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Does R&D, Human Capital and FDI matter for TFP in OECD?

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September 2019

Abstract:

This study investigates the interplay between research & development (R&D), human capital, foreign direct investment (FDI) and total factor productivity (TFP) in OECD. The analysis follows the endogenous growth theory and applies a panel data approach over the period 2000-2015. R&D and human capital have a positive effect on TFP, whilst FDI has a positive and significant effect only in the case of non-European countries. Moreover, the contribution of human capital is higher than that of R&D in European countries. On the other hand, the effect of R&D is higher than that of human capital and FDI in non-Europeans countries. Thus, based on these findings policies fostering R&D, higher education and investment should be a priority.

Keywords: R&D, Human capital, FDI, Total Factor Productivity, OECD, Panel Data.

JEL: C33, F21, H63, I25, O30, O40

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1. Introduction

Economic theory stresses the importance of technical change as the major driver of productivity growth in the long-run. Both in the neoclassical model of Solow (1956) as well as in the endogenous growth theories introduced by Romer (1990) and Lucas (1988), the key determinant of economic growth is the rate of technological progress, which can be approximated by TFP growth. Mahadevan (2003) discusses that TFP is the main factor for sustaining output growth and so it drives the economic growth in the long run. However, a key difference between the neoclassical theory and the endogenous growth theories is that in the latter the rate of technological progress can be enhanced through economic policy decisions (Howitt, 2004). The endogenous growth models introduced by Lucas (1988), Romer (1990), Grossman and Helpman (1991a, 1991b), and Aghion and Howitt (1992) have focused on the key role of R&D efforts, human capital (HC) and FDI in driving technical progress and productivity. They argue that there are interactions among the variables R&D, HC and FDI, while considered as key factors for explaining productivity growth.

R&D activities produce new knowledge, while the development activity launches state-of-the-art or advanced products and processes (OECD, 2005). Grossman and Helpman (1991a) argue that TFP depends not only on the size of R&D activity but also can be raised by an increase in the R&D capital. Since the 1990s, developed countries, worldwide, have been engaged in an innovation race, investing more resources in R&D. At the beginning of the 2000s, the European Union set itself the ambitious goal to raise overall R&D investment to 3% of GDP by 2010 and become the most competitive and dynamic knowledge-based economy in the world (known as the Lisbon strategy). In this way, the European Union (EU) tried to narrow the innovation gap with the more technologically advanced countries, such as USA, South Korea, Singapore and Japan (Ramzi, 2015). Many reforms are concerned, such as the establishment of an effective internal market, flow without restrictions for researchers, knowledge and technology, an improved education system, and a more productive innovation and research base. In 2010, the EU introduced the “Innovation Union”, as a strategy to improve the conditions for the research and innovation in Europe and to create an innovation-friendly environment that will bring to the economy growth and jobs.

HC proxied by higher education (HE) can lead to economic growth through both private (productivity, entrepreneurship, specialisation, jobs) and public (research and development, foreign direct investment, governance, safety, social development) channels. A workforce with higher education will have more potential for change and for being innovative (Pegkas and Tsamadias, 2014).

FDI flows increase productivity by providing new investment, better technologies and managerial skills to the host countries and in this way contribute to economic growth. Findlay (1978) argues that FDI increases the rate of technical progress in the host country through a knowledge diffusion effect often referred as externalities or efficiency spillovers, from the more advanced technology and management practices used by foreign firms. This effect is dependent on the level of technological advance of a host economy, the economic stability, the state investment policy, the degree of openness and the amount of human capital (Borensztein et al., 1998). Adefabi, (2011) argue that FDI creates potential spillovers of knowledge to the local labour force while at the same time, the host country’s level of human capital determines how much FDI it can attract and whether local firms are able to absorb the potential spillover benefits.

The purpose of this study is to empirically investigate the contribution of R&D capital, FDI capital and HC to TFP in the OECD countries. Moreover, the full sample is divided into two sub-groups, the Europeans and the non Europeans countries. The analysis is based on the theoretical framework of the endogenous growth theory and employs panel data for the period 2000-2015. The present study contributes to the existing literature in several respects. First of all, to the best of our knowledge, it is the first study of the aforementioned issues for the OECD countries that compare the results between the European and non European members of the OECD and sets the basis for policy recommendations. Moreover, the selected period was particularly important for the OECD and especially for the European countries, for a number of reasons. First of all, this period was characterized by the broadening and deepening of the most OECD countries in the economic, social and political fields. Furthermore, in Europe a common currency, the euro, was introduced and circulated in the euro-area member states. Additionally, structural reforms and functional adjustments were implemented in most EU countries, albeit at varying degrees of intensity, extent and success. Also, in this period the international economic and financial crisis took place and, as a result, the global GDP experienced a significant fall. Last but not least, R&D, FDI and HC have been placed at the core of the OECD and EU growth strategy.

The rest of the paper is organized as follows. Section 2 reviews the literature on the relationship between R&D, FDI, HC and TFP, including empirical studies. Section 3 provides a brief description of the methodology and the data. Section 4 presents the empirical analysis, discusses the methodology, explains sources and data and reports the empirical results based on the econometric analysis. Section 5 presents the concluding remarks.

