18.48109	-17.61719	-18.22421
2	280.4793	17.31289	1.52e-12	-18.77625	-17.48041	-18.39093
3	299.0320	20.61413*	8.47e-13	-19.48386	-17.75607	-18.97009
4	316.1577	15.22283	5.81e-13*	-20.08576*	-17.92603*	-19.44356*
Uni. Kingdom						
0	186.4565	---	3.94e-10	-13.14493	-12.71298	-13.01649
1	263.0786	119.1899	2.68e-12	-18.15397	-17.29008	-17.89709
2	285.6366	30.07729*	1.04e-12*	-19.15827	-17.86243*	-18.77295*
3	289.4357	4.221259	1.72e-12	-18.77302	-17.04523	-18.25926
4	306.7724	15.41035	1.16e-12	-19.39054*	-17.23082	-18.74834

Note: LogL: Log Likelihood, LR: Sequential Modified LR Test Statistic, FPE: Final Prediction Error, AIC: Akaike Information Criterion, SC: Schwarz Information Criterion, HQ: Hannan-Quinn Information Criterion
Source: Author's estimations.

Table 3: Results of Bounds Test at 5% Level

Countries	F Statistic	W Statistic	Outcome
Austria	5.5847 (6.3568, 7.4286)	16.7540 (19.070, 22.285)	**No Cointegration**
Belgium	2.8317(6.3568, 7.4286)	8.4951 (19.0704, 22.2857)	**No Cointegration**
Denmark	2.9348 (6.3568,7.4286)	8.8045 (19.0704,22.2857)	**No Cointegration**
Finland	5.4084 (6.4597, 7.5938)	16.2251 (19.3792, 22.7814)	**No Cointegration**
France	40.5977(6.4247, 7.4867	121.7930(19.2741, 22.4602)	**Cointegration**
Germany	5.4339 (6.4247, 7.4867)	16.3016 (19.2741, 22.4602	**No Cointegration**
Greece	2.5160(6.4597, 7.5938)	7.5479 (19.3792, 22.7814)	**No Cointegration**
Italy	0.1829 (6.4597, 7.5938)	0.5487 (19.3792, 22.7814)	**No Cointegration**
Luxembourg	7.2336 (6.2915, 7.3503)	21.7008 (18.8744, 22.0508)	**No Cointegration**
Netherlands	9.7540(6.3568, 7.4286)	29.2620 (19.0704, 22.2857)	**Cointegration**
Portugal	5.2418(6.4247, 7.4867)	15.7255 (19.2741, 22.4602)	**No Cointegration**
Sweden	15.8066(6.4597, 7.5938)	47.4199(19.3792, 22.7814)	**Cointegration**
Uni. Kingdom	2.5513 (6.4247, 7.4867)	7.6538(19.2741, 22.4602)	**No Cointegration**

Note: The lower and upper critical values are in parenthesis.
Source: Author's estimations.

Table 4: Estimated Long-run Coefficients

Variables	Coefficient	Stan. Error	T-Ratio
France			
Cap. Stock	-0.4287	0.7313	-0.5862
Sci. Papers	0.3293	0.1270	2.5933**
Crisis	-0.0414	0.0088	-4.7237***
Constant	22.2045	11.7868	1.8838*
Trend	0.0181	0.0092	1.9613*
Diagnostic Tests	**LM Test Stat.**	**P-value**	
Serial Correlation	1.0359	0.309	
Normality	1.6474	0.439	
Heteroscedasticity	4.1144	0.043	
Netherlands			
Cap. Stock	-0.0869	1.1876	-0.0732
Sci. Papers	0.0512	0.0691	0.7408
Crisis	-0.0644	0.0182	-3.5437***
Constant	16.0128	18.5762	0.8620
Trend	0.0222	0.0186	1.1939
Diagnostic Tests	**LM Test Stat.**	**P-value**	
Serial Correlation	0.032446	0.857	
Normality	6.4747	0.039	
Heteroscedasticity	2.1463	0.143	
Sweden			
Cap. Stock	-2.5472	0.7713	-3.3026***
Sci. Papers	0.5478	0.2340	2.3411**
Crisis	-0.0631	0.0189	-3.3465***
Constant	64.4651	14.6116	4.4119***
Trend	0.0614	0.0102	6.0128***
Diagnostic Tests	**LM Test Stat.**	**P-value**	
Serial Correlation	11.9393	0.001	
Normality	2.6365	0.268	
Heteroscedasticity	0.48016	0.488	

