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Human capital, mechanisms of technological diffusion and the role of technological shocks in the speed of diffusion.

Evidence from a panel of Mediterranean countries[§]

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ABSTRACT

Our main goal is to ascertain the importance of human capital as a facilitator of technological diffusion in a sample of seven Mediterranean countries (Algeria, Cyprus, Israel, Egypt, Syria, Tunisia, and Turkey) for the period 1960-2000.

First, we estimate the technological progress growth rate and the technological gap between each country in our sample and the technological leader (the USA), following the methodology of Benhabib and Spiegel (2002). We then address the issue of the importance of technology diffusion for the TFP growth rate through the Nelson and Phelps (1966) hypothesis - the potential speed of technology diffusion is inversely related to the degree of technological backwardness of the follower country and its ability to absorb new technologies will depend positively on its human capital level. The non-linear specification of the TFP growth rate proposed by Benhabib and Spiegel (2002) is estimated to control for the type of technological diffusion: logistic or exponential.

The empirical analysis is applied to two samples: a smaller one consisting of the above-mentioned countries, and a larger one that includes some European countries. First, we studied the unit root characteristic of the TFP growth rate series using unit root panel tests. The results obtained allowed the use of traditional econometric methods for both equations. For the first equation estimations were performed using the NLLS estimation procedure, as it is a non-linear equation. The second equation, was estimated using OLS with robust errors, the fixed effects model and the random effects model, as it is a linear equation.

The empirical importance of human capital in fostering technological diffusion is also addressed through the FDI channel, by which technology is transferred from the leader to the followers. The host economy needs a sufficient level of human capital in order to apply the technology of the leader, i.e., the stock of human capital of the follower country limits its absorptive capability. We also analyse the role of human capital as a facilitator of the diffusion of a particular type of technology, ICT, where there is a role for different educational levels. In both cases we take Lee (2000) as the basic framework for our estimations.

Finally, the last part of the paper discusses the importance of technological shocks to the process of technological diffusion. The speed of technological diffusion, and consequently the evolution of cross-country differences in GDP growth rates and levels, depend, to a large extent, on exogenous shocks. We propose to model technological shocks for each of the seven countries in our sample in a simple VAR model with four variables: their TFP growth rate, the logarithm of GDP per capita, the logarithm of investment per capita, and the logarithm of the stock of human capital.

JEL Classification: C33, O5
Keywords: economic growth, education, human capital, panel data, VAR models

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1. Introduction

Our main goal is to ascertain the importance of human capital as a facilitator of technological diffusion in a sample of seven Mediterranean countries (Algeria, Cyprus, Israel, Egypt, Syria, Tunisia, and Turkey) for the period 1960-2000.

First, we estimate the technological progress growth rate and the technological gap between each country in our sample and the technological leader (the USA) following the methodology of Benhabib and Spiegel (2002). Then, the importance of technology diffusion to TFP growth rate is addressed using the Nelson and Phelps (1966) hypothesis - the potential speed of technology diffusion is inversely related to the degree of technological backwardness of the follower country and its ability to absorb new technologies will depend on its human capital level. The non-linear specification of the TFP growth rate proposed by Benhabib and Spiegel (2002) is estimated to control for the type of technology diffusion, logistic or exponential. The empirical analysis is applied to two samples – a smaller one consisting of the above-mentioned countries and a larger one that includes some European countries. First, we studied the unit root characteristic of the TFP growth rate series using unit root panel tests. The results obtained enabled traditional econometric methods to be used for both equations. For the first equation, estimations were performed with NLLS, as it is a non-linear equation, and for the second equation, estimations were performed with OLS with robust errors, as well as with the fixed effects model and with the random effects model, as it is a linear equation. The results for our sample do not support the hypothesis that human capital is a main determinant of technological imitation. On the contrary, they support the hypothesis that human capital is fundamental for innovation, which might mean that the human capital level for these countries is already higher than the threshold identified by Benhabib and Spiegel (2002) in their logistic formulation of the process of technological diffusion.

The empirical importance of human capital in fostering technological diffusion, since it determines a country’s absorptive capability is also addressed through the channel of FDI, through which the leader’s technology is transferred to the followers. However, the host economy needs a sufficient level of human capital in order to apply the technology of the leader, i.e., the stock of human capital of the follower country determines its absorptive capability. We also analyse the role of human capital as a facilitator of the diffusion of a particular type of technology, ICT, where there is a role for different levels of education. In both cases we take Borensztein, Gregorio, and Lee (1998) and Lee (2000) as the basic framework for our estimations. Although FDI seems to influence the growth rate of TFP in our sample the results do not show any complementarity between the diffusion of technology through FDI and human capital. On the other hand, human capital is fundamental for the diffusion of ICTs, especially human capital acquired through higher education.

Finally, in the last part of the paper we try to understand the importance of technological shocks on the process of technological diffusion. The speed of technological diffusion and consequently the evolution of cross-country differences in GDP growth rates and levels depend, to a large extent, on exogenous shocks. We propose to model technological shocks for each of our seven countries in a simple VAR model with four variables: the TFP growth rate, the logarithm of GDP per capita, the logarithm of investment per capita and the logarithm of the stock of human capital. The main result is the following: for almost all of the seven countries the three types of shock have shown factor complementarity in technology, physical capital and human capital.

The paper is divided into five sections: after the Introduction, Section 2 gives the theoretical background of the relationship between human capital and the technological catch-up hypothesis and develops the empirical analysis of this relationship based on the methodologies of Benhabib and Spiegel (2002) and Nelson and Phelps (1966). Section 3 analyses the relationship on the basis of the complementarity between human capital and FDI as a channel of technological diffusion, on the one hand, and the importance of human capital for the diffusion of a particular type of technology, ICTs, on the other. Section 4 analyses the relationship between technological shocks and technological catch-up, and Section 5 presents some concluding remarks.

2. Technological catching-up and the role of human capital: the Benhabib and Spiegel (2002) and the Nelson and Phelps (1966) methodologies

2.1. Theoretical framework

The resurgence of Economic Growth in the eighties with the seminal articles of Romer (1986) and Lucas (1988) led to research into the possible different influences of human capital on growth. As is well known, Solow’s neoclassical growth theory regained importance in the eighties with the Mankiw, Romer, and Weil (1992) model, but the results of the estimation of the β-equation reveal only a very small influence of human capital on growth, and sometimes even the estimated coefficient has the wrong sign. In that type of model, human capital is taken as a factor of production and, according to the theory, will have two effects on growth: a permanent level effect on real GDP per capita and a transitory growth effect on GDP growth.

The weak empirical results associated with the Mankiw, Romer, and Weil (1992) model led many economists to try and improve them with a view to finding the correct influence of human capital on growth. Three different basic routes were followed, as well as a blend of all three: a) better databases and better human capital proxies; b) new econometric methodologies for the estimation of growth equations; and c) new specifications of human capital in growth models.

At the same time, the endogenous growth literature has focused its research agenda on explaining TFP, that is, the mechanisms that cause technological progress and influence the TFP growth rate of a country. In this new theoretical setting human capital has two new roles: it is a facilitator of domestic technological innovation and a facilitator of technological catch-up. It is the level of human capital that is considered in both roles. These two roles mean that human capital determines the TFP growth rate, causing permanent growth effects in the first case and transitory growth effects in the second. In fact, in a steady state growth (SSG) model of technological diffusion, the transitory growth effects will last until the follower country reaches the TFP level of the leader country.

In this paper, human capital is regarded as acting through these two roles in accordance with the Nelson and Phelps (1966) hypothesis. This hypothesis suggests that the shifting of the technological frontier towards the northeast depends on the rate of inventions while the TFP growth rate depends on the rate of technological diffusion, which is positively related to the technological gap: the distance between the TFP level of the leader country and that of the follower country. In order to study the technological diffusion process between two countries it is assumed that the leader country is on the technological frontier or closer to it than the follower country. The technological catch-up hypothesis means that the TFP growth rate of the follower is positively related to its technological backwardness. This is a potential economic advantage for the follower, but as the authors have pointed out, the speed at which the technological gap is closed depends on the stock of human capital of the follower country.

Benhabib and Spiegel (2002) transformed their initial model of technological diffusion (Benhabib and Spiegel (1994)), which was based on the Nelson and Phelps (1966) model, and use another specification which also allows for the evolution of technological diffusion along a logistic path. This generalisation has the advantage of reconciling the theory with some stylised facts. Technological divergence between the follower and the leader will occur if the level of human capital of the follower is below a critic threshold. The introduction of a threshold of this kind reconciles the model with convergence clubs' results.

The micro-foundations of innovation and imitation are missing from the first generation of technological diffusion models, such as Nelson and Phelps (1966), Dowrick and Nguyen (1989), and Fuente (1995). Second generation models explicitly introduce agents' behaviour, the Barro and Sala-i-Martin (1997) model being a good example. Although the Benhabib and Spiegel (2002) specification does not include agents' behaviour related to their innovation and imitation activities, they prove that their results are in accordance with those of Barro and Sala-i-Martin (1997). If the diffusion process is exponential, the leader country will act as a driving force and there will be technological convergence. As for the logistic path, only under special conditions does technological convergence occur.

