UNIVERSIDADE DE ÉVORA

DEPARTAMENTO DE ECONOMIA

DOCUMENTO DE TRABALHO N.º **2003/07**

May

Distinguishing between potential sources of growth and types of convergence for the Portuguese economy within the EU *

A panel data – time series study of the aggregate production function

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*** 6EMES RENCONTRES EURO-MEDITERRANEENNES**
"Régulations institutionnelles, intégration régionale et convergence dans la zone euro-méditérranéenne."

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Abstract:

What are the potential sources of growth and how is the convergence process of the Portuguese economy within the EU characterised? We answer this question by determining the most suitable specification of the aggregate production function, CES or Cobb-Douglas, for the EU countries as in Duffy&Papageorgiou (2000). If the aggregate production technology is best described by a CES production function then the potential sources of growth are wider than the ones associated with a Cobb-Douglas technology. For instance, with an elasticity of substitution between inputs greater than one ($\sigma>1$) it is possible to have endogenous growth (see Jones&Manuelli (1990), Rebelo (1991)) while for $\sigma<1$ multiple equilibriums arise (see Azariadis (1993, 1996, 2001). To test for the most suitable production function specification we consider a sample of seventeen European countries between 1960 and 1987. The tests are conducted within a panel data and time series framework based on data retrieved from the STARS database of the World Bank. Three different kinds of samples were considered: a) all the seventeen countries; b) three of the cohesion countries, Portugal, Greece, Ireland, and Iceland; and c) each country separately, and two types of production functions – one with raw labour and one with human capital adjusted labour. By considering groups of countries and not only each country separately it is possible to distinguish between each country's behaviour and that of the average economy and also to characterise σ according to the income level of the different countries in our sample. Previous to the estimation of the non-linear production function by maximum likelihood and GMM techniques we tested the series for stationarity both in a time series and a panel data framework. We also used linear estimation techniques, generalised least squares with individual fixed effects and cointegration techniques. We conclude that it is not possible to reject the CES specification for the countries in our sample. Since $\sigma>1$,it is possible to have endogenous growth although the characterisation of our series does not allow us to ignore the spurious regression problem.

Palavras-chave/Keyword economic growth, endogenous growth, CES production technology,Cobb-Douglas production technology, human capital, panel data,time series data, cointegration in panel data

Classificação JEL/JEL Classification:

INTRODUCTION

What are the potential sources of growth and how is the convergence process of the Portuguese economy within the EU characterised? We answer this question by determining the most suitable specification of the aggregate production function, CES or Cobb-Douglas, for the EU countries as in Duffy and Papageorgiou (2000). If the aggregate production technology is best described by a CES production function then the potential sources of growth are wider than the ones associated with a Cobb-Douglas technology. For instance, with an elasticity of substitution between inputs greater than one ($\sigma>1$) it is possible to have endogenous growth (see Jones and Manuelli (1990), Rebelo (1991)), while for $\sigma<1$ multiple equilibriums arise (see Azariadis (1993, 1996, 2001).

To test for the most suitable production function specification we consider a sample of seventeen European countries[1], in ascending order according to their average GDP per worker, between 1960 and 1987. The tests are conducted within a panel data and time series framework based on data retrieved from the STARS database of the World Bank. Three different kinds of samples were considered: a) all the seventeen countries; b) three of the cohesion countries, Portugal, Greece, Ireland, and Iceland; and c) each country separately, and two types of production functions – one with raw labour and one with human capital adjusted labour. By considering groups of countries and not only each country separately it is possible to distinguish between each country's behaviour and that of the average economy and also to characterise σ according to the income level of the different countries in our sample.

Previous to the estimation of the non-linear production function by maximum likelihood and GMM techniques we tested the series for stationarity within both in a time series and in a panel data framework. We also used linear estimation techniques, generalised least squares with individual fixed effects and cointegration techniques[2]. We conclude that it is not possible to reject the CES specification for the countries in our sample. Since $\sigma>1$, it is possible to have endogenous growth although the

[1] Austria, Belgium, Denmark, Finland, France, the former Federal Republic of Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and Iceland
[2] The tests were conducted using the econometric packages RATS 5.00, PCGive 10 et NPT 1.3 (Kao and Chiang, 2002).

characterisation of our series does not allow us to ignore the spurious regression problem.