2. Review of Empirical Literature

The current literature review involves studies which have dealt with the effect of R&D, HC and FDI on TFP, either for each variable separately, for some of them together, or for all variables simultaneously. Most of the studies are based on the endogenous growth economic theory. For comparative results we concentrate more on empirical studies that examine OECD member states and using panel data. The basic findings can be summarized as follows:

R&D and TFP

Grossman and Helpman (1991a, 1991b) have shown that an increase of the available R&D capital has a positive effect on the TFP level of the economy. A huge literature starting from the inspirational paper of Coe and Helpman (1995), mostly focused on cross-country data, has empirically demonstrated the positive effect of R&D activity on productivity. Guellec and van Pottelsberghe de la Potterie (2001) examined a panel of 16 OECD countries over the period 1980-1998 and found significant positive effects of R&D on TFP. Zachariadis (2004), using aggregate and manufacturing sector data for 10 OECD countries over the period 1971-1995, exhibits a strong positive and significant relationship between R&D intensity and productivity growth.

HC and TFP

Benhabib and Spiegel (1994), for 78 counties over the period 1965-1985, observed HC stock to have a positive effect on TFP through its influence on the rate of catch-up with more advanced economies. Canton (2007), from a sample of 31 countries for the years 1960, 1970, 1980, 1990 and 2000, found positive effect of HC stock on TFP. De la

Fuente (2011), for 21 OECD countries over the period 1960-1990, concludes that HC has a positive, significant and sizable effect on productivity. Mason et. al (2012), using together a five-country multi-industry dataset, observed positive HC effects on productivity.

FDI and TFP

Although the role of FDI in facilitating technology transfer is well known in the literature, empirical evidence regarding the effect of FDI on TFP growth is mixed (Baltabaev, 2014). The impact of FDI on productivity may depend on other factors that reflect the macroeconomic environment of a country such as low inflation, appropriate macroeconomic fiscal and exchange rate policies (Alfaro et al. (2009). Xu (2000) investigates the relationship between FDI and TFP for 40 countries from 1966 to 1994. The results show that the technology transfer via FDI contributes to the productivity growth. Pessoa (2005), in a sample of 16 OECD countries over the period 1985-2002, found positive effects of FDI on aggregate TFP. Lee (2006), using panel data from 16 OECD countries over the period 1981-2000, concludes that international knowledge spillovers through inward FDI are significant and robust. Azman-Saini et al., (2010) in a panel of 85 countries, observe that FDI by itself has no direct (positive) effect on output growth.

Combinations of examined determinants and TFP

A number of other studies have focused on various explanatory variables of TFP like HC and inward FDI. Engelbrecht (1997) for 21 countries over the period 1971-1985 found positive contribution of R&D capital and HC to TFP. Loko and Diouf (2009), examining 62 countries over the period 1970-2005, found significant positive effects of HC to TFP, but insignificant effects for FDI. Van Pottelsberghe de la Potterie and Lichtenberg (2001), for 13 industrialized countries over the period 1971-1990, found significant positive effects of R&D and not significant effects of inward FDI on TFP. Coe et. al. (2009), for 22 countries over the period 1971-2004, found positive effects of R&D and HC in TFP. Griffith et al. (2003, 2004), using a panel of industries across twelve OECD countries for the period of 1974 to 1990, observe that both R&D and HC affect the rate of cross-country convergence in productivity growth. Kneller (2006), applying data from 9 manufacturing industries in 12 OECD countries over the period 1973-1991, finds the effect of HC to be quantitatively more important than that of R&D on absorptive capacity; the latter matters only for smaller OECD countries.

To the best of our knowledge there are very few studies which have taken into consideration all these variables together. Khan and Luintel (2006) investigate the impact of R&D capital stock, HC stock and inwards stock of FDI as determinants of productivity for 16 OECD countries that includes 13 European countries plus Australia, Canada, Japan and United States, over the period 1980-2002. They found positive and significant effects of R&D capital (coefficient 0.10) and HC (coefficient 0.37) and insignificant effects for FDI capital (coefficient -0.002). Bodman and Le (2007) found positive and significant effects of R&D capital (coefficient 0.09), FDI capital (coefficient 0.08) and HC (coefficient 1.22) for 15 OECD countries over the period 1982-2003. Zhang, et. al. (2014) found positive and significant effects of R&D capital (coefficient 0.001), HC (coefficient 0.19) and insignificant result for FDI capital (coefficient 0.008) for China over the period 1998-2012. Luintel et. al., (2014) include R&D capital stock, HC stock and inward stock of FDI as determinants of productivity. The sample of 16 OECD countries includes 13 European countries plus Australia, Canada and United States, over the period 1982-2004. They found positive and significant effects of R&D capital (coefficient 0.17), HC (coefficient 0.38) and FDI capital (coefficient 0.02).

In summary, evidence from the literature, showed that the TFP elasticity in relation to R&D capital is positive and significant in the studies which have taken into consideration these variables together, varying from 0.001 (Zhang et. al., 2014) to 0.17 (Luintel et. al., 2014). The TFP elasticity with respect to HC ranges significantly in the literature, from 0.19 (Zhang et al, 2014) to 1.22 (Bodman and Le, 2007), while with respect to FDI ranges from 0.02 (Luintel et al, 2014) to 0.08 (Bodman and Le, 2007). Also, there are other empirical studies where FDI capital does not affect the TFP (Khan and Luintel, 2006; Zhang et al, 2014).

3. Empirical Analysis

3.1. Methodology and the Data set

The endogenous growth theory argues that R&D (Romer, 1990; Grossman and Helpman, 1991a, 1991b; Aghion and Howitt, 1992; Coe and Helpman, 1995), HC (Engelbrecht, 1997) and FDI (Van Pottelsberghe de la Potterie and Lichtenberg, 2001) drive long-run aggregate productivity and economic growth. Our empirical model builds on the theoretical framework provided by these insights. The productivity model includes innovation, measured by R&D expenditure, HC, approximated by the stock of labor force, and FDI, approximated by the inwards flows. Finally, the variations in the TFP level of each country are explained by the changes in the R&D capital, HC and FDI capital. Equation 1 shows a mathematical representation of this empirical model:

$$\log TFP = a + b \cdot \log RD + c \cdot \log HC + d \cdot \log FDI + \varepsilon_t \qquad (1)$$

where *TFP* stands for total factor productivity, *RD* for domestic R&D capital, FDI for foreign direct investments capital, HC human capital stock and ε_t is the error term.