2.2. Empirical analysis

As far as the empirical analysis is concerned, two different exercises were carried out: the computation of the capital stock series for all the countries in both samples, using the Klenow and Rodriguez-Clare (1997) methodology, which is based on the inventory method; and econometric estimations of the Benhabib and Spiegel (2002) and Nelson and Phelps (1966) equations. First, we have studied the unit root characteristic of the TFP growth rate series using unit root panel tests. Traditional econometric methods were then used because the TFP growth rate is not a unit root series. Since the Benhabib and Spiegel (2002) equation is non-linear, the NLLS estimation procedure was used for the estimations, including a constant, a trend or individual constants. As for the Nelson and Phelps (1966) linear equation, OLS with robust errors was used, including a constant, a trend or individual constants. Fixed effects and random effects models were also used to estimate this specification.

2.2.1. Samples and databases

We have considered two samples. The Mediterranean sample which includes seven countries: Algeria, Cyprus, Egypt, Israel, Syria, Tunisia and Turkey, and a larger sample of thirteen countries which includes the former countries plus six EU countries - France, Greece, Ireland. Italy, Portugal and Spain. The European Countries were included for geographical as well as for economic reasons.

We have four panel databases with both annual and 5-year frequencies for the period 1960-2000. We have used PWT 6.1 to get data on the following variables: real GDP per capita (rdgpl), investment share as a ratio to GDP (ki) and Population (POP). From the Barro and Lee (2000) database we use average years of schooling for the population aged 15 and over (TYR) as a proxy for human capital.

Human capital data is provided at 5-year intervals and so was annualised using a non-linear interpolation following RATS procedure DISTRIB.rsc. This procedure computes a distribution of a series, changing the frequency to a higher one, and we have supposed that the original series is a random walk. The data not available for Cyprus (1997-2000) and Tunisia (1960) was obtained using ARIMA models for each variable.

2.2.2. Determination of the TFP growth rates

In order to estimate the TFP equations we first had to estimate the stock of physical capital, and then we had to estimate the TFP levels and growth rates. We have built the stock of physical capital series using the Benhabib and Spiegel (2002) methodology, which is identical to the Klenow and Rodriguez-Clare (1997) methodology.

2.2.2.1. The physical capital stock series

First we have estimated the initial stock of physical capital according to the formula,

$$(1) \qquad \left(\frac{K}{Y}\right)_{it_0} = \frac{\left(\frac{\overline{I}}{Y}\right)_i}{\gamma_i + \delta_i + n_i}$$

where $\left(\frac{\overline{I}}{Y}\right)_i$ represents the average investment rate of country i over period 1960-2000; γ_i represents the GDP average per capita growth rate of country i for the period 1960-2000; and δ_i is the depreciation rate, equal to 0.03 by assumption.

Equation (1) is found to be

$$(2)\qquad K_{it_0} = \left[\frac{\left(\frac{\overline{I}}{Y}\right)_i}{\gamma_i + \delta_i + n_i}\right]\left(\frac{Y}{POP}\right)_{it_0} POP_{it_0}$$

We have considered t_0=1959 for the stock of physical capital under the inventory formula. Under these assumptions, equation (2) becomes,

$$(3)\qquad K_{i1959} = \left[\frac{\left(\frac{\overline{I}}{Y}\right)_i}{\gamma_i + \delta_i + n_i}\right]\left(\frac{Y}{POP}\right)_{i1960}\left(\frac{1}{1+r_{y1960}}\right) POP_{i1960}\left(\frac{1}{1+r_{POP1960}}\right)$$

where $r_{pop1960}$ represents the average growth rate of the population of country (i) for 1960-2000 and r_{y1960} represents the average growth rate of real GDP per capita of country i for 1960-2000.

Real investment of country (i) at time (t), I_{it}, is computed using the formula,

$$(4)\qquad I_{it} = \left(\frac{I}{Y}\right)_{it}\left(\frac{Y}{POP}\right)_{it} POP_{it}$$

Finally, the physical capital stock series is computed using the inventory method, according to the formula,

$$(5)\qquad K_{it} = \sum_{j=0}^{t}(1-\delta)^{t-j} I_{ij} + (1-\delta)^t K_{1959}$$

2.2.2.2. TFP levels and growth rates

Based on a Cobb-Douglas production function with α=0.3 we have calculated the TFP levels using the following equation,

$$(6)\qquad a_{it} = y_{it} - \frac{1}{3}k_{it} - \frac{2}{3}l_{it}$$

where a_{it} is the log of the TFP level of country (i) at time t, y_{it} is the log of real GDP per capita of country (i) at time (t), k_{it} is the log of the physical stock of capital of country(i) at time (t) and l_{it} is the log of the population of country (i) at time (t)[1]. Having the series for the TFP levels, both annual and at 5-year intervals, we have computed the TFP growth rates.

2.2.3. Analysis of the process of the TFP growth rate series

In order to determine the correct econometric methods for estimating the Benhabib and Spiegel (2002) equation and the Nelson and Phelps (1966) equation, we studied the unit root characteristic of the TFP growth rate series.

Table 2.2.3.1.Unit-Root Panel Tests for the TFP Growth Rate Series

	7 Country Sample	**13 Country Sample**
TFP Growth rate	t_δ	t_δ
LL_1	22.22 (0.0)	31.31 (0.0)
LL_2	32.63 (0.0)	47.19 (0.0)
LL_3	48.49 (0.0)	74.51 (0.0)
	$\overline{Z}$	$\overline{Z}$
ADF without trend	-12.25 (0.0)	-14.61 (0.0)
ADF with trend	-11.81 (0.0)	-13.78 (0.0)

Note: In square brackets we have the level of probability; ADF $\overline{Z}$ test is the test proposed by Im, Pesaran, and Shin (1997) and t_δ test corresponds to the equations in Levin and Lin (1993) for the null of unit root. LL_: $\Delta Y_{it}=\delta_i Y_{it-1}+e_{it}$; LL_2: $\Delta Y_{it}= \alpha_i+ \delta_i Y_{it-1}+e_{it}$; LL_3: $\Delta Y_{it}= \alpha_{0i}+ \alpha_{1i}T+ \delta_i Y_{it-1}+e_{it}$.

As we can see from the results in Table 2.2.3.1. above for all tests we can reject the presence of a unit root, so classical econometric methods are applied, which are appropriate for stationary series.

2.2.4. The Benhabib and Spiegel (2002) methodology

Below, the equation estimated is:

$$(7) \qquad g_{(TFP)it} = b + \left(g + \frac{c}{s} \right) h_{it} - \left(\frac{c}{s} \right) h_{it} \left(\frac{A_{it}}{A_{mt}} \right)^{s} + \varepsilon_{it}$$

where $g_{(TFP)it}$ is the TFP growth rate of country (i) at time (t); b is the constant term; h_{it} is the stock of human capital of country (i) at time (t) in logarithms; A_{it} is the TFP level

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[1] Lee, Jong-Wha, (2000), "Education for technology readiness: Prospects for developing countries." *mimeo, Korea University*. This method was also used but the results were not considered here since they are economically meaningless.

of the follower country (i) at time (t); and A_{mt} is the TFP level of the leader country (USA).

The TFP growth rate of country (i) at time (t) depends: a) on the constant term b; b) positively, on the level of the stock of human capital whose coefficient is [g+(c/s)]. The expression $[g+(c/s)]h_{it}$ represents the contribution of the innovation process of country (i) at time (t) for its TFP growth rate; c) negatively, on the degree of technological backwardness, taking into account the level of the stock of human capital whose coefficient is [-(c/s)]. The expression $[-(c/s)]h_{it}(A_{it/}A_{mt})$ represents the contribution of the diffusion process of country (i) at time (t) for its TFP growth rate; and d) on the error term that is i.i.d distributed.

Equation (7) allows us to control for two types of technological diffusion paths: exponential (s=-1) and logistic (s=1).

We have estimated different versions of equation (7) using NLLS. We have estimated models A and B for both samples, considering annual data and three cases: the model with constant term, the model with trend, and the model with individual constants. As for model A, estimations were also performed for all the three cases with 5-year data. Model A takes annual data for the stock of human capital and model B considers the initial human capital stock average for the period 1960-1965.

As we can see from the results in Tables 2, 3, and 4 below, we cannot accept the Benhabib and Spiegel (2002) specification for our two samples. In fact, the results obtained are very weak. Let us briefly interpret the results obtained in each of the three Tables 2.2.4.1., 2.2.4.2., and 2.2.4.3..