The remaining of the paper is organised as follows. In section 2 we develop the theoretical framework of our empirical study, i.e., we present a Solow growth model with a CES production function emphasising its conclusions concerning the possibilities of growth in the absence of technological progress and convergence. In section 3 we test the conclusions from the model in the former section. We first test the series for stationarity within a time series framework. We then test for stationarity within a panel data framework. After this previous stationarity tests we can estimate the CES production function using maximum likelihood estimation techniques, GMM techniques, generalised least squares and panel cointegration techniques, for both the CES non-linear specification and Kmenta's linear approximation. In section 4 we conclude.

2 A NEOCLASSICAL GROWTH MODEL WITH CES TECHNOLOGY

Our representative economy produces a single good, Y, than can be used either for consumption, C, or investment, I. Market clearing implies that in every period savings, S, equals investment.

In each period a constant fraction of output is saved,

$$S = sY \tag{1}$$

where s is the exogenous and constant savings ratio.

The law of motion of physical capital K states that this input is accumulated by foregoing consumption, i.e., equals total investment minus the amount necessary to compensate for depreciation[3],

$$\dot{K} = \frac{dK}{dt} = I - \mu K \tag{2}$$

where μ is the exogenous and constant physical capital depreciation rate.

Labour force L grows at a constant and exogenous growth rates, n, so that in each period the labour force is given by:

$$L(t) = L(0)e^{nt} \tag{3}$$

We have not yet described the production technology used by the economy. Consider a well-behaved production function that does not respect the Inada condition that states that the marginal product of physical capital tends to zero as the amount of this input used in production tends to infinity, $\lim_{K\to\infty}\frac{\partial Y}{\partial K}=0$. Under this assumption the representative economy will be characterised by endogenous growth even in the absence of technological progress. It is also possible to maintain the convergence predictions between economies in the sense of convergence of income levels and growth rates at least for certain values of the capital stock.

For comparison purposes we are going to develop the model with both a CES[4] production function and a Cobb-Douglas technology, which is a special case of the former and the standard technology specification in growth models.

The CES technology is described by,

$Y=A\{\delta K^{-\rho}+(1-\delta)L^{-\rho}\}^{-1/\rho}$, with $A>0$, $\delta \in [0,1]$ e $\rho\geq -1$ (4)

Whatever the amounts of K and L used its elasticity of substitution, σ, remains constant and equal to:

$$\sigma=-\frac{\partial(L/K)}{L/K}\frac{(\partial Y/\partial K)/(\partial Y/\partial L)}{\partial[(\partial Y/\partial K)/(\partial Y/\partial L)]}=\frac{1}{1+\rho} \quad (5)$$

Another standard assumption of Solovian growth models is that of constant returns to scale. If we keep this assumption then we can write output in per worker units:

$$y=A\{\delta k^{-\rho}+(1-\delta)\}^{-1/\rho},\ y=\frac{\mathrm{Y}}{\mathrm{L}}\ \text{e}\ k=\frac{\mathrm{K}}{\mathrm{L}} \quad (6)$$

The marginal and average products of physical capital are, respectively, equal to,

$$f'(k)=A\delta\{\delta+(1-\delta)k^{\rho}\}^{-(1+\rho)/\rho} \quad (7)$$

$$\frac{f(k)}{k}=A\{\delta+(1-\delta)^{-\rho}k^{\rho}\}^{-1/\rho} \quad (8)$$

both positive and decreasing in k for every value of ρ.

The growth rate of income is a function of the growth rate of physical capital, which in turn depends on its average product:

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[3] $\dot{x}=dx/dt$ stands for the instantaneous growth rate of x.

[4]Constant elasticity of substitution between inputs.

$$\frac{\dot{k}}{k} = s\frac{f(k)}{k} - (n+\mu) \tag{9}$$

If the average product of capital, although decreasing, converges to a positive value higher than (n+μ), then k and y will grow at a positive growth rate in the long run:

$$\lim_{k\to\infty} f'(k) = \lim_{k\to\infty} f(k)/k = A\delta^{-1/\rho} > 0 \tag{10}$$

If ρ>-1, i.e., when the elasticity of substitution is high (σ>1), the growth rate of physical capital becomes,

$$\frac{\dot{k}}{k} = sA\delta^{-1/\rho} - (n+\mu) \tag{11}$$

We have plotted this growth rate in Figure 1. The growth rate of k is equal to the difference between the average depreciation line (n+μ) and the average investment line (sf(k)/k).