In the following empirical analysis, we estimate equation (1) to examine the macroeconomic impact of R&D, human capital and FDI capital on TFP employing panel data for the period 2000-2015, for the thirty five countries of OECD. In particular, we employ panel estimation techniques to estimate equation (1) and investigate if these factors are statistically significant determinant of TFP.

TFP has been calculated for each country in the following way:

$$TFP=Y / (K^{\beta} \bullet L^{1-\beta}) \qquad (2)$$

where Y is the GDP, K is the physical capital, L is the labour input (defined as total employment times average annual hours worked per worker) and β is the physical capital share of total income. We assume constant returns to traditional inputs (K and L), perfect competition and two standard assumptions in the reviewed empirical studies (Coe and Helpman 1995) that allow us to define β as the capital income share and 1 – β as the labour income share, the latter to be calculated as residual.

Data for TFP have been obtained from AMECO, except those of Chile, Israel, Korea and Turkey that were not available and have been taken from the databank of the Federal Reserve Bank of St. Louis. Data for domestic R&D expenditure as percentage of GDP were taken from the World Development Indicators of the World Bank database (2017). Data on HC was taken from the World Bank database (2017). The proxy of HC that was used in this study is the labor force with HE (h_t). Specifically, the labor force with HE is the share of the total labor force that attained or completed HE as the highest level of education (World Bank 2017). Labor force holding a HE degree may provide some insight into the capabilities of a country to be efficient at work considering that the longer a person is educated, the longer is forced to develop the skills and gain new knowledge. Data for FDI inwards flows as percentage of GDP were taken from the UNCTAD database (2017). All amounts provided in local currency and current prices were divided by GDP deflators (2010=100) and expressed in the price reference year 2010. We used an interpolation method to obtain the few missing values. All variables are expressed in logarithmic format.

There were no available historical data for the R&D and FDI capital in all countries. Therefore, R&D and FDI capital have been calculated by the perpetual inventory method on the basis of available data for R&D expenditure and inward flows of FDI, respectively. In particular, the R&D capital at the end of each year has been calculated as the sum of the previous year's R&D capital and the current year's R&D expenditure, after deducting the amount of depreciated capital, as presented in the following equation:

$$RD_t = (1 - \delta) \cdot RD_{t-1} + I_t \quad (3)$$

where RD_t and RD_{t-1} stand for the domestic R&D capital of the current and the previous year respectively, I_t is the annual R&D expenditure in year t and δ is the annual depreciation rate[1] of the domestic R&D capital. The estimation of the domestic R&D capital at the beginning of the examined period, which was necessary for the application of the perpetual inventory method, was calculated using the formula:

$$K_1 = \frac{I_1}{(\delta + g)} \quad (4)$$

where K_1 is the estimate of the domestic R&D capital at the end of year 1, I_1 is the annual R&D expenditure in year 1, δ is the annual depreciation rate and g is the average of yearly growth rates of R&D expenditure over the period 2000-2015. FDI capital has been calculated by the same method as R&D capital.

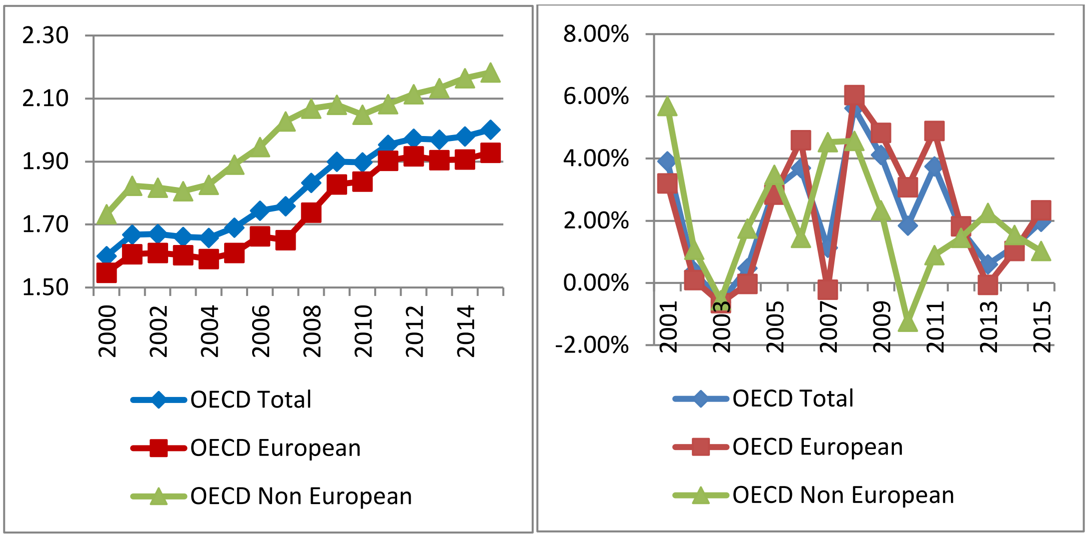
[1]The depreciation rate for FDI was set at 10% taking into account the depreciation rates used in previous studies (Wei, 1996; Subasinghe, et al., 2013) and for R@D (Griliches, Z. 1990; Kim and Park 2003; Luintel, Khan and Theodoridis, 2014). A sensitivity analysis performed for the value of 15% of the depreciation rate did not affect significantly the main findings of the study. Coe and Helpman (1995) and other studies have found that empirical results are not sensitive to the assumed value for the depreciation rate.