TABLE 2.2.4.1. Seven countries (Benhabib and Spiegel (2002))

	TFP Annual Growth Rate					
NLLS	**Model A with constant**	**Model A with trend**	**Model A with c_{is}**	**Model B with constant**	**Model B with trend**	**Model B with c_{is}**
b	-0.044 (3.84***)	-0.043 (4.14***)	-	-0.001 (0.17)	-0.042 (4.36**)	-
g	0.026 (0.36)	0.010 (1.27)	0.056 (5.24***)	0.008 (1.23)	0.007 (1.18)	-0.233 (0)
c	0.014 (0.04)	-0.00000002 (0.21)	-0.00002 (0.43)	-0.000008 (0.38)	-0.0000005 (0.27)	-0.0006 (1.03)
s	2.182 (0.06)	-12.5 (3.66***)	-7.75 (4.36***)	-8.883 (4.34***)	-10.963 (3.99***)	-5.899 (7.43***)
b_1	-	-	-0.052 (3.65***)	-	-	-0.001 (0.14)
b_2	-	-	-0.090 (4.13***)	-	-	0.396 (25.56***)
b_3	-	-	-0.049 (3.51***)	-	-	0.008 (0.78)
b_4	-	-	0.122 (4.82***)	-	-	0.427 (37.62***)
b_5	-	-	0.0025 (1.35)	-	-	0.191 (11.71***)
b_6	-	-	0.036 (2.53***)	-	-	-0.037 (3.35***)
b_7	-	-	-0.077 (4.78***)	-	-	0.0165 (13.58***)
trend	-	0.001 (3.31**)	-	-	-0.002 (5.24***)	-
see	0.071	0.068	0.067	0.074	0.031	0.073
n-k	276	275	270	276	52	270

*significant at 10% level; **significant at 5% level; *** significant at 1% level; in brackets t-student values; trend – time effect coefficient.

As for models A and B with constant, g and c are not significant and the coefficient [-(c/s)] has the wrong theoretical sign. As for s, it is significant at the 1% level for B but its value neither confirms a logistic path, nor does it confirm an exponential path. As for the models with trend, both models A and B improve in comparison with the previous models with a constant term. For model A with trend, s becomes significant and for model B, the coefficient b becomes significant; but, for both models with trend, c is not significantly different from zero. This is an extremely implausible result from a theoretical point of view. Like the previous models, [-(c/s)] has the wrong sign and again the value of s is different from one or minus one.

As for model A with individual constants the results have improved compared with those obtained for the model with trend: g becomes significant at the 1% level, but c is not significantly different from zero and s is not equal to minus 1. As for model B with individual constants, the results have not improved compared with the model with trend.

TABLE 2.2.4.2. Seven countries (Benhabib and Spiegel (2002))

	TFP 5-year average growth rate		
NLLS	**Model A**	**Model A with trend**	**Model A with c_{is}**
b	-0.046 (3.69***)	-0.057 (4.84***)	-
g	1.231 (0.02)	-77.05 (0.13)	0.073 (5.42***)
c	-23.052 (0.02)	2812.618 (0.13)	-0.002 (0.65)
s	19.204 (0.11)	36.50 (0)	-3.457 (2.42**)
b_1	-	-	-0.057 (3.89***)
b_2	-	-	-0.109 (4.91***)
b_3	-	-	-0.056 (3.97***)
b_4	-	-	-0.153 (5.77***)
b_5	-	-	-0.044 (2.36**)
b_6	-	-	-0.050 (3.47 ***)
b_7	-	-	-0.086 (5.47***)
trend	-	0.001 (3.09***)	-
see	0.034	0.032	0.028
n-k	52	51	46

*significant at 10% level; **significant at 5% level; *** significant at 1% level; in brackets t- student values; trend – time effect coefficient.

Estimations of model A with c_{is}, with 5-year-interval data, have improved in relation to those with annual data. In fact all the individual constants are significant, and the SEE is 2.8%, against 6.7% from the previous estimations. Nonetheless, the coefficient c is not significantly different from zero.

TABLE 2.2.4.3. Thirteen countries (Benhabib and Spiegel (2002))

	TFP Annual Growth Rate			TFP 5-year average growth rate		
NLLS	**Model A**	**Model A with trend**	**Model A with c_{is}**	**Model A**	**Model A with trend**	**Model A with c_{is}**
b	-0.041 (5.15***)	-0.049 (6.25***)	-	-0.051 (4.41***)	-0.052 (5.71***)	-
g	0.074 (1.74*)	0.042 (0.85)	4.544 (1.09)	0.029 (4.59***)	0.010 (1.52)	0.003 (0.85)
c	-0.490 (0.66)	-0.410 (0.36)	-649.319 (1.07)	0.004 (0.29)	-0.000 (1.17)	-0.011 (0.30)
s	10.057 (1.23)	12.163 (0.66)	144.734 (0)	-0.956 (0.14)	54.76 (0)	9.399 (0.65)
b_1	-	-	-0.068 (5.81***)	-	-	-0.012 (0.88)
b_2	-	-	-0.100 (5.93***)	-	-	0.007 (0.51)
b_3	-	-	-0.061 (5.34 ***)	-	-	-0.008 (0.61)
b_4	-	-	-0.126 (6.88***)	-	-	-0.005 (0.37)
b_5	-	-	-0.077 (5.90***)	-	-	-0.006 (0.41)
b_6	-	-	-0.054 (4.68***)	-	-	0.0004 (0.03)
b_7	-	-	-0.083 (6.40***)	-	-	-0.013 (0.93)
b_8	-	-	-0.115 (6.95***)	-	-	0.950 (0)
b_9	-	-	-0.112 (6.72***)	-	-	0.928 (0)
b_{10}	-	-	-0.117 (6.66***)	-	-	0.902 (0)
b_{11}	-	-	-0.105 (6.57***)	-	-	4.377 (0)
b_{12}	-	-	-0.074 (5.60***)	-	-	0.910 (0)
b_{13}	-	-	-0.101 (6.50***)	-	-	0.640 (0)
trend	-	0.002 (6.22***)	-	-	-0.001 (5.35***)	-
see	0.058	0.0056	0.057	0.032	0.028	0.36
n-k	516	515	504	100	99	88

*significant at 10% level; **significant at 5% level; *** significant at 1% level; in brackets t- student values; trend – time effect coefficient.

As for model A with constant and annual data, g becomes significant at the 10% level compared with the same model with the same data frequency for the smaller sample. c and s are not significantly different from zero. As for the A models with trend and c_{is}, using annual data, the results are worse. For model A with trend, s is no longer significant compared with the same model for the smaller sample, while for model A with c_{is}, g and s are no longer significantly different from zero.

If we compare the results obtained with model A for annual data in Table 2.2.4.3. above, the best model is A with constant; nonetheless, the results are very weak. In fact, only g and b are significant at the 10% level. The results obtained with this model with 5-year data have improved compared with the same model with annual data, because g and b are now significant at 1% level.

If we look at the results obtained with model A with 5-year data, comparing the larger sample with the smaller sample, the results are better for the model with constant, and worst for the model with c_{is}.

As stated below, because the three coefficients, g, s and c are not significant at the same time, and do not have the signs predicted by the theory, and because the coefficient c is never significantly different from zero, and also because the value of s is not equal to unity or to minus unity, we conclude that the technological diffusion process specification by Benhabib and Spiegel (2002) is not suitable for our samples[2].

2.2.5. The Nelson and Phelps (1966) methodology

The Nelson and Phelps (1966) equation is the following,

$$\frac{\dot{A}_i(t)}{A_i(t)} = gH_{it} + cH_{it}\left(\frac{A_{m(t)}}{A_{it}} - 1\right) + \varepsilon_{it} \tag{8}$$

The rate of technological progress depends on the rate of innovation, which is a positive function of the stock of human capital (gH_{it}), and depends on technological catch-up, which is also a positive function of the stock of human capital. The rate of technological progress is positively related to the degree of technological backwardness of the economy due to the definition of technological backwardness. In fact, we have estimated equation (9) in order to normalise the values for human capital and the technological gap (deviations from the average value).

$$\begin{aligned} & g_{TFPit} = gH_{it} + c_{it}Z_{it} + \varepsilon_{it} \\ (9) \quad & Z_{it} = \left(H_{it} - \overline{H}\right)\left[\left(\frac{A_{m(t)}}{A_{it}} - 1\right) - \overline{\left(\frac{A_{m(t)}}{A_{it}} - 1\right)}\right] \end{aligned}$$

Regarding the Nelson and Phelps (1966) specification, we only estimated model A with constant or with trend, or with c_{is}, using annual data or 5-year data for the smaller sample and for the larger sample. Since the equation is linear, we have estimated it with OLS (robust errors), and also with the fixed effects model and the random effects model.

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[2] We have also estimated the models by ML methods with one variance and individual variances for a AR1 process, but the results were not good.

TABLE 2.2.5.1.Seven countries (Nelson and Phelps (1966) equation)

	TFP Annual Growth Rate			TFP 5-year average growth rate		
OLS ROBUST ERRORS	Model A with constant	Model A with trend	Model A with c_{is}	Modelo A	Model A with trend	Model A with c_{is}
B	-0.032 (2.88***)	-0.047 (3.67***)	-	-0.035	-0.051 (4.46***)	-
g	0.009 (3.76***)	0.004 (1.51)	0.001 (1.11)	0.008	0.004 (1.36)	0.001 (0.87)
c	0.007 (2.50**)	0.004 (1.48)	0.004 (1.48)	0.006	0.003 (1.01)	-0.003 (1.36)
b_1	-	-	0.046 (2.75***)	-	-	0.009 (0.31)
b_2	-	-	-0.006 (2.06***)	-	-	-0.007 (2.29**)
b_3	-	-	0.026 (1.94*)	-	-	0.025 (2.76***)
b_4	-	-	0.009 (0.40)	-	-	0.009 (0.33)
b_5	-	-	0.029 (2.19**)	-	-	0.018 (7.11***)
b_6	-	-	0.009 (1.93*)	-	-	0.011 (2.32**)
b_7	-	-	-0.045 (2.05**)	-	-	-0.040 (1.27)
trend	-	0.001 (3.30**)	-	-	0.001 (3.08***)	-
see	0.071	0.069	0.067	0.034	0.031	0.033
n-k	277	276	272	53	52	48

*significant at 10% level; **significant at 5% level; *** significant at 1% level; in brackets t- student values; trend – time effect coefficient.(n-k) – degrees of freedom.