Note: ***, **, * denotes the significance at 1%, 5% and 10% levels respectively. Besides long-run coefficient estimates the table also shows the results of diagnostic tests. According to the normality test results, the disturbance terms are not normally distributed for the Netherlands. However, since the number of observations is higher than 30 this does not create a problem. Similarly, the results indicate that there is a problem of heteroscedasticity and serial correlation for France and Sweden respectively. Since ARDL model is robust against serial correlation (Laurenceson and Chai 2003: 30) and detecting heteroscedasticity is natural due to the mixed orders of integration of the series (Shrestha and Chowdhury, 2005) these results do not indicate a problem.
Source: Author's estimations.

Finally, the stability of the model should be checked by employing the CUSUM and CUSUMSQ technique which is developed by Brown et al. (1975). Appendix A, appendix B and appendix C present the plots of CSUM and CSUMSQ for France, the Netherlands and Sweden respectively. As it is clearly seen the plots of CSUM and CSUMSQ are within the 95% critical bounds implying that all coefficients estimated in the ECM are stable over the sample period under investigation.

Table 5: Error-Correction Model Results

Variables	Coefficient	Stan. Error	T-Ratio
France			
ARDL (3,1,3) selected based on Akaike Information Criterion			
ΔGDP1	-0.2760	0.1333	-2.0711*
ΔGDP2	-0.2519	0.1372	-1.8365*
ΔCap. Stock	5.2821	0.5660	9.3318***
ΔSci. Papers	0.0231	0.0351	0.6588
ΔSci. Papers1	-0.1668	0.0388	-4.5778***
ΔSci. Papers2	-0.0809	0.0388	-2.0863*
ΔCrisis	-0.0218	0.0056	-3.9291***
ΔTrend	0.0096	0.0029	3.3338***
ecm (-1)	-0.5275	0.1417	-3.7226***
R-Squared: 0.95200 R-Bar Squared: 0.91900		Akaike Info. Criterion: 108.9019	
SER: 0.0042661		Schwarz Bayesian Criterion: 100.9087	
DW-Statistic: 2.2582		F-Statistic: 35.2604 (0.000)	
Netherlands			
ARDL (1,1,0) selected based on Akaike Information Criterion			
ΔCap. Stock	2.9309	0.5618	5.2174***
ΔSci. Papers	0.0202	0.0287	0.7042
ΔCrisis	-0.0254	0.0089	-2.8609***
ΔTrend	0.0088	0.0060	1.4587
ecm (-1)	-0.3950	0.1088	-3.6299***
R-Squared: 0.77730 R-Bar Squared: 0.71657		Akaike Info. Criterion: 91.9537	
SER: 0.0091591		Schwarz Bayesian Criterion: 87.1682	
DW-Statistic: 2.0285		F-Statistic: 15.3577 (0.000)	
Sweden			
ARDL (2,4,3) selected based on Akaike Information Criterion			
ΔGDP	-0.2518	0.1518	-1.6586
ΔCap. Stock	5.4099	0.5040	10.7349***
ΔCap. Stock1	-2.9660	1.1375	-2.6074**
ΔCap. Stock2	0.0703	1.2894	0.0545
ΔCap. Stock3	2.9246	0.7745	0.0545***
ΔSci. Papers	0.0704	0.0671	3.1940***
ΔSci. Papers1	0.0704	0.0647	1.0877
ΔSci. Papers2	0.0972	0.0595	1.6334
ΔCrisis	-0.0254	0.0082	-3.0984***
ΔTrend	0.0247	0.0035	7.0507***
ecm(-1)	-0.4025	0.0916	-4.3955***
R-Squared: 0.96989 R-Bar Squared: 0.93978		Akaike Info. Criterion: 94.5187	
SER: 0.0062654		Schwarz Bayesian Criterion: 85.4478	
DW-Statistic: 2.7216		F-Statistic: 38.0677 (0.000)	

Note: ***, **, * denotes the significance at 1%, 5% and 10% levels respectively.
Source: Author's estimations.