3.2. The Sample

In the following empirical analysis, the sample is comprised of data from thirty five OECD countries for the period 2000-2015. Countries and years have been selected on the basis of data availability over the examined time period. The sample is split into two sub-groups. Sub-group A, comprises of twenty five countries which are the European countries members of OECD (Austria, Belgium, Czech, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom). Sub-group B, consists of ten countries which are the non-European countries members of OECD (Australia, Canada, Chile, Israel, Japan, Korea, Mexico, New Zealand, Turkey and United States).

As presented in Graph 1, total R&D expenditure increased over the period 2000-2015 for all groups. Non-European OECD countries invested more on R&D, as percentage of GDP, compared with the European OECD countries.The European Commission put R&D investment high on the agenda for tackling the financial and economic crisis that hit Europe in 2008 (European Commission, 2016). Indeed, some EU member states, such as Germany, Austria and the Nordic countries, boosted public R&D expenditure to stimulate economic growth and encouraged private R&D investment. As a result, an increase in R&D intensity was observed in these countries over the period 2007-2009.

Graph 1: Total average R&D expenditure as GDP and growth rates

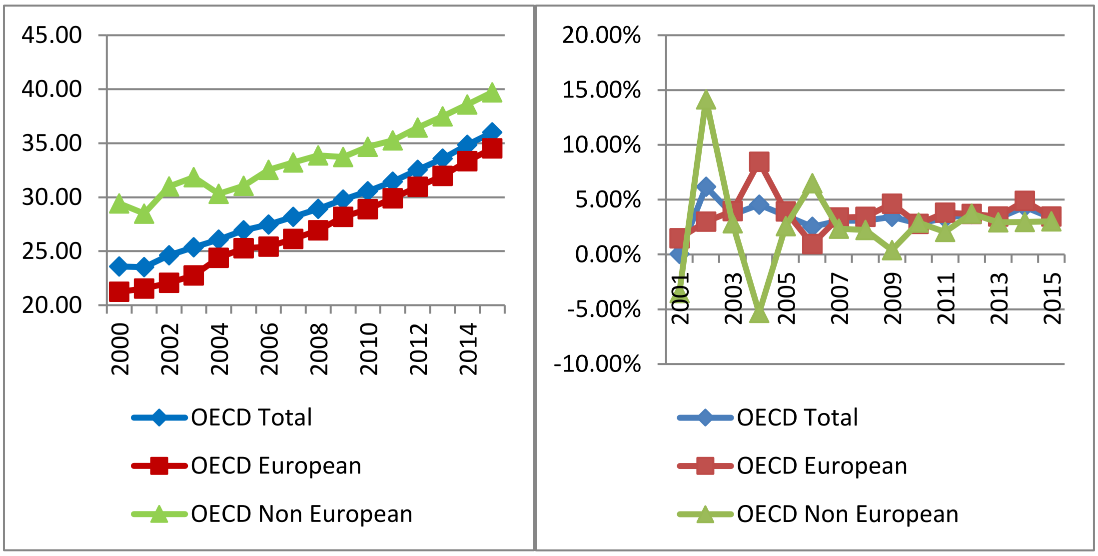


Source: World Bank database.

There are significant differences among the European OECD countries in relation to R&D expenditure intensities. Specifically, over the period 2000-2015, R&D expenditure, on average, ranged from 0.54% (Latvia) to 3.43% (Sweden) of GDP. Northern European countries not only share a pattern of high expenditure, but they have also set the most ambitious national R&D growth targets. Countries with lower R&D expenditure levels, i.e. below 1% of GDP, are mostly located in Eastern and Southern Europe. European OECD countries presented a very similar average growth rate compared with the non-European OECD countries, especially after 2003, as they were trying to catch up. In general, the European countries have become more innovative over the last decades. Actually, they have managed to narrow the innovation gap with the United States, Japan, Korea and Israel although they are still lagging behind (European Commission, 2013).

Graph 2 presents the evolution of the HC proxied by the number of workers with HE as a percentage of total employment. HC, on average, increases significantly over the examined period, in all cases. Non-European OECD countries present higher levels of workers with HE than European OECD countries. While all countries have increased the percentage of workers with HE over the examined period, there are still differences among the countries. Indeed, for non-European OECD countriesin 2015, the average percentage of workers with HE was almost 40%, while for European OECD countries was almost 35%. Specifically, over the period 2000-2015, the percentage of workers with HE, on average, ranged from 15.31% (Portugal) to 36.78% (Belgium) across European OECD countries. On the other hand, for non European OECD countries, the ratio ranged from 14.43% (Turkey) to 46.02% (Canada). The average growth rates for all groups remains relatively stable, especially after the year 2005.