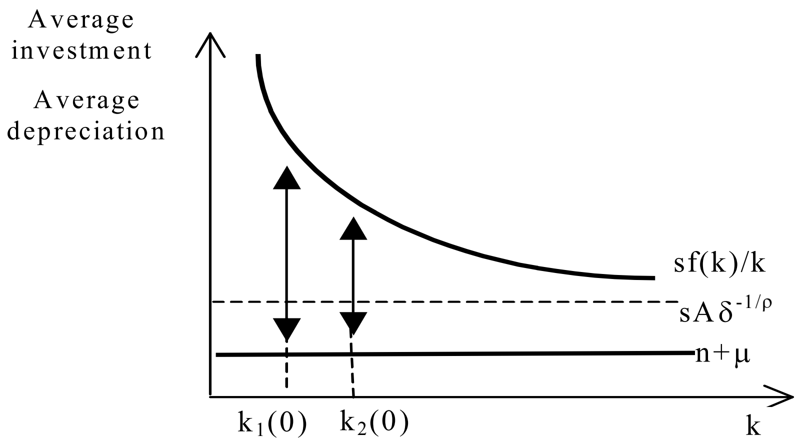

Fig. 1. *Growth rate of k with CES technology*

In the long run, physical capital per worker and thus income per worker will grow at a positive rate even in the absence of technological progress. In the short run, provided that two economies share the same structural characteristics, income levels will approach a common value. It is possible to compute the speed of convergence (β) of income per worker around the steady state:

$$\frac{d\log y}{dt} = -\beta \log\frac{y}{y*} \tag{12}$$

where y* is the steady state income per worker level. We arrive at:

$$\beta = -(n+\mu)\left[1 - \delta\left(\frac{sA}{n+\mu}\right)^{-\rho}\right] \tag{13}$$

The speed of convergence is a function of the savings ratio, s, and the technology parameter, A; contrary to what happens in a Solovian growth model with Cobb-Douglas technology. When the elasticity of substitution is high, i.e., $\rho<0$, β is decreasing in *sA*.

The Cobb-Douglas technology is a particular case of the CES technology corresponding to the situation where ρ tends to zero, which in turn implies that σ tends to 1.

Writing the CES technology in logs and computing its limit as $\rho\to 0$ we arrive at[5]:

$$Y = AK^{\alpha} L^{1-\alpha} \text{ with } \alpha=\delta \tag{14}$$

This is no more than the Cobb-Douglas technology where the input shares and the elasticity of substitution are constant. For the Cobb-Douglas specification the average product of capital approaches zero as k tends to infinity and its growth rate is equal to:

$$\frac{\dot{k}}{k} = sAk^{\alpha-1} - (n+\mu) = s\frac{f(k)}{k} - (n+\mu) \tag{15}$$

We plotted the growth rate of k in figure 2.