In summary, the results of this empirical analysis demonstrate that there is a long-run relationship between scientific publications and the level of GDP per capita only in France, the Netherlands and Sweden out of 15 European Union countries over the period 1981-2011. While scientific publications do not have a statistically significant effect on GDP per capita in the Netherlands both in the short-run and the long-run this variable influences the level of GDP per capita in France and Sweden. Although the impact of scientific publications on the GDP per capita is negative in France in the short-run this impact becomes positive in the long-run. In Sweden scientific publications have a strong positive effect on GDP per capita both in the short-run and the long-run. These results indicate that whilst a long time is necessary to transform the scientific products into commercial products in France this transformation can be achieved even in the short-run in Sweden.

6. CONCLUSION

Since the begining of 1990s research and development activities and technology have been accepted as one of the main drivers of productivity and economic growth both by economists and policy makers. Hence, the effect of these variables on the level of productivity and GDP has been investigated intensively in recent years. Although there are many studies which use input indicators such as research and development expenditures while investigating the relationship between technology and the level of productivity or GDP the number of studies which employ output indicators such as scientific publications is very low. In this empirical analysis, it is tried to fill in this gap in the existing literature.

In order to elucidate the effect of scientific publications on the level of GDP per capita in the European Union countries ARDL methodology to cointegration is applied for the 15 European Union countries over the period 1981-2011. The results of the empirical analysis indicate that there is a long-run relationship between scientific publications and the level of GDP per capita only in France, the Netherlands and Sweden out of 15 European Union countries. While in France and Sweden scientific publications have a statistically significant effect on the level of GDP per capita both in the short-run and the long-run this variable does not have a statistically significant impact on the level of GDP per capita in the Netherlands. Moreover, although the effect of scientific publications on the level of GDP per capita is negative in France in the short-run this negative effect turns out to be positive in the long-run. As for Sweden scientific publications influence the level of GDP per capita positively both in the short-run and the long-run. According to these results, it is suggested that a long time is necessary in order to transform scientific products into commercial and marketable products in France. However, in Sweden scientific products can be turned into commercial products even in the short-run.

To conclude, it is argued that scientific products do not have an effect on the level of GDP per capita in most of the European Union countries except France and Sweden. This result indicates that the cooperation between laboratories, universities and the industry is still weak in the European Union. Thus, in order to improve this cooperation and in this way to increase the contribution of scientific products to the level of economic activity science policies which empower the linkage between laboratories, universities and the industry should be implemented immediately.

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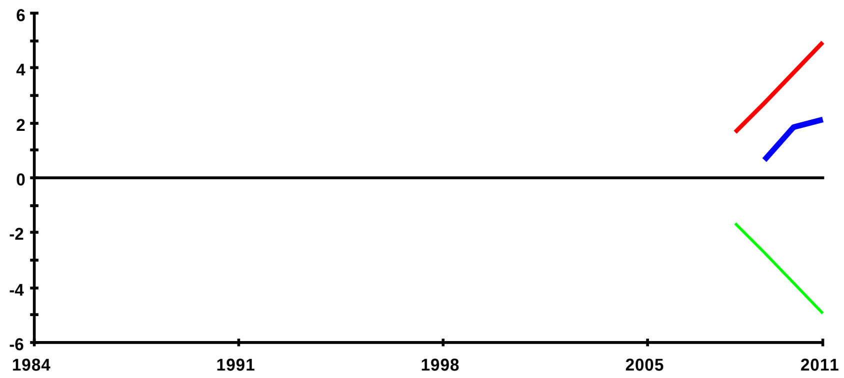
APPENDIX A