Graph 2: Total Average Labor Force with Higher Education and growth rates

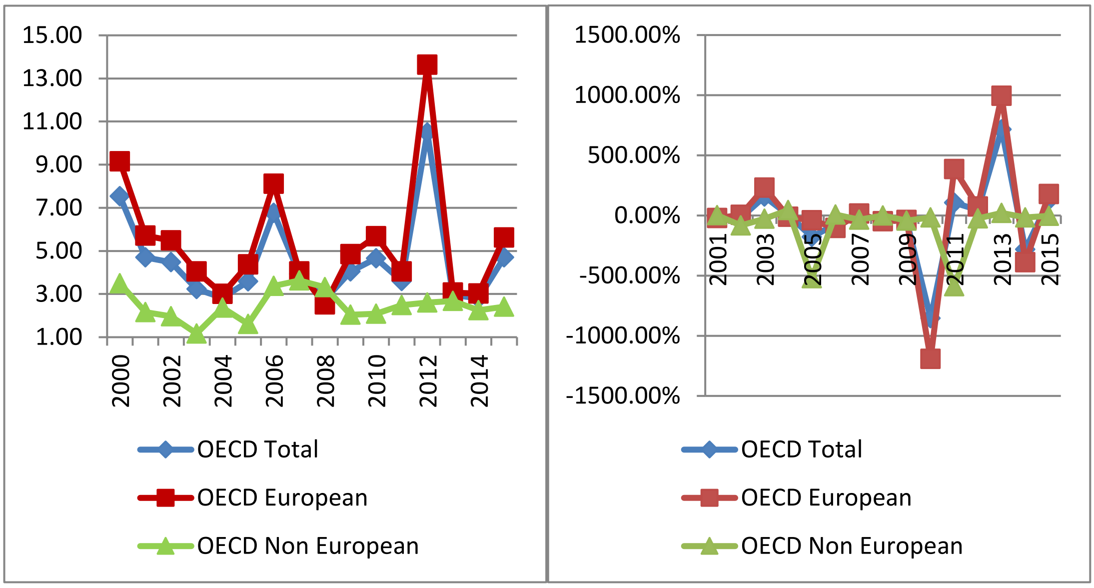


Source: World Bank database.

FDI as percentage of GDP, have different direction for the two sub-groups. Over the examined period, except for year 2008, European OECD countries present higher FDI levels than their non-European counterparts (graph 3). Specifically, FDI expenditure, on average, ranged from 0.71% (Greece) to 38.35% (Luxemburg) of GDP across European OECD countries. On the other hand, for non-European OECD countries FDI expenditure, it ranged from 0.12% (Japan) to 6.83% (Chile). European countries presented a similar average growth rate pattern compared with their non

European counterparts. European countries present the lowest and highest average growth rate in 2010 and 2013, respectively. The average growth rate for non European OECD countries is relatively stable, except for years 2005 and 2011, when it decreased.

Graph 3: TotalAverage FDI expenditure as GDP and growth rates

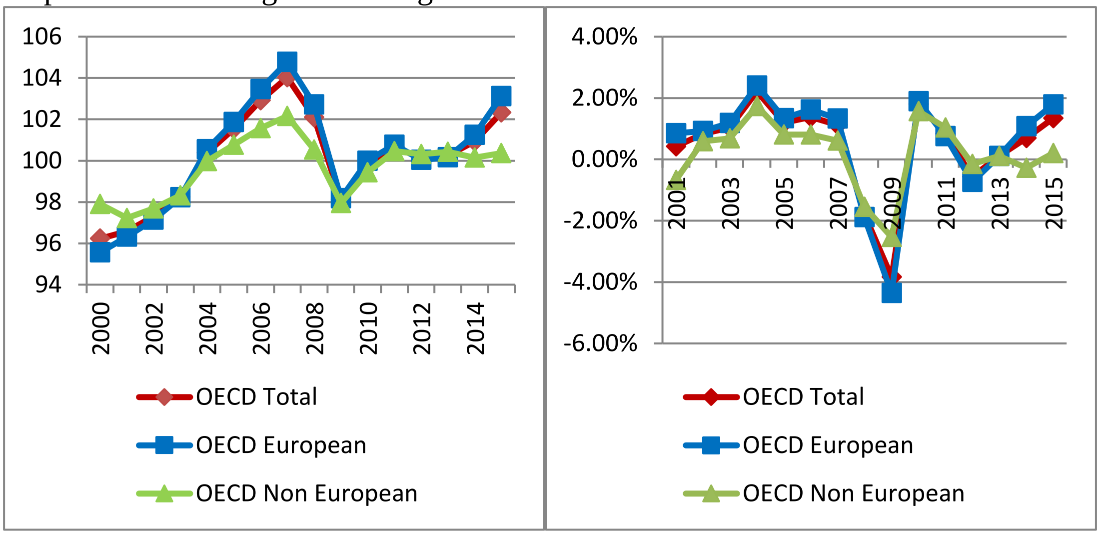


Source: UNCSTAD database.

Graph 4 presents the evolution of the average TFP level for the whole sample and the two sub-groups. The average TFP of the sub-group for European OECD countries has increased more than that of the sub-group for non-European OECD countries, until 2007. Thereafter, the TFP levels have declined in both sub-groups, until 2009. At year 2009, both groups began from a common point and afterwards TFP levels increased.After year 2013, TFP levels have increased more significantly for European OECD countries compared with their non-European counterparts. On average, TFP levels ranged from 93.23% (Slovakia) to 107.20% (Norway) across European OECD countries. On the other hand, for non-European OECD countries, TFP levels, on average, ranged from 93.07% (Korea) to 105.24% (Mexico). European OECD countries, on average, present higher growth rates, compared with the non European

OECD countries; however, in 2008-2009, it decreased significantly for all groups, especially for European OECD counties.

Graph 4: Total average TFP and growth rates



Source: Ameco database. Note: Data for Chile, Israel, Korea and Turkey were taken from the databank of the Federal Reserve Bank of St. Louis.

4. Econometric analysis

This section focuses on the effect of total R&D capital, HC and FDI capital on TFP, testing for panel cointegration, so as to reveal any underlying long-run relationships among the main variables. Then, we proceed with estimating Granger (1986, 1988) causality tests, based on a vector error correction model (VECM) approach.