Let us first analyse the results for the smaller sample, in Table 2.2.5.1.. Considering the annual data results, the best model is model A with constant. In fact all the coefficients are significant and have the sign predicted by the model. Nonetheless the values of g and c are very small. The other two models behave very badly. In fact, g and c are never significantly different from zero in these models. As for the results with 5-year data, these models should be disregarded: g and c are never significantly different from zero.

TABLE 2.2.5.2. Seven countries (Nelson and Phelps (1966) equation)

Fixed effects model	TFP annual growth rate	TFP 5-year growth rate
g	0.016 (5.19***)	0.016 (5.11***)
c	0.004 (1.69*)	0.003 (1.15)
see	0.067	0.032
n-k	310	47

*significant at 10% level; **significant at 5% level; *** significant at 1% level; in brackets t- student values; trend – time effect coefficient.(n-k) – degrees of freedom.

The results have improved for the estimation with the fixed effects model and the best result is obtained with annual data. In fact, all the coefficients are significant at both the 1% level and the 10% level. Notice that the value of g has increased compared with the OLS estimation - the value of g is higher than c, whose value is very small.

With 5-year data c is no longer significantly different from zero. The results are very sensitive to the frequency of the data.

TABLE 2.2.5.3. Seven countries SAMPLE (Nelson and Phelps (1966) equation)

Random effects model	TFP annual growth rate	TFP 5-year growth rate	TFP 5-year growth rate
constant	-0.064 (3.48***)	-0.066 (3.47***)	-
g	0.014 (5.59***)	0.013 (4.89***)	0.006 (3.45***)
c	0.006 (2.67***)	0.005 (1.75)	0.006 (2.14**)
see	0.066	0.031	0.033
n-k	317	53	54

*significant at 10% level; **significant at 5% level; *** significant at 1% level; in brackets t- student values; trend – time effect coefficient. (n-k) – degrees of freedom.

With respect to the random effects model with annual data, all the coefficients are significantly different from zero at the 1% level and the same is true for the model without constant using 5-year data. The value of coefficient c is higher in both models compared with those obtained with the fixed effects model and for the last model g is no longer higher than c.

Let us now analyse the results obtained for the thirteen-country sample, given in Tables 2.2.5.4., 2.2.5.5., 2.2.5.6..

TABLE 2.2.5.4. Thirteen countries (Nelson and Phelps (1966) equation)

	TFP annual growth rate			TFP 5-year growth rate		
OLS ROBUST ERRORS	**Model A with constant**	**Model A with trend**	**Model A with c_{is}**	**Modelo A with constant**	**Model A with trend**	**Model A with c_{is}**
constant	-0.024	-0.037	-	-0.030	-0.045	-
	(3.27***)	(4.83***)		(3.40***)	(5.17***)	
g	0.005	0.0009	-0.008	0.006	0.001	-0.0001
	(4.27***)	(0.72)	(2**)	(4.17***)	(1.07)	(0.14)
c	0.004	0.004	-0.044	0.002	0.003	-0.0001
	(1.77*)	(1.72*)	(2.07**)	(0.061)	(0.83)	(0.14)
b_1	-	-	0.025	-	-	0.011
			(2.43**)			(1.64)
b_2	-	-	-0.026	-	-	-0.020
			(3.10***)			(2.93***)
b_3	-	-	0.019	-	-	0.011
			(2.81***)			(1.61)
b_4	-	-	-0.018	-	-	-0.006
			(2.41**)			(0.90)
b_5	-	-	0.018	-	-	0.012
			(2.24**)			(2.30**)
b_6	-	-	0.009	-	-	0.008
			(2.52**)			(1.13)
b_7	-	-	0.091	-	-	0.023
			(3.44***)			(1.09)
b_8	-	-	-0.012	-	-	-0.006
			(1.93*)			(0.78)
b_9	-	-	-0.030	-	-	-0.20
			(2.10**)			(1.24)
b_{10}	-	-	-0.019	-	-	-0.014
			(3.56***)			(2.76***)
b_{11}	-	-	0.019	-	-	-0.017
			(2.61***)			(1.34)
b_{12}	-	-	0.013	-	-	0.017
			(0.63)			(1.21)
b_{13}	-	-	-0.034	-	-	-0.031
			(2.75***)			(1.83)
trend	-	0.002	-	-	0.002	-
		(7.11***)			(5.69***)	
see	0.059	0.056	0.057	0.032	0.028	0.033
n-k	517	516	505	101	100	90

*significant at 10% level; **significant at 5% level; *** significant at 1% level; in brackets t- student values; trend – time effect coefficient.(n-k) – degrees of freedom.

Considering annual data, the best results are those derived from model A with constant; in fact all the coefficients are significant and g and c have the signs predicted by theory, but the values of g and c are very small. As for the model with trend, all the coefficients are significant except g. The results that are hardest to interpret are those of model A with c_{is}. In fact, all the coefficients are significant, except for b_{12}, but g and c have the wrong signs.

As for the results with five-year data, they are worse. For model A with constant, c is not significant, for the model with trend only coefficients b and trend are significant and for model A with c_{is} only the constants b_2, b_5 and b_{10} are significant.

TABLE 2.2.5.5. Thirteen countries (Nelson and Phelps (1966) equation)

Fixed effects model	TFP annual growth rate	TFP 5-year growth rate
g	0.016 (8.12***)	0.016 (6.80***)
c	0.004 (2.22**)	0.003 (0.62)
see	0.056	0.029
n-k	544	89

*significant at 10% level; **significant at 5% level; *** significant at 1% level; in brackets t- student values; trend – time effect coefficient. (n-k) – degrees of freedom.

Regarding the fixed effects model, all the coefficients are significant: g at the 1% level and c at the 5% level, considering annual data. The results get worse with 5-year data; in this case, c is no longer significantly different from zero.

If we compare the results of this model, using annual data, with the model with constant, g is now higher. Notice also that the values of the coefficients g and c for the two samples are the same when the fixed effects model is used.

TABLE 2.2.5.6. Thirteen countries (Nelson and Phelps (1966) equation)

Random effects model	TFP annual growth rate	TFP 5-year growth rate	TFP 5-year growth rate
constant	-0.070 (4.94***)	-0.072 (4.80***)	-
g	0.013 (7.55***)	0.013 (6.20***)	0.005 (3.94***)
c	0.005 (2.86***)	0.002 (0.78)	0.007 (2.23**)
see	0.055	0.028	0.031
n-k	557	101	102

*significant at 10% level; **significant at 5% level; *** significant at 1% level; in brackets t- student values; trend – time effect coefficient. (n-k) – degrees of freedom.

With respect to the results obtained with the random effects model, using annual data, all the coefficients are significant at 1% level. For the model with five-year data, however, both coefficients are significant at 1% and 5% levels, respectively, but only for the model without constant. The results are also very sensitive to data frequency.

3. Human capital and channels of technology diffusion

In this section we propose to analyse the role of human capital in the process of technological diffusion a little further. We shall focus on the complementarity between human capital and foreign direct investment (FDI) as determinants of the technological progress growth rate, on the one hand, and on the importance of human capital as a facilitator of the diffusion of information and communication technologies (ICT) responsible for a large part of technological progress in the World today, on the other hand. We follow closely Borensztein, Gregorio, and Lee (1998) and Lee (2000).

3.1. The complementarity between human capital and FDI in the process of technological diffusion

The purpose of this section is to examine empirically the complementarity between human capital and FDI in the process of technology diffusion in our sample of Mediterranean countries. FDI is one of the channels[3] through which the technology from the leader is transferred to the followers. However, the host economy needs a sufficient level of human capital in order to apply the technology of the leader, i.e., the stock of human capital of the follower country limits the degree to which it can absorb the technology incorporated in FDI.

We tested this complementarity hypothesis in a panel data framework between 1970 and 1998 following Borensztein, Gregorio, and Lee (1998) and Lee (2000) and their basic formulation:

$$(10) \qquad D(TFP)_{it}=a_0+a_1 GTFP_{it-1}+a_2 TYR_{it-1}+a_3 FDI_{it}+a_4 FDI_{it}\mathrm{x}SHYR_{it}+\eta_i+\varepsilon_{it}$$

where $D(TFP)_{it}$ is the annual growth rate of technology as defined in the previous section, $GTFP_{it-1}$ is the initial technology level gap relative to the USA, the World's technological leader, TYR_{it-1} is the initial stock of human capital measured as average years of total schooling in the population aged 15 and over, $SHYR_{it}$ is average years of secondary and higher education in the population aged 15 and over, FDI_{it} is the net FDI flows as a ratio of GDP, η_i represents country-specific effects, and ε_{it} is the error term with the usual properties.

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[3] Another channel of technology diffusion from the leader to the followers is imports of machinery and transport equipment. Unfortunately, we were not able to get access to data on imports of machinery and transport equipment from OECD countries, the countries responsible for most of the World's R&D effort, for our sample of Mediterranean countries.