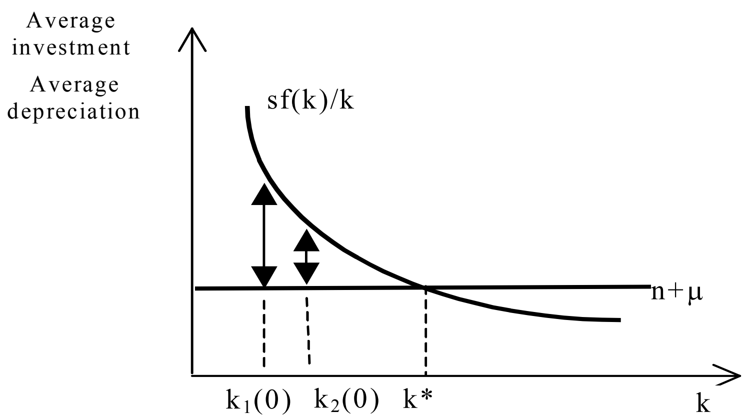

Fig. 2. *Growth rate of k with Cobb-Douglas technology*

[5] $\lim_{\rho\to 0}\log Y = \log A - \frac{1}{\rho}\lim_{\rho\to 0}\log(\delta K^{-\rho} + (1-\delta)L^{-\rho}) = \log A + \frac{0}{0}$. Applying L'Hôpital's rule: $\lim_{\rho\to 0}\log Y = \log A + \lim_{\rho\to 0}\frac{\delta K^{-\rho}\log K + (1-\delta)L^{-\rho}\log L}{\delta K^{-\rho} + ((1-\delta)L)^{-\rho}} = l\og A + \delta\log K + (1-\delta)\log L$.

In the long run physical capital per worker will stop growing in the absence of technological progress. We can also compute the speed of convergence of income per worker around its steady state and confirm that it does not depend on the savings ratio or the technology parameter.

$$\beta = (1-\alpha)(n+\mu) \qquad (16)$$

The parameter δ can be interpreted as a distribution parameter (see Duffy and Papageorgiou (2000, p.100)), which is equal to the capital share α in the case of the Cobb-Douglas technology. With CES technology it is harder to interpret this parameter since the capital share is a function not only of δ, but also of K, L and ρ, according to,

$$s_k = \frac{\delta K^{-\rho}}{\delta K^{-\rho} + (1-\delta)L^{-\rho}} \qquad (17)$$

Since $s_k \in [0,1]$, then $\delta \in [0,1]$. Furthermore, $\partial s_k/\partial\delta > 0$, for given K, L and ρ, the higher is δ, the higher the capital share.

3. EMPIRICAL ANALYSIS

Our sample consists of seventeen European countries: fourteen of the fifteen EU members[6] and also Iceland, Norway, and Switzerland. We have annual data from 1960 to 1987 from the World Bank STARS database used by Duffy and Papageorgiou (2000). The data for GDP and the physical capital stock was converted from national currency units into constant 1987 dollars. Labour force data refers to working age population (aged 14-64). Human capital data was taken from Nehru, Swanson and Dubey (1995), the only one to our knowledge that has annual data for human capital. The human capital measure was corrected for dropouts and grade repeaters. The values for Ireland however were rather high and also decreasing so we used the Barro and Lee (2000) to get the human capital data for Ireland by polynomial interpolation.

[6] We do not consider the Luxembourg due to lack of human capital data.

3.1 STATIONARITY ANALYSIS OF $logY_{IT}$, $logYP_{IT}$, $logK_{IT}$, $logL_{IT}$, $logH_{IT}$, and $logHL_{IT}$[7] - TIME SERIES

We are going to analyse the characteristics of the six time series Y_{it}, YP_{it}, K_{it}, L_{it}, H_{it}, and HL_{it} in logs for each country. The series $logYP_{it}$ was computed using the Hodrick-Prescott filter from the series $logY_{it}$ correcting for end points. Considering potential GDP in growth studies instead of actual GDP allows us to deal with two issues: a) the influence of the cyclical behaviour of each country in the growth performance, and b) the error structure of the model is not a function of the dependent variable. We can in this way deal with the endogeneity problem that affects growth studies.

We want to determine if the series are stationary or integrated of order 1. We consider that a variable is integrated of order 1 if at least one of the ADF test - $n(\hat{\rho}-1)$ or $t_{\hat{\rho}}$ – does not allow us to reject the unit root hypothesis[8]. The number of lags included in the ADF equation was determined according to an LM test to the null hypothesis of no serial correlation. We first estimate the model with trend, and, if the null hypothesis concerning its coefficient is not excluded, we estimate the model with intercept only. We present the results in table 1.

TABLE 1 – Results of the unit root tests of the series logY, logYP, logK, logL, logH and logHL.