4.1. Unit root tests

Initially, unit root tests were employed to examine the order of integration of the variables in the panel data set. Different unit root tests were estimated, according to Im et al (2003) and Dickey and Fuller (ADF) (1979, 1981), to test the hypothesis that each panel data series has a common unit root process.

Table 1: Panel unit roots tests

Variable	Unit root tests	OECD		Europeans		Non Europeans	
		Levels	First differences	Levels	First differences	Levels	First differences
TFP	Im, Pesaran and Shin W-test	0.01	-6.05***	0.93	-3.99***	-1.25	-7.10***
	ADF–Fisher test	67.99	158.96***	41.21	99.48***	27.46	82.39***
RD	Im, Pesaran and Shin W-test	1.54	-2.52***	0.95	-0.90	1.39	-3.30***
	ADF–Fisher test	74.53	112.47***	58.55	66.86**	15.98	45.60***
HC	Im, Pesaran and Shin W-test	8.31	-14.45***	8.06	-13.61***	-0.94	-6.48***
	ADF–Fisher test	34.95	281.81***	18.99	213.85***	23.84	72.55***
FDI	Im, Pesaran and Shin W-test	0.39	-8.74***	0.60	-6.99***	-0.19	-5.27***
	ADF–Fisher test	76.61	202.10***	53.48	140.17***	23.13	61.93***

Notes: Selection of lags based on Modified Schwarz (1978) information criterion; Newey and West (1994) bandwidth selection using Bartlett kernel; H_0: Unit root (assumes individual unit root process). ***, ** *Significant at 1% and 5% level respectively.*

Table 1 presents the results of panel unit roots tests for each variable, first in levels and next in first differences. The null hypothesis of unit root is not rejected for the levels of the variables. On the contrary, tests reject the null hypothesis for the first differences, for all variables. So, from the combined results, the series appear to be non-stationary in the levels and become stationary after first-order differencing. Therefore, we conclude that each variable is, in fact, integrated of order one, i.e. I (1).

4.2. Panel cointegration

From the stationary panel tests, we can conclude that R&D, HC, FDI and TFP could be cointegrated. Next, different panel cointegration tests are employed to test the hypothesis that a long-run relationship exists among the variables. Kao (1999), Madala and Wu (1999) and Pedroni (1999) developed several tests to examine the existence of co-integration. Pedroni (1999, 2000) did it in a dynamic panel, allowing for heterogeneity among the individual countries. The Kao test follows the same basic approach as the Pedroni's one, but specifies the regression with individual intercepts, no deterministic trend and homogenous regression coefficients. Madala and Wu (1999) proposed a Fisher co-integration test based on the multivariate framework of Johansen (1988), combining tests from individual cross-section to obtain a test statistic for the whole panel.

Table 2: Panel co-integration tests

Co-integration Statistics	OECD	Europeans	Non Europeans
1. Pedroni co-integration tests			
Panel v-Statistic	-4.33	-2.87	-2.55
Panel p-Statistic	0.48	-0.59	2.01
Panel t-Statistic: (non-parametric)	-4.00***	-4.49***	-6.05***
Panel t-Statistic: (parametric)	-4.53***	-5.50***	-5.05***
Group p-Statistic	3.68	2.56	3.67
Group t-Statistic (non-parametric)	-1.31*	-1.15	-5.43***
Group t-Statistic (parametric)	-5.10***	-4.62***	-3.73***
2. Kao co-integration test	-1.77**	-1.36*	-3.19***
3. Fisher co-integration (Trace test) for one vector	86.43***	75.94***	64.69***
Fisher co-integration (Trace test) for two vectors	14.20	25.37	21.39
Fisher co-integration (Trace test) for three vectors	2.73	9.08	4.34
Fisher co-integration (Trace test) for four vectors	0.06	0.21	0.48
4. Fisher co-integration (Maximum Eigenvalue test) for one vector	72.23***	50.56***	43.30***
Fisher co-integration (Maximum Eigenvalue test) for two vectors	11.46	16.28	17.05
Fisher co-integration (Maximum Eigenvalue test) for three vectors	2.66	8.87	3.85
Fisher co-integration (Maximum Eigenvalue test) for four vectors	0.07	0.21	0.48

Note:***,**, * indicate rejection of the null hypothesis of no co-integration at 1%, 5%and 10% level of significance respectively. Trace and max-eigenvalue tests indicate no cointegration at the 0.05 level.

Table 2 summarizes the results of the panel co-integration analysis among the variables using the Pedroni, Kao and Fisher statistics. In the cases of the full sample of the countries and the non-Europeans countries, four out of seven Pedroni tests reject the null hypothesis of no co-integration, using both the panel and group version tests. In the case of the Europeans countries, three out of seven Pedroni tests reject the null hypothesis of no co-integration. In addition, Kao and Fisher tests reject the null hypothesis of no co-integration., both Kao and Fisher tests reject the null hypothesis of no co-integration. Moreover, Trace and Maximum Eigenvalue test show that there is one co-integrating relationship among the variables in all the samples.

The next step is the estimation of the long-run relationship among variables, using the Fully Modified Ordinary Least Squared (FMOLS) approach suggested by Pedroni (2000, 2001). The FMOLS estimator not only generates consistent estimates in small samples, but it also controls for the likely endogeneity of the regressors and serial correlation.

Table 3: Panel cointegration estimates

Sample / Variables	OECD	Europeans	Non Europeans
RD	0.29 (4.51)***	0.19 (1.74)*	0.47 (7.62)***
HC	0.20 (6.77)***	0.27 (6.25)***	0.07 (2.04)**
FDI	-0.00 (0.89)	-0.00 (-1.23)	0.04 (1.69)*

Notes: The dependent variable is logTFP; t-statistics in the parentheses; ***,** and * indicate significance at 1%, 5% and 10% level of significance respectively.