The technological progress growth rate depends positively on the initial technological gap between the leader and the follower country – the higher the initial gap, the higher the potential for the adoption and implementation of new technologies, i.e., the higher the TFP growth rate of the follower, so we expect a positive and significant a_1, which is the usual technological catch-up assumption in technology diffusion models such as the Barro and Sala-i-Martin (1997) model of technological diffusion. Human capital also has a positive influence on the TFP growth rate since the adoption and implementation of new technologies requires at least basic skill levels ($a_2>0$), as in the Nelson and Phelps (1966) model. On the other hand, FDI is a fundamental channel through which less developed countries have access to the advanced technologies of developed countries, which means that a_3 should be positive. Finally, the hypothesis that the diffusion of technology through FDI is only effective if the host economy has the necessary absorptive capability in the form of human capital is tested through the interactive term *FDI*x*SHYR* – if its coefficient is positive and significant this means that the technology spillovers due to FDI depend on the stock of human capital.

The TFP and human capital data are the same as those used in the previous sections. The FDI data comes from the OECD publication "Geographical distribution of financial flows to aid recipients " (OECD (2003)) and measures the net flows of FDI received by the countries in our sample from the OECD countries, responsible for most of the R&D effort in the World.

We estimated our relationship using four different estimation procedures – the pooled ordinary least squares (OLS), the within-groups estimator, the first-differenced generalized method of moments (GMM-DIF) proposed by Arellano and Bond (1991), and the system generalized method of moments (GMM-SYS) proposed by Arellano and Bover (1995) and Blundell and Bond (1998), each corresponding to different assumptions concerning the econometric properties of the relationship we are analyzing.

The pooled OLS estimator delivers unbiased and consistent estimators if there are no country-specific effects in the relationship and if the regressors are strictly exogenous. Where there are country-specific effects and the regressors are still strictly exogenous, however, the within-groups estimator delivers unbiased estimators. In the presence of country-specific effects and where the assumption of strict exogeneity of the regressors is violated, the OLS estimators of the coefficient on initial TFP is biased upwards, while the within-groups estimator is biased downwards. The results from these two procedures thus provide us with an upper and lower bound for the coefficient on initial TFP. Also, in the presence of weak instruments, the first-differenced GMM estimator is biased towards the within-groups estimator. The results reported in the GMM-DIF and GMM-SYS columns are for the one-step procedure since. According to Blundell and Bond (1998), for small samples like ours and in the presence of heteroskedasticity, inference based on the two-step procedure is unreliable due to the fact that the standard errors of the two-step GMM estimators can be seriously biased downwards.

Table 3.1.1 gives the results of the estimation of the different equations using annual data and the four different estimation procedures mentioned before. To control for the possibility of business cycle effects on the TFP growth rate we also estimated the different equations averaging the data over 5-year periods[4]. The results for these estimations are presented in Table 3.1.2.

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[4] For the last period, 1995-1998, we used 3-year averages.

Table 3.1.1 – Human capital and technology diffusion through FDI flows (annual data)

Dependent variable: *D(TFP) - Annual growth rate of TFP, 1970-1998*

	Pooled OLS			**Within Groups**			**GMM-DIF**^{c}			**GMM-SYS**		
GTFP(t-1)	0.105	0.106	0.106	0.171	0.173	0.175	0.41	0.179	0.195	0.181	0.161	0.18
	(4.86)**	(5.05) **	(5.12) **	(2.15) **	(2.26) **	(2.25) **	(7.59) **	(10.2) **	(9.20) **	(17.0) **	(25.8) **	(20.8) **
TYR(t-1)	0.0027	0.0027	0.0026	0.004	0.004	0.004	-0.01	0.002	0.002	0.004	0.004	0.004
	(4.18) **	(4.31) **	(4.13) **	(2.07) **	(2.24) **	(2.30) **	(-0.952)	(0.802)	(0.665)	(3.72) **	(5.80) **	(5.60) **
FDI(t)		0.002	0.0009		0.002	0.0008		0.001	-0.0024		0.003	0.0012
		(2.66) **	(0.549)		(1.63) *	(0.247)		(0.779)	(-0.448)		(1.42)	(0.205)
*FDI*SHYR(t)*			0.0007			0.0007			0.002			0.0009
			(1.21)			(0.594)			(0.947)			(0.393)
AR(2)^{a}							0.72	0.792	0.824	0.761	0.770	0.782
Sargan Test^{b}							0.029	0.921	1.000	0.000	0.000	0.000
Obs.	203	203	203	203	203	203	189	189	189	196	196	196

Notes: values of the t-Student statistic in brackets. ** significant at the 5% level. * significant at the 10% level.

Instruments used in GMM-DIF: lnTFP_{it-2}, lnTYR_{it-3} ; lnFDI_{Pit-2} , $\text{lnFDI*SHYR}_{Sit-2}$, and lags up to the fourth lag.

Instruments used in GMM-SYS: same as for GMM-DIF, and, in addition, instruments for the levels equations are $\Delta\text{lnTFP}_{it-1}$, $\Delta\text{lnTYR}_{Pit-2}$; $\Delta\text{lnFDI}_{Pit-1}$, $\Delta\text{lnFDI*SHYR}_{Sit-1}$.

[a] p-values for the null hypothesis that the errors in the first-difference regression exhibit no second-order serial correlation. [b]p-values for the null hypothesis of overall validity of the instruments used. [c] Results for the one-step GMM estimator with standard errors robust to heteroskedasticity since the standard errors of the two-step GMM estimator can be seriously biased downwards.

Table 3.1.2– Human capital and technology diffusion through FDI flows (5-year averages)

Dependent variable: *D(TFP) - Annual average growth rate of TFP, 1970-1998*

	Pooled OLS			**Within Groups**			**GMM-DIF**^{c}			**GMM-SYS**		
GTFP(t-1)	0.067	0.065	0.065	0.075	0.094	0.095	0.499	0.203	0.201	0.331	0.146	0.203
	(4.20) **	(4.34) **	(4.35) **	(3.11) **	(3.75) **	(3.42) **	(2.97) **	(4.84) **	(3.74) **	(6.53) **	(6.89) **	(5.40) **
TYR(t-1)	0.0017	0.0017	0.0017	0.002	0.002	0.002	-0.003	-0.002	0.003	0.009	0.006	0.006
	(3.93) **	(3.31) **	(2.70) **	(2.25) **	(2.16) **	(1.81) **	(-0.350)	(-0.331)	(0.362)	(2.64) **	(1.77) *	(2.05) **
FDI(t)		0.0003	0.0005		-0.001	0.0003		-0.008	-0.010		-0.006	-0.014
		(0.320)	(0.133)		(-0.631)	(0.055)		(-0.834)	(-0.786)		(-0.751)	(-1.13)
*FDI*SHYR(t)*			-.00009			-0.001			0.0019			0.005
			(-0.059)			(-0.519)			(0.332)			(0.999)
AR(2)^{a}							0.772	0.677	0.363	0.261	0.265	0.292
Sargan Test^{b}							0.231	0.530	0.795	0.009	0.055	0.082
Obs.	42	42	42	42	42	42	35	35	35	42	42	42

Notes: values of the t-Student statistic in brackets. ** significant at the 5% level. * significant at the10% level.

Instruments used in GMM-DIF: lnTFP_{it-2}, lnTYR_{it-3} ; lnFDI_{Pit-2} , $\text{lnFDI*SHYR}_{Sit-2}$, and lags up to the fourth lag.

Instruments used in Sys-GMM: same as for GMM-DIF and, in addition, instruments for the levels equations are $\Delta\text{lnTFP}_{it-1}$, $\Delta\text{lnTYR}_{Pit-2}$; $\Delta\text{lnFDI}_{Pit-1}$, $\Delta\text{lnFDI*SHYR}_{Sit-1}$.

[a] p-values for the null hypothesis that the errors in the first-difference regression exhibit no second-order serial correlation. [b]p-values for the null hypothesis of overall validity of the instruments used. [c] Results for the one-step GMM estimator with standard errors robust to heteroskedasticity since the standard errors of the two-step GMM estimator can be seriously biased downwards.

With respect to the results using annual data (Table 3.1.1), the technological catch-up hypothesis is confirmed for all the equations – the coefficient on the initial technological gap is always positive and significant, meaning that the initially more technological backward countries were indeed the ones that exhibited faster TFP growth rates. The role of the initial level of human capital is also confirmed (except when we use the first-differenced GMM estimator) – its coefficient is always positive and significant. In the equation where FDI is included on its own its expected positive influence over the TFP growth is confirmed only when the pooled OLS and the within-groups estimators are used. In the case of the first-differenced GMM estimator the coefficient, although positive, is not significant, and with the system GMM estimator it is positive but only significant at the 25% level. The hypothesis we are focusing on is that the technology originating in FDI flows is effectively used only if the host country has the necessary human capital to effectively use it, which means that in our full equation the coefficient on the interaction term between FDI and human capital should be positive and significant. But our results show that this is not the case – although the coefficient is always positive it is never significant. Furthermore, the coefficient on FDI alone is also always non-significant, and even negative, when using the GMM-DIF estimator. Our hypothesis of complementarity between FDI flows and human capital is therefore not supported by the data for our seven Mediterranean countries.