Countries	Model	logY	logYP	logK	logL	logH	logHL
ISL	T	0	1			1	1
	C			1	1		
IRL	T		1		1		1
	C	1		1		1	
PRT	T			1	1	1	1
	C	1	1				
GRC	T		1		1		1
	C	1		1		1	
NOR	T	1	1	1		1	1
	C				1		
FIN	T		1		1		1
	C	1		1		1	
DNK	T	1			1	1	
	C		1	1			1
AUT	T				1		1
	C	1	1	1		1	

[7] Y_{it} – Real GDP in country i at time t; YP_{it} – Potential real GDP in country i at time t, K_{it} – physical capital stock in country i at time t t, L_{it} – labour force in country i at date t, H_{it} – Human capital in country i at time t, HL_{it} – human capital adjusted labour force in country i at time t.

[8] We consider a 5% significance level.

Countries	**Model**	log**Y**	log**YP**	log**K**	log**L**	log**H**	log**HL**
BEL	T				1		
	C	1	1	1		1	1
SWE	T	1	1	1	1	1	
	C						1
SWT	T		1		1	1	1
	C	1		1			
NLD	T					1	
	C	1	1	1	1		1
SPA	T		1	1	1		1
	C	1				1	
UK	T	1			1	1	1
	C		1	1			
IT	T		1		1		1
	C	1		1		1	
FRA	T				1	1	1
	C	1	1	1			
DEU	T		1		1	1	1
	C	1		1			

Note – The countries are presented in ascending order of its average incomer per capita, 0 – stationary series and 1 – series integrated of order 1; T – model with trend; C – model with intercept and without trend.

From the results presented in table 1 we should retain that all series are integrated of order 1 since we cannot reject the null hypothesis of a unit root at the 5% level[9]. This kind of analysis is very important since it determines the suitable estimation procedures but we must also test for stationarity in a panel data framework.

3.2 STATIONARITY ANALYSIS OF logY, logY$_{L}$, logY$_{HL}$, logYP, log, logYP$_{HL}$, logK, logK$_{L}$, logK$_{HL}$ logL, logH, logHL, (logK$_{L}$)^{2} and (logK$_{HL}$) - PANEL DATA

We also tested our series for stationarity in a panel data framework focusing on the series used to test for Kmenta's (1967) log linearization of the CES production function[10]. We will used this series later (see 3.5 and 3.6) to test the log linear CES production function specification. We carried out this stationarity analysis using the Hadri (2000) test that considers stationarity as the null hypothesis. We estimated the model with trend (T) and without trend (WT) (see tables 2, 3 and 4).

[9] With the exception of Real GDP for Iceland, which is stationary around a trend.
[10] Also used by Duffy and Papageorgiou (2000)

TABLE 2 – Results from the tests for stationarity of the series logY, $\ln Y_L$, $\log Y_{HL}$, logYP, $\log YP_L$, $\log YP_{HL}$

	logY		$\log Y_L$		$\log Y_{HL}$		logYP		$\log YP_L$		$\log YP_{HL}$	
	WT	T	WT	T	WT	T	WT	T	WT	T	WT	T
Z	23.10	5561	22.1	3560	20.8	1272	23.32	9327	22.5	5617	21.49	3393
SL	0	0	0	0	0	0	0	0	0	0	0	0

Note SL – Significance level; z – Hadri's statistic; WT – model without trend; T – model with trend

TABLE 3 – Results from the tests for stationarity of the series logK, $\log K_L$, $\log K_{HL}$, $(\log k)^2$, $(\log k_L)^2$ and $(\log k_{HL})^2$.

	logK		$\log K_L$		$\log K_{HL}$		$(\log K_L)^2$		$(\log K_{HL})^2$	
	WT	T	WT	T	WT	T	WT	T	WT	T
Z	23.4	7457	22.9	5259	22.45	3595	23	5679	22.5	3831
SL	0	0	0	0	0	0	0	0	0	0

Note SL – Significance level; z – Hadri's statistic; WT – model without trend; T – model with trend

TABLE 4 - Results from the tests for stationarity of the series logL, logH, logHL

	logL		logH		logHL	
	WT	T	WT	T	WT	T
Z	22.32	10122	18.6	5130	21.8	31705
SL	0	0	0	0	0	0

Note SL – Significance level; Z– Hadri's statistic; WT – model without trend; T – model with trend

In face of these results we rejected the null hypothesis of stationarity for all the series analysed. Considering again the time series results from sections 3.1 and 3.2 it is not possible to reject the existence of a unit root for each series in each country with the exception of the series logy for Iceland (3.1). Also we reject the null hypothesis of stationarity in panel for all the series. This means that the traditional estimation procedures should not be used in this case due to the spurious regression problem. Nevertheless, in the next section we use the maximum likelihood (ML) estimation procedure to estimate the CES production function for each country. For every country we test for the presence of unit root in the residuals of each equation through an ADF test.