The FMOLS estimated co-integration relationships are presented in Table 3. For the full sample, the size of the estimated coefficient (i.e., the long-run elasticity) for this variable is 0.29 statistically significant at 1%. The elasticity of TFP with respect to workers with higher education is 0.20 statistically significant at 1%. The impact of FDI capital is not statistically significant.

For the European countries, the elasticity of TFP with respect to R&D capital is 0.19 statistically significant at 10%. The elasticity of TFP with respect to workers with higher education is 0.27 statistically significant at 1%. The impact of FDI capital is not statistically significant.

For the non-European countries, the elasticity of TFP with respect to R&D capital is 0.47 statistically significant at 1%. The elasticity of TFP with respect to workers with higher education is 0.07 statistically significant at 1%. The elasticity of TFP with respect to FDI capital is 0.04 statistically significant at 10%. A 10% increase in FDI capital will foster productivity by about 0.4%.

4.3. Granger causality tests

Next the short-run and long-run Granger (1988) causality between the variables can be investigated empirically via VECM[2] models. The optimal lag length is one in all VECMs based on the Akaike information criterion. The VECMs pass all the standard diagnostic tests for residual serial correlation, normality and heteroscedasticity. Although the existence of a long-run relationship between the variables suggests that there must be causality in at least one direction, it does not indicate the direction of temporal causality between the variables. This temporal Granger-causality can be captured through the VECM derived from the long-run cointegrating vectors (Granger

[2] The results of VECMs are available from the authors upon request.

1986, 1988). The direction of the causality in this case can only be determined by the lagged error-correction term. While the t-statistic on the coefficient of the lagged error-correction term represents the long-run causal relationship, the F-statistic on the explanatory variables represents the short-run causal effect (Narayan and Smyth, 2006).

Tables 4, 5 and 6 report the findings for the causality between R&D, HC, FDI, and TFP, based on the error-correction equations.

Table 4: Granger causality tests for the OECD Countries

Variables	Short-run dynamics non-causality				Long-run dynamics non-causality
	TFP_t	RD_t	HC_t	FDI_t	ECT
TFP_t	-	1.38 (0.23)	0.13 (0.71)	0.84(0.35)	- 0.21*** [-7.68]
RD_t	17.19*** (0.00)	-	16.73*** (0.00)	33.10*** (0.00)	-0.01 [-1.05]
HC_t	0.53 (0.46)	0.01 (0.98)	-	2.80* (0.09)	-0.07*** [-2.98]
FDI_t	1.84 (0.17)	0.05 (0.81)	0.20 (0.65)	-	-0.19*** [-6.51]

Notes: The p-values are presented in parentheses. In the short-run dynamics, asterisks indicate rejection of the null hypothesis that there is a short-run non-causal relationship between the two variables. The t-statistics are presented in brackets. The asterisks of the lagged ECTs are distributed as t-statistics and indicate rejection of the null hypothesis that there is a long-run non-causal relationship between all the variables. ***, **,* indicate significance at 1%, 5% and 10% level, respectively. The results are based on a one period lag time.

For the full sample (table 4) estimates of the parameters show that the error-correction term is negative and statistically significant for all the equations at the 1% level, except for the R&D equation. Therefore, the evidence is in favour of unidirectional long-run causality running from R&D to TFP, to HC and to FDI and bidirectional long-run causality between TFP, FDI and HC. In the short-run dynamics, the tests indicate that there is a unidirectional Granger causality running from TFP, FDI and HC to R&D and from FDI to HC.

Table 5: Granger causality tests for the European OECD Countries

Variables	Short-run dynamics non-causality				Long-run dynamics non-causality
	TFP_t	RD_t	HC_t	FDI_t	ECT

TFP_t	-	2.13 (0.14)	0.39 (0.53)	0.42 (0.51)	- 0.20*** [-6.09]
RD_t	0.06 (0.80)	-	0.12 (0.72)	26.02*** (0.00)	0.005 [0.49]
HC_t	0.07 (0.78)	0.57 (0.44)	-	6.75*** (0.00)	-0.02 [-0.87]
FDI_t	3.63** (0.05)	0.01 (0.94)	2.39 (0.12)	-	-0.22*** [-5.92]

Notes: The p-values are presented in parentheses. In the short-run dynamics, asterisks indicate rejection of the null hypothesis that there is a short-run non-causal relationship between the two variables. The t-statistics are presented in brackets. The asterisks of the lagged ECTs are distributed as t-statistics and indicate rejection of the null hypothesis that there is a long-run non-causal relationship between all the variables. ***, **,* indicate significance at 1%, 5% and 10% level, respectively.

For the European OECD countries (table 5) estimates of the parameters show that the error-correction term is negative and statistically significant for the TFP and FDI equations at the 1% level. Therefore, there is a bidirectional long-run causality between TFP and FDI. Also, there is unidirectional long-run causality running from R&D and HC to TFP and from R&D and HC to FDI. In the short-run dynamics, the tests indicate that there is a unidirectional Granger causality running from FDI to HC and to R&D and from TFP to FDI.