Turning now to the results using 5-year averages, nothing much changes. The coefficients on the initial technological gap and human capital are still always positive and significant (except for the human capital coefficients using GMM-DIF), the coefficient on FDI when introduced on its own is never significant and it is only positive when using the pooled OLS estimator. Finally when the full equation is estimated the coefficient on FDI remains non-significant and the same happens with the coefficient on the interaction term.

To sum up, we can say that human capital on its own influences the technological progress growth rate of our seven Mediterranean countries, but the evidence does not support its role in determining the TFP growth rate as a determinant of the absorptive capability of the imported technology coming from FDI flows. Maybe a better measure for the spillovers of technology from the technological leaders to the followers would be imports of machinery and transport equipment, which unfortunately we could not gain access to for our sample.

3.2. Human capital as a facilitator of the diffusion of IC technologies

It is widely accepted that today Information and Communication technologies (ICTs) play a major role in technological progress, and so the diffusion of these new technologies could help to speed up technological diffusion in our sample of Mediterranean countries. However, these new technologies require more than basic skills for full implementation, i.e., human capital levels are a major determinant of the absorptive capability of ICTs in Mediterranean countries. In order to test this hypothesis we estimated the relationship between human capital and a set of ICT indicators in a panel data framework, as in the following equations:

$$ICT_{it}=b_0+b_1 logRGDP_{it}+b_2 TYR_{it}+\mu_i+\nu_{it} \quad (11)$$

$$ICT_{it}=c_0+c_1 logRGDP_{it}+c_2 PYR_{it}+c_3 SYR_{it}+c_4 HYR_{it}+\mu_i+\nu_{it} \quad (12)$$

where ICT_{it} is an ICT indicator, measured alternatively as main telephone lines, number of personal computers, internet hosts, daily newspapers, and number of TV sets, all per 1,000 people[5]; $logRGDP_{it}$ is the natural logarithm of real GDP per capita from the PWT Mark 6.1 and proxies for the constraint that national financial resources represent for the necessary investments in building ICT infrastructures; TYR_{it} is the average years of total schooling of the population aged 15 and over from Barro and Lee (2000) and proxies for the skills necessary to implement ICTs; PYR_{it} is the average years of primary schooling of the population aged 15 and over (from Barro and Lee (2000)); SYR_{it} is the average years of secondary schooling of the population aged 15 and over (from Barro and Lee (2000)); and HYR_{it} is the average years of higher schooling of the population aged 15 and over (from Barro and Lee (2000)). Education levels have been broken down in this way as basic literary skills may not be enough to take full advantage of the ICTs, so each level of schooling may have an effect on the evolution of different ICT indicators; μ_i is a country-specific effect and ν_{it} is the error term with the usual properties.

We present the results for the different equations in Tables 3.2.1 and 3.2.2. In the first Table the presence of country-specific effects in determining the evolution of ICTs are disregarded, i.e., we estimated our different equations using the pooled OLS estimator. In the second Table we consider that there might be country-specific effects

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[5] Except the number of internet hosts, which are measured per 10,000 people. The period coverage varies according to data availability – 1975-1998 for main telephone lines, daily newspapers and the number of TV sets, 1990-1998 for the number of personal computers, and 1994-1998 for internet hosts.

governing the evolution of ICTs, so the results of the estimation of the different equations are displayed using the within-groups estimator.

Table 3.2.1 – Human capital and ICT diffusion (Pooled OLS)

Dependent variable	**log(RGDP per capita)**	**TYR**	**PYR**	**SYR**	**HYR**	$\bar{R}^2$	**Obs.**
Telephone lines	139.939 (2.89) **	24.6327 (2.72) **				0.798	172
	185.333 (5.68) **		-92.3 (-4.6) **	53.16 (2.51)**	745.6 (7.80)**	0.888	172
Personal computers	26.3 (2.42) **	17.7 (3.58) **				0.81	32
	51.9 (1.77) **		-17.65 (-0.482)	-25.38 (-1.79)*	272.72 (1.36)	0.886	32
Internet hosts	3.22 (0.365)	12.04 (2.62) **				0.519	35
	28.06 (0.917)		-23.18 (-0.554)	-27.69 (-1.99)**	259.43 (1.16)	0.701	35
Daily papers	66.52 (2.04) **	16.63 (1.37)				0.700	63
	79.40 (1.94) **		9.34 (0.266)	-87.62 (-4.65)**	293.4 (1.40)	0.905	63
TV sets	75.20 (1.84) **	11.36 (1.20)				0.643	172
	69.30 (1.79) **		29.61 (1.45)	-46.91 (-1.91)**	62.38 (0.497)	0.703	172

Notes: *values of the t-Student statistic in brackets. ** significant at the 5% level. * significant at the 10% level.*

The results using the pooled OLS estimator show that real GDP and average years of schooling explain most of the development in ICTs in the Mediterranean countries with $\bar{R}^2$ higher than 50%. The availability of financial resources is an important determinant for the development of ICTs, except in the case of internet hosts, when only human capital is significant. As for human capital, the results confirm that average years of total schooling influence the implementation of phone lines, personal computers and internet hosts, all variables are significant at the 5% level, while the diffusion of daily newspapers and TV sets does not depend on the population’s years of schooling – human capital is only significant at the 25% level. When we examine the influence of the different schooling levels the results are somewhat awkward – average years of primary schooling do not in general influence the development of any of the ICTs indicators, and even show a negative influence as far as phone lines are concerned; average years of secondary schooling show a negative influence over all ICTs indicators (negative and significant coefficients) except for phone lines, for which the influence is positive and significant, as expected; finally, average years of higher schooling show a positive influence over all ICTs indicators, as expected, but only significant in the phone lines case.

Table 3.2.2 – Human capital and ICT diffusion (Within-Groups)

Dependent variable	log(RGDP per capita)	TYR	PYR	SYR	HYR	$\bar{R}^2$	Obs.
Telephone lines	409.4 (3.94) **	-19.14 (-0.951)				0.674	172
	278.37 (2.66) **		-47.4 (-0.614)	-47.01 (-0.357)	717.76 (5.22) **	0.766	172
Personal computers	200.8 (2.11) **	7.8 (0.279)				0.273	32
	44.74 (0.432) **		-362.3 (-1.9) **	428.3 (1.44)	565.65 (0.852)	0.551	32
Internet hosts	108.9 (2.14) **	7.72 (0.314)				0.114	35
	-72.29 (-0.552)		-292.6 (-1.7) *	250.9 (0.926)	1047.6 (1.56) *	0.53	35
Daily papers	66.59 (1.58) *	-14.75 (-1.48)				0.128	63
	32.45 (0.843)		-12.34 (-0.347)	-126.85 (-2.12) **	503.59 (5.29) **	0.592	63
TV sets	55.58 (1.07)	26.04 (1.96) **				0.530	172
	75.59 (3.25) **		120.8 (1.83) *	-163.17 (-1.57) *	218.42 (1.30)	0.62	172

Notes: *values of the t-Student statistic in brackets. * significant at the 5% level. ** significant at the 10% level.*

Bearing in mind that there might be country-specific effects in the development of ICTs, we used the within-groups estimator to estimate our different relationships, as mentioned before. The fit of the equations is not as good as before, especially when the different schooling levels are included in the regressions, although there are some small $\bar{R}^2$, such as in the case of personal computers, internet hosts and daily newspapers when average years of total schooling is considered. Again, the availability of financial resources is an important determinant for the development of ICTs, except in the case of internet hosts and daily newspapers, when the different schooling levels are considered, and in the case of TV sets with average years of total schooling. As for human capital, the results do not confirm that average years of total schooling influences the implementation of ICTs with the exception of the diffusion of TV sets– human capital is significant at the 10% level. When we examine the influence of the different schooling levels the results are mixed – only average years of primary schooling show a positive and significant influence in the TV sets case, the influence on personal computers and internet hosts is negative and significant, while the remaining influences are not significant. Average years of secondary schooling show negative and significant coefficients in the case of daily newspapers and TV sets, while all the other influences are non significant. Finally, average years of higher schooling show a positive influence over all ICT indicators, as expected, but that is only significant for the phone lines, daily newspapers and TV sets cases.

From the tests carried out in this section we can say without a doubt that to fully benefit from the diffusion of ICTs, responsible for the acceleration of technological progress in recent years, the Mediterranean countries need the financial resources to build the necessary infrastructures and the human capital capable of working with these new technologies. The role of the different schooling levels is not so clear, although one would expect that the diffusion of some ICTs like personal computers and Internet hosts requires more than just the basic literary skills gained from primary schooling. Puzzling, however, are some of the results that point to a negative and significant influence of primary and secondary schooling on the development of ICTs.

4. Technological shocks and human capital shocks

4.1. The VAR model

In order to ascertain the influence of TFP growth rate shocks and human capital shocks on the economy we built a VAR model in the Sims (1980) tradition. It is a VAR model that applies to all seven economies of the smaller sample and has four variables: real GDP per capita, annual TFP growth rate, investment per capita and the stock of human capital, all expressed in logarithms.

The number of lags was chosen using the BIC criteria and the system stationarity condition: for Algeria, Egypt, Israel, Syria, and Turkey the number of lags is two, for Tunisia three, and for Cyprus five. The shocks simulated over the variables are unit shocks. In the case of the TFP growth rate, the impulses resulting from the shocks were accumulated so that the TFP are plotted in all the figures.