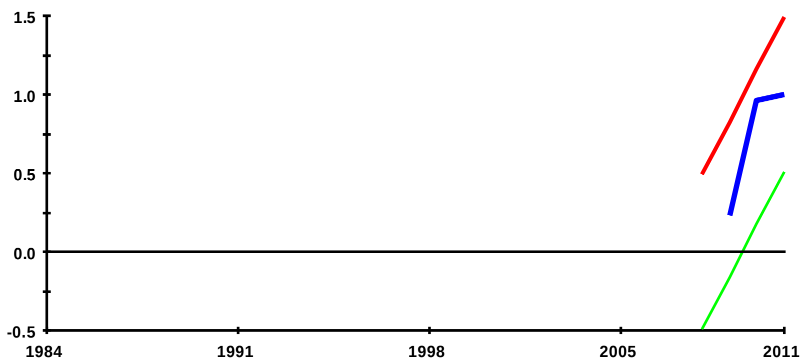
FRANCE

Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

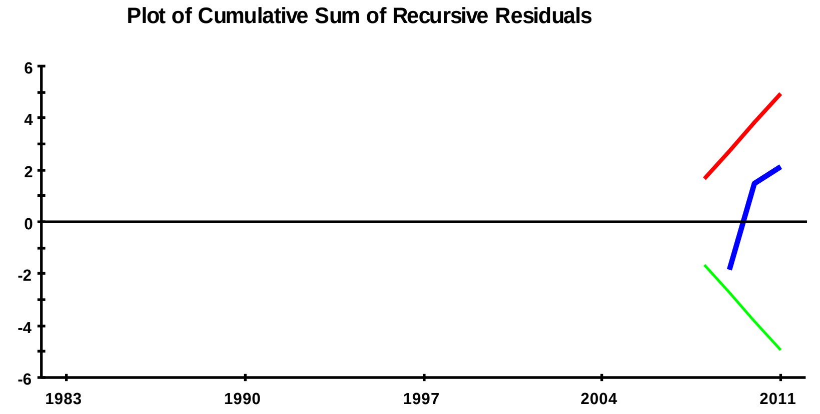
Plot of Cumulative Sum of Squares of Recursive Residuals



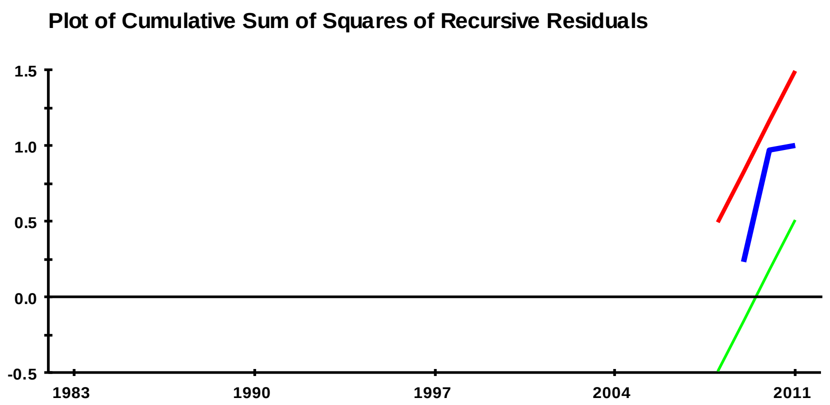
The straight lines represent critical bounds at 5% significance level

APPENDIX B

THE NETHERLANDS



The straight lines represent critical bounds at 5% significance level



The straight lines represent critical bounds at 5% significance level

APPENDIX C

SWEDEN

Plot of Cumulative Sum of Recursive Residuals

The straight lines represent critical bounds at 5% significance level

Plot of Cumulative Sum of Squares of Recursive Residuals

The straight lines represent critical bounds at 5% significance level