Table 6: Granger causality tests for the non European OECD Countries

Variables	Short-run dynamics non-causality				Long-run dynamics non-causality
	TFP_t	RD_t	HC_t	FDI_t	ECT
TFP_t	-	0.12 (0.72)	0.19 (0.66)	0.01 (0.99)	- 0.29*** [-5.54]
RD_t	25.1*** (0.00)	-	1.31 (0.25)	6.34*** (0.01)	-0.02 [-1.16]
HC_t	0.54 (0.45)	0.51 (0.47)	-	0.63 (0.42)	-0.16*** [-2.69]
FDI_t	12.43*** (0.00)	1.03 (0.31)	1.92 (0.16)	-	-0.07*** [-2.72]

Notes: The p-values are presented in parentheses. In the short-run dynamics, asterisks indicate rejection of the null hypothesis that there is a short-run non-causal relationship between the two variables. The t-statistics are presented in brackets. The asterisks of the lagged ECTs are distributed as t-statistics and indicate rejection of the null hypothesis that there is a long-run non-causal relationship between all the variables. ***, **,* indicate significance at 1%, 5% and 10% level, respectively.

For the non-European countries (table 6) estimates of the parameters show that the error-correction term is negative and statistically significant for all the equations at the 1% level, except for the R&D equation. Therefore, there is evidence of unidirectional long-run causality running from R&D to TFP, to FDI and to HC. Also, there is bidirectional long-run causality between TFP, FDI and HC. In the short-run dynamics, the tests indicate that there is a unidirectional Granger causality from TFP and FDI to R&D and from TFP to FDI.

Overall, the empirical results reveal that there is a cointegrating relationship between TFP, R&D, HC and FDI, in all examined groups of OECD countries. This implies that long-run movements of the variables are determined by an equilibrium relationship.

Taking into consideration the theoretical framework and the findings from the majority of the empirical studies we were expecting to find a positive impact of R&D, HC and FDI on TFP. The role of the examined variables, especially for R&D and HC, on economic growth seems to be important and significant. The results of the cointegration estimates in all groups reveal that R&D and HC have a positive impact on the TFP. FDI has a positive impact on the TFP only for the sample of the non European countries, while for the full sample and for the European OECD countries is not statistical significant.

For the full sample and for the non-European OECD countries, R&D appears to have the highest contribution to TFP level and the estimated range of values for the elasticity is higher than usually seen in the literature. On the other hand, for the European countries, the effect of HC on TFP appears to be higher than for the non European countries and the estimated range of values for the elasticity is consistent with the ranges found in the literature. It seems that over the examined period, in the

European OECD countries, employees with higher education have a better match with available jobs and are of better quality.

FDI capital is positive and significant only for the non-European countries. In this case the TFP elasticity reported in the literature is consistent with our estimated values. One possible explanation of this result could be that the financial crisis, especially during the period 2008-2010, has affected FDI through at least two channels: less access to financial resources (for both internal and external financing of firms) and lower propensity to take risks in new investments. This effect seems to be stronger in the case of the European countries. As a result, what is observed is a significant, by -3.35%, fall in the average FDI capital growth rate, while the respective one for the non European OECD countries is 2.47%.

Finally, our findings are in line with those of the empirical literature. Most of the studies found that the total R&D capital, HC and FDI capital have a positive and significant stimulus on the TFP level. Specifically, the results of a positive contribution of R&D capital, HC and FDI capital on TFP are consistent with the studies mentioned in the literature review and especially with those that applied models which included these variables together (Bodman and Le, 2007; Luintel, Khan and Theodoridis, 2014). Also, insignificant results for FDI are in line with some studies which suggest that the FDI capital has an insignificant effect on TFP (Zhang, et. al, 2014; Khan and Luintel, 2006).

5. Conclusion and Policy Recommendations

The main objective of this study has been to investigate empirically the causal relationship between R&D, human capital, FDI and TFP and also, to estimates the effect of these variables on TFP, in OECD countries. The full sample of countries is divided into two sub-groups, the European and non-European OECD countries. The empirical analysis follows the endogenous growth theory and employs panel data over the period 2000-2015.

The empirical analysis reveals that, in the long-run, R&D and HC affect positively TFP. Also, the results indicate a positive long-run effect of FDI capital on TFP only for non-Europeans countries. Moreover, the results show that there are strong long run causality relationships between variables in all the examined samples.

Based on these empirical findings, we recommend the development of eco-systems, friendly to the development of science, research and innovation. Increasing public and private resources invested in R&D and higher education, with a consistent ongoing spending review and policies to promote the quality, efficiency and productivity of all public and private systems should be priorities. Moreover, policymakers should design and implement “smart” tax policies to promote research and innovation and attract investment, especially in the least developed countries. In particular, these countries, in order to successfully be hosted countries, should, according to the literature, draw their attention to create a favourable environment for investment by shaping appropriate factors, like the exchange rate, the market size and its potential, the openness of trade, investment and financial flows, the labour, trade and investment costs, the trade deficit, human capital, the taxation, inflation, macro economic stability (fiscal deficit and public debt), government consumption and domestic investment, energy usage, the institutional quality, physical infrastructure, import tariffs, government regulation andendowments, as well as the political stability (Bloningen, 2005). Finally, the “strategic-asset” motive is related to maintaining foreign firms’ international position and competitiveness. Among the reforms that could be implemented, the establishment of an effective internal market, flow without restrictions for researchers, an improved education system and a more productive innovation and research base, should be included.

Future research could add value two folds: through a comparative assessment of the effects of the interpretative variables used in the current study for the EU countries with the BRIGS member states and by investigating the effect of international trade on the change in overall productivity, as long as the necessary data are available.

To conclude, as the President of the ECB Mario Draghi recently stated[3], the burden of raising potential growth must fall on productivity. There are a number of areas in which domestic policies could encourage an upward shift in productivity growth, such as competition, research and development.

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[3]Speech by Mario Draghi, President of the ECB, at the Economic Policy Symposium of the Federal Reserve Bank of Kansas City, Jackson Hole, 25 August 2017.

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