The number of periods is twenty except for Cyprus, which is thirty, when a unit shock is simulated over TFP growth rate to show that the model is stationary.

Let us write the VAR model,

$$\begin{aligned}
y_t &= const_1 + \sum_{i=1}^{k} \alpha_{1i} y_{t-i} + \sum_{i=1}^{k} \alpha_{2i} h_{t-i} + \sum_{i=1}^{k} \alpha_{3i} inv_{t-i} + \sum_{i=1}^{k} \alpha_{4i} g_{TFP(t-i)} + \varepsilon_{1t} \\
g_{TFP(t)} &= const_4 + \sum_{i=1}^{k} \gamma_{1i} y_{t-i} + \sum_{i=1}^{k} \gamma_{2i} h_{t-i} + \sum_{i=1}^{k} \gamma_{3i} inv_{t-i} + \sum_{i=1}^{k} \gamma_{4i} g_{TFP(t-i)} + \varepsilon_{2t} \\
inv_t &= const_3 + \sum_{i=1}^{k} \delta_{1i} y_{t-i} + \sum_{i=1}^{k} \delta_{2i} h_{t-i} + \sum_{i=1}^{k} \delta_{3i} inv_{t-i} + \sum_{i=1}^{k} \delta_{4i} g_{TFP(t-i)} + \varepsilon_{3t} \\
h_t &= const_2 + \sum_{i=1}^{k} \beta_{1i} y_{t-i} + \sum_{i=1}^{k} \beta_{2i} h_{t-i} + \sum_{i=1}^{k} \beta_{3i} inv_{t-i} \sum_{i=1}^{k} \beta_{4i} g_{TFP(t-i)} + \varepsilon_{4t}
\end{aligned} \tag{13}$$

4.2 Shock Simulation

Below we will analyse very briefly the main effects of the three types of shocks considered upon the seven Mediterranean economies[6].

Summary Table

IMPACT SHOCK	TFP level	Investment	Human capital	GDP
TFP growth rate	*positive and permanent*	*initially strong but temporary*	*positive and permanent*	*positive and permanent*
Human capital	*positive and permanent*	*initially strong but temporary*	*positive and permanent*	*positive and permanent*
Investment	*positive and permanent*	*temporary*	*positive and permanent*	*positive and permanent*

Regarding technological shocks[7], there is complementarity between technology, physical capital and human capital (see Figure A.1.1) with the exception of Turkey (see Figure A.1.2). As for human capital shocks[8], there is complementarity between technology, physical capital and human capital (see Figure A2.1) with the exceptions of Algeria (see Figure A.2.2) and Israel (see Figure A.2.3), which exhibit substitutability between physical capital and human capital in the first four and twelve years). With respect to investment shocks[9], there is complementarity between TFP, physical capital and human capital (see Figure A.3.1), with the exception of Egypt (see Figure A.3.2)

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[6] Syria is a representative country of our set when faced with each of the three types of shocks. Only Figures for Syria are included in Appendix A, relative to the representative effects of the shocks. Figures for the remaining countries are available on request from the authors.

[7] See Figures A.1.1 and A.1.2 in Appendix A.

[8] See Figures A.2.1, A.2.2 and A.2.3 in Appendix A.

[9] See Figures A.3.1, A.3.2 and A.3.3 in Appendix A.

and Israel (see figure A.3.3), which show substitutability between physical investment and human capital.

5. Concluding remarks

In recent years, within the growth literature the technological progress growth rate has been identified as a major source of growth, and this in turn depends crucially on the availability of human capital, because of its influence on innovation and imitation activities. This paper has focused on a sample of developing Mediterranean countries and the role of human capital as a facilitator of technological diffusion, i.e., the transfer of technology from developed countries to developing countries. The basic methodologies followed were those of Benhabib and Spiegel (2002) and Nelson and Phelps (1966).

The specifications of Benhabib and Spiegel (2002) and Nelson and Phelps (1966) were estimated in section 2 to ascertain the quantitative importance of human capital as a facilitator of innovation and technological imitation. Regarding the Benhabib and Spiegel (2002) specification, in neither model is the coefficient c significantly different from zero, and the coefficient s, when it is significant, does not take the values one or minus one. Furthermore, the catching-up coefficient does not have the sign predicted by the theory. The coefficient g is significant in several of the specifications. These results lead us to conclude that this type of specification does not capture the influence of human capital as a facilitator of technological diffusion. Benhabib and Spiegel (2002) considered a specification that can accomodate a logistic path for the technological diffusion process, but this kind of path does not seem to apply to our two samples. One possible explanation for this is the fact that, for the smaller sample, the level of human capital necessary to adopt foreign technology is not constrained by a threshold, which would probably happen if we had worked with a larger more heterogeneous sample, as the authors did, including the poorest countries of the world.

The results above led us to estimate the Nelson and Phelps (1966) equation, which is a linear specification. We obtained good results, especially for the fixed effects and random effects models with annual data. Nonetheless, although the importance of human capital is confirmed by our estimations, its influence is very low, taking into account the value of the estimated coefficient, c. To conclude, we would say that the

Nelson and Phelps (1966) specification seems to capture the process of technological diffusion in our seven countries, even though the importance of human capital as a facilitator of technological imitation, though confirmed, is small.

It was also interesting to analyse the relationship between human capital and the channel through which technology is transferred from the leaders to the followers. Like Borensztein, Gregorio, and Lee (1998) and Lee (2000), we focused on FDI as a major channel of technological diffusion which is only effective if the host country has the necessary human capital available. Although the results of our analysis support the technological catch-up hypothesis and the importance of initial human capital stocks for the TFP growth rate, as with the analysis in the previous section, we were not able to confirm the existence of a complementarity between FDI and human capital. This may be due to the proxy used for the channel of technological diffusion: this analysis should be checked against an alternative channel such as that of diffusion through imports of machinery and transport equipment, which unfortunately we were not able to carry out due to unavailability of data. We also analysed the role of human capital in the diffusion of a particular kind of technology, ICTs, identified as a major source of technological progress in the World today. We considered both the aggregate influence of human capital, which was found to be significant, and the influence exerted through human capital acquired via the different schooling levels. In this last case, the results support higher education as a main determinant of ICT diffusion, a result in accordance with the idea that the diffusion of this kind of technology needs more than basic literacy levels.

Inspection of the three types of shocks to the seven Mediterranean economies yields the following main conclusions: relative to technological shocks, there is complementarity between technology, physical capital and human capital with the exception of Turkey; as for human capital, there is also complementarity between technology, physical capital and human capital shocks, except for Algeria and Israel, which exhibit factor substitutability between physical capital and human capital in the first four and twelve years; finally, investment shocks lead to factor complementarity between TFP, physical capital and human capital, with the exception of Egypt, which shows factor substitutability between physical investment and human capital, and Israel.

To sum up, the evidence presented in this paper confirms the importance of human capital as a determinant of technological progress based on the results of the tests of the Nelson and Phelps (1966) hypothesis. A somewhat surprising finding was the fact that the influence of human capital is felt mainly through innovation and not imitation activities. This is, however, in accordance with the results of the tests of the Benhabib and Spiegel (2002) hypothesis. It was not possible to confirm that the TFP growth rate follows a logistic function, i.e., the human capital in our sample is already higher than the threshold necessary to exert an influence over the technological progress growth rate. It is also not surprising that the second specification delivers better results relative to human capital as a facilitator of imitation activities, despite the rather low value of the imitation coefficient. Analysis of the complementarity between human capital and FDI also confirms the importance of the former as a facilitator of innovation activities rather than imitation activities, since the results do not support the idea that the technology diffused through FDI needs human capital to become effective. Furthermore, human capital, especially that acquired through higher education, is fundamental for the diffusion of ICTs.

Finally, the existence of factor complementarity between TFP, physical capital and human capital, as a consequence of any of the three types of shocks considered for almost all the seven Mediterranean economies, is in accordance with the main results described in sections 2 and 3, namely, the influence of human capital as a facilitator of technical progress. Notice, however, that in section 4 we did not control for its double role, in the innovation and imitation processes. If we had had data on machinery and transport equipment imports from developed countries for our seven countries, we would have been able to build VAR models whose results for human capital complementarity with machinery imports would also control for the role of human capital as a facilitator of technological imitation.

These results should, however, be considered with some care, for the following reasons: a) they are sensitive to the method used to compute the series of the physical capital stock and of the TFP levels and growth rates. That is to say, TFP was computed based on a Cobb-Douglas aggregate production function that was imposed and not estimated; b) the usual concerns about data reliability are in order for these countries, especially as far as human capital is concerned; and c) other channels of technological diffusion should be considered, such as imports of machinery and transport equipment.

These are tasks for future work on the analysis of the process of technological diffusion for this specific sample of countries.