3.3 ESTIMATES OF THE CES PRODUCTION FUNCTION IN LOGS FOR EACH COUNTRY THROUGH ML

Following Duffy and Papageorgiou (1999), we consider the non-linear CES aggregate production function:

$$Y_{it} = A_0\left[\delta K_{it}^{-\rho} + (1-\delta)L_{it}^{-\rho}\right]^{-\frac{\nu}{\rho}} e^{\lambda t+\varepsilon_{it}} \qquad (18)$$

where A_0 is the initial value (1960) of the scale effects parameter with Hicks-neutral technological progress.

$$A_t = A_0 e^{\lambda t} \tag{19}$$

Considering the aggregate production function in logs,

$$\log Y_{it} = \log A_0 + \lambda t - \frac{\nu}{\rho}\log\left[\delta K_{it}^{-\rho} + (1-\delta)L_{it}^{-\rho}\right] + \varepsilon_{it}$$
$$\varepsilon_{it} = \rho\varepsilon_{i,t-1} + \nu_t \text{ with } \nu_t \sim N(0,\sigma^2_\nu) \tag{20}$$

We estimate equation (20) focusing on the estimates of ρ. If ρ<0, then σ=1/(1+ρ)>1, i.e., we reject the Cobb-Douglas specification which in turn implies that we cannot reject the endogenous growth hypothesis. The estimates were carried out considering potential GDP and either the raw labour force (L) or the human capital adjusted labour force (HL). We also tested for CR imposing v=1through an Wald test. When the hypothesis was not rejected we estimated a RLM with v=1. We imposed in our ML estimated an AR(1) error structure and we corrected the var/cov matrix for heteroscedasticity using the White procedure (see table 5).

TABLE 5 – Results from the estimate of the CES production function for each country through ML

Country			logA	λ	v	ρ	δ	SEE	SL, v=1	ADF
ICL	1	L	2,268	0,005	0,975	-0,023	0,722			
		(t)	(7,040)	5,470	61,330	1,810	65,720	0,007	0,110	-2,90
	2	L	1,514	0,008	1,000	0,102	0,854			
		(t)	(4,800)	1,470		1,020	17,020	0,007		-2,64
	3	HL	1,640	0,002	1,013	-0,020	0,658			
		(t)	(39,430)	7,880	206,520	3,260	518,980	0,006	0,006	-2,90
IRL	4	L	12,226	0,014	0,496	-0,850	0,203			
		(t)	(17,020)	5,300	11,400	2,290	3,380	0,007	0,000	
	5	HL	1,018	-0,018	0,991	-0,390	0,557			
		(t)	(6,090)	40,920	485,190	2,300	7,680	0,037	0,000	
PRT	6	L	1,672	0,009	1,034	0,001	0,603			
		(t)	(175,30)	2,000	1212,00	0,150	121,870	0,092	0,000	
	7	HL	1,086	-0,011	0,990	-0,384	0,471			
		(t)	(217,62)	18,450	110,280	10,380	7,130	0,008	0,288	
	8	HL	0,535	-0,011	1,000	-0,269	0,624			
		(t)	(27,990)	17,380		8,700	35,690	0,008		
GRC	9	L	1,578	-0,007	1,031	-0,087	0,582			
		(t)	(1,510)	3,400	20,420	4,700	37,640	0,007	0,534	
	10	L	1,693	-0,006	1,000	-0,043	0,695			
		(t)	(56,510)	4,710		1,960	43,010	0,007		
	11	HL	1,696	0,008	1,002	0,211	0,789			
		(t)	(136,50)	9,910	842,460	25,540	163,030	0,019	0,139	
	12	HL	1,383	-0,007	1,000	-0,031	0,681			
		(t)	(13,150)	7,640		4,110	41,820	0,005		
NOR	13	L	8,965	0,018	0,632	0,065	0,897			