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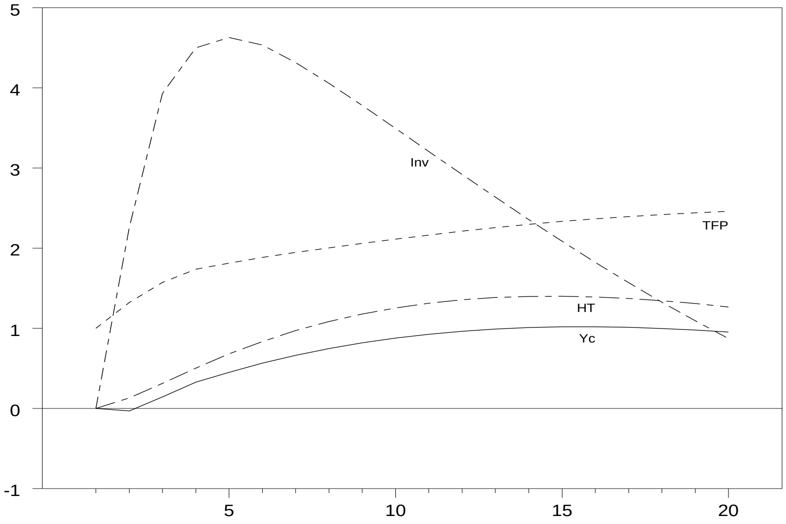
Appendix A – Graphical analysis of technological shocks

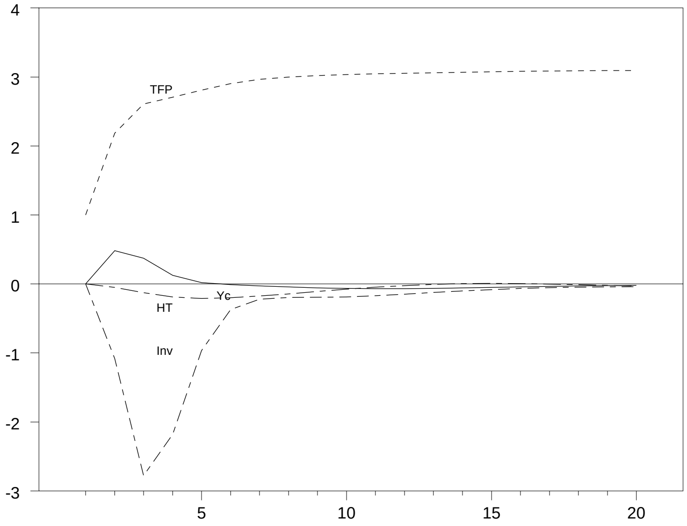
Technological shocks

Syria [Fig. A.1.1]



Unit shock on dTFP

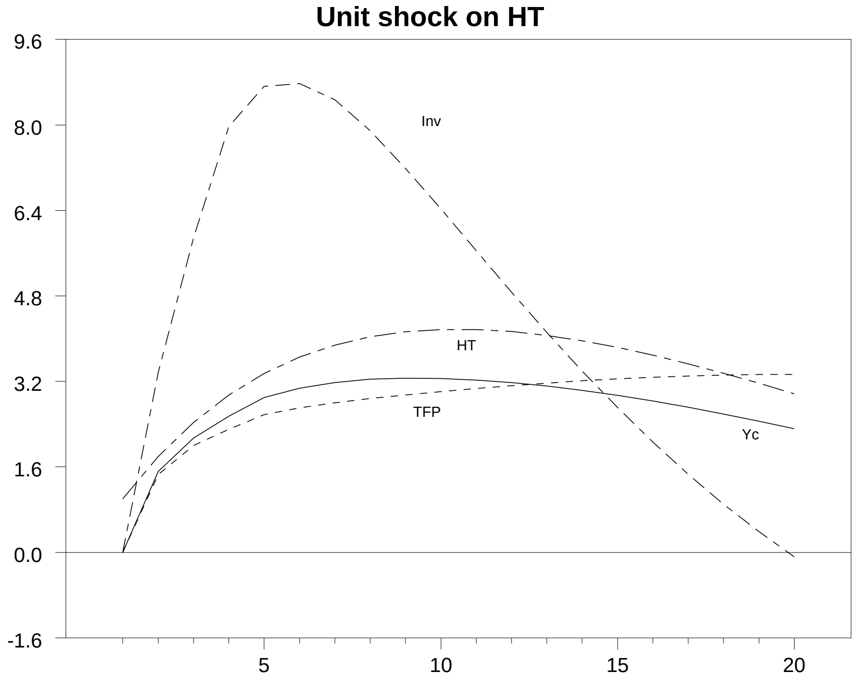
Turkey [Fig. A.1.2]



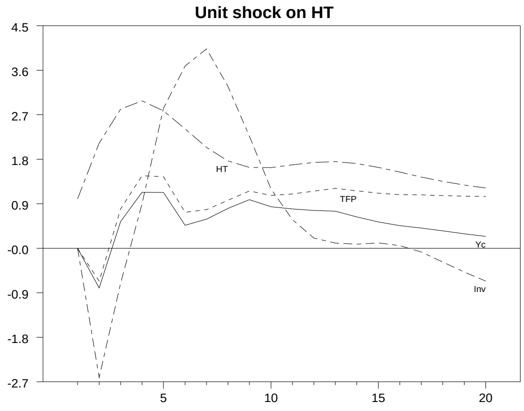
Unit shock on dTFP

Human Capital shocks

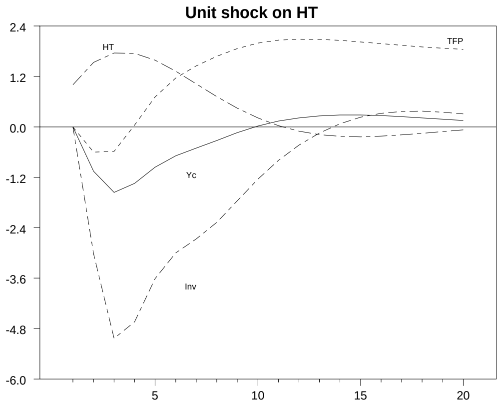
Syria [Fig. A.2.1]


Unit shock on HT

Algeria [Fig. A.2.2]

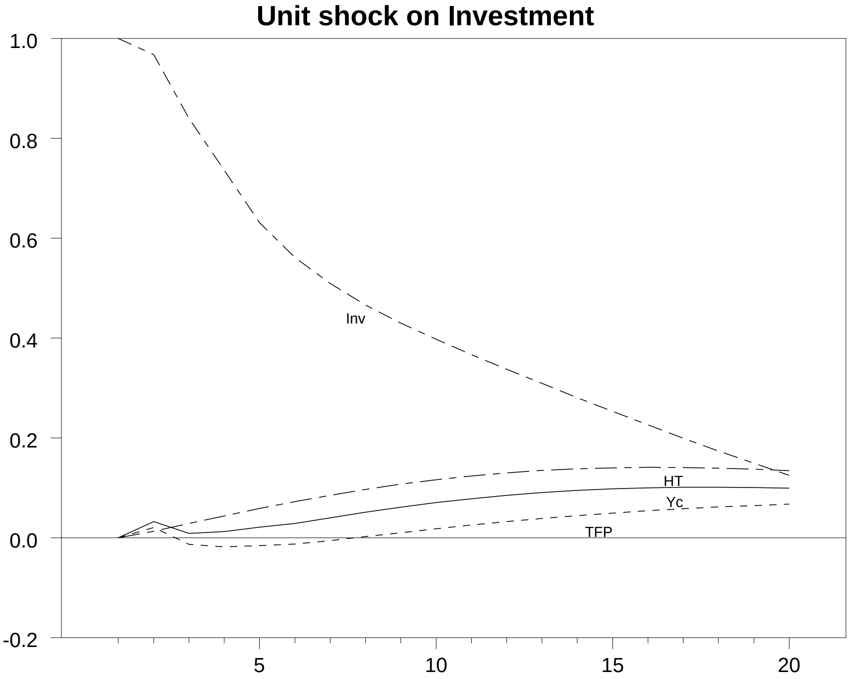

Unit shock on HT

Israel [Fig. A.2.3]

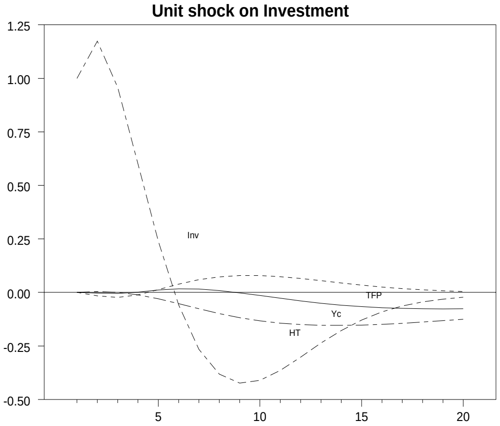

Unit shock on HT

Investment shocks

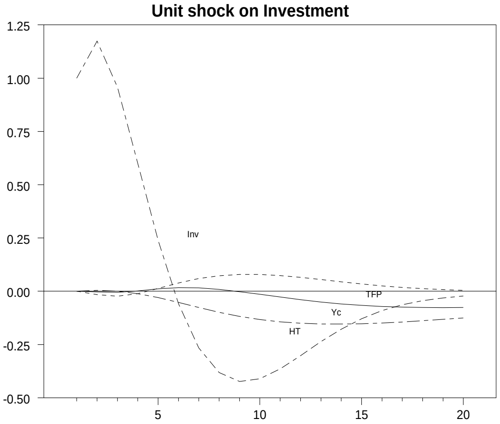
Syria [Fig. A.3.1]


Unit shock on Investment

Egypt [Fig. A.3.2]


Unit shock on Investment

Israel [Fig. A.3.3]


Unit shock on Investment

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