Country			logA	λ	v	ρ	δ	SEE	SL, v=1	ADF
ICL	1	L	2,268	0,005	0,975	-0,023	0,722			
		(t)	(7,040)	5,470	61,330	1,810	65,720	0,007	0,110	-2,90
	2	L	1,514	0,008	1,000	0,102	0,854			
		(t)	(4,800)	1,470		1,020	17,020	0,007		-2,64
	3	HL	1,640	0,002	1,013	-0,020	0,658			
		(t)	(39,430)	7,880	206,520	3,260	518,980	0,006	0,006	-2,90
		(t)	(2,500)	3,650	3,560	1,330	9,070	0,006	0,038	
	14	HL	10,988	0,016	0,569	-0,517	0,273			
		(t)	(15,160)	12,270	18,130	48,390	25,920	0,006	0,000	
FIN	15	L	3,055	0,012	0,958	0,092	0,784			
		(t)	(6,940)	6,330	63,050	4,870	84,060	0,005	0,006	
	16	HL	1,133	0,009	1,004	-0,203	0,516			
		(t)	(334,59)	2,230	3150,40	18,590	60,190	0,154	0,000	-5,91
DNK	17	L	2,589	0,007	1,006	0,231	0,880			
		(t)	(30,460)	13,100	426,870	39,860	530,820	0,005	0,006	
	18	HL	1,795	0,004	1,026	0,271	0,849			
		(t)	(32,900)	2,970	542,650	10,400	98,330	0,015	0,000	-2,28
AUT	19	L	1,779	-0,008	1,040	-0,064	0,589			
		(t)	(19,220)	28,160	280,230	27,430	188,270	0,006	0,000	
	20	HL	2,023	-0,007	0,972	-0,035	0,706			
		(t)	(18,550)	8,490	174,070	1,770	56,620	0,005	0,000	
BEL	21	L	1,872	-0,066	1,052	-0,002	0,692			
		(t)	(12,570)	0,420	111,760	0,050	13,060	1,191	0,000	
	22	HL	2,223	-0,002	0,965	-0,349	0,417			
		(t)	(8,320)	5,810	73,170	20,130	50,380	0,009	0,007	
SWE	23	L	1,232	-0,005	1,012	-0,174	0,603			
		(t)	(225,78)	3,730	2546,200	101,740	590,750	0,040	0,000	
	24	HL	1,755	-0,003	0,986	-0,027	0,712			
		(t)	(7,170)	3,330	103,730	1,310	49,520	0,005	0,135	
	25	HL	0,241	-0,003	1,000	-0,104	0,533			
		(t)	(14,130)	3,540		5,470	303,760	0,005		
SWT	26	L	2,420	-0,007	1,014	0,068	0,761			
		(t)	(8,100)	3,610	114,490	3,390	60,630	0,006	0,120	-2,83
	27	L	1,667	-0,007	1,000	0,171	0,909			
		(t)	(24,920)	5,420		9,910	155,680	0,006		-4,54
	28	HL	1,607	-0,004	0,950	0,380	0,982			
		(t)	(49,700)	3,090	161,770	39,820	380,900	0,013	0,000	-6,18
NLD	29	L	1,306	-0,035	1,018	-0,149	0,636			
		(t)	(291,99)	6,200	2227,10	30,310	245,290	0,244	0,000	
	30	HL	6,220	-0,002	0,787	-0,865	0,178			
		(t)	(12,700)	2,330	41,870	546,90	25,240	0,003	0,000	-4,66
SPA	31	L	1,602	-0,015	1,037	-0,162	0,507			
		(t)	(7,430)	1,870	139,300	0,950	2,820	0,017	0,000	
	32	HL	0,844	-0,012	0,986	-0,603	0,526			
		(t)	(3,580)	0,490	66,380	5,450	6,660	0,078	0,365	-3,64
	33	ACH	0,677	-0,014	1,000	0,063	0,872			
		(t)	(12,270)	4,160		0,310	9,980	0,016		
UK	34	L	2,456	0,006	1,050	0,170	0,759			
		(t)	(10,840)	6,140	130,880	14,480	135,850	0,005	0,000	
	35	HL	4,765	0,003	0,862	0,239	0,891			
		(t)	(13,040)	2,880	72,430	29,590	246,140	0,005	0,000	-7,49
IT	36	L	1,765	0,004	1,040	0,012	0,450			
		(t)	(297,70)	0,320	1533,60	0,700	417,630	0,046	0,000	
	37	HL	1,256	-0,049	1,013	-0,094	0,660			

Country			logA	λ	v	ρ	δ	SEE	SL, v=1	ADF
ICL	1	L	2,268	0,005	0,975	-0,023	0,722			
		(t)	(7,040)	5,470	61,330	1,810	65,720	0,007	0,110	-2,90
	2	L	1,514	0,008	1,000	0,102	0,854			
		(t)	(4,800)	1,470		1,020	17,020	0,007		-2,64
	3	HL	1,640	0,002	1,013	-0,020	0,658			
		(t)	(39,430)	7,880	206,520	3,260	518,980	0,006	0,006	-2,90
		(t)	(9,480)	2,160	161,870	0,390	22,140	0,348	0,033	
FRA	38	L	2,232	-0,004	0,982	0,053	0,807			
		(t)	(7,680)	3,170	95,000	4,830	138,250	0,004	0,076	-3,45
	39	L	1,689	-0,004	1,000	0,077	0,833			
		(t)	(43,130)	4,130		5,800	123,240	0,004		
	40	HL	1,620	-0,008	0,986	-0,025	0,746			
		(t)	(40,270)	7,850	580,330	1,660	7447,00	0,006	0,000	-2,91
DEU	41	L	1,904	-0,006	0,985	-0,071	0,701			
		(t)	(6,050)	7,050	77,790	6,780	58,040	0,004	0,247	
	42	L	1,489	-0,007	1,000	-0,072	0,705			
		(t)	(18,950)	13,150		4,620	34,710	0,004		
	43	HL	5,780	-0,002	0,839	-0,295	0,416			
		(t)	(4,970)	1,360	18,770	9,710	12,720	0,004	0,000	-4,16

Note: when the unit root hypothesis is not rejected we do not present the results from the ADF test.
L – model with raw labour force, HL – model with human capital adjusted labour force. t-statistic values in brackets.
SL- significance level.

Through the inspection of the results presented in table 5 we conclude that the estimated value of ρ is negative, except for Denmark, Switzerland and the United Kingdom. As for Iceland, according to equation 2 we are not able to reject the null hypothesis. However, considering equations 1 and 3 we can accept for both models that ρ is negative. Portugal has a negative estimate for ρ in the human capital adjusted model only (equations 7 and 8). We get in equation 11 a positive estimate of ρ for Greece but when we impose CRS (equation 12) ρ becomes negative. Norway and Finland present a negative estimate of ρ for the model with human capital, while Austria, Belgium, Sweden and the Netherlands present negative estimates of ρ in both models. Spain also has a negative estimate of ρ in equations 31 and 32 but not in the human capital adjusted model with CRS. Italy and France present a negative ρ in the human capital adjusted model, and finally Germany presents a negative ρ in both models.

We recall that we could not reject the null hypothesis of the presence of a unit root in the series used. According to the ADF test the only residuals that can be considered stationary are those in equations 1, 2, 3, 16, 18, 26, 27, 28, 30, 32, 35, 38, 40 et 43. This means that the conventional estimation procedures do not eliminate the spurious regression problem. Nevertheless we can conclude that the estimated value of ρ is negative for most countries.

3.4 ESTIMATION OF THE CES PRODUCTION FUNCTION USING GMM

Unobserved country effects may cause the fact that our estimates differ. Following again Duffy and Papageorgiou (2000) we are going to estimate equation (21) that considers these effects using GMM (see also Hansen and Singleton (1982)) and sets v equal to 1.

$$\log \frac{Y_{it}}{Y_{i,t-1}} = \lambda - \frac{1}{\rho} \log \left[\frac{\delta K_{it}^{-\rho} + (1-\delta) L_{it}^{-\rho}}{\delta K_{i,t-1}^{-\rho} + (1-\delta) L_{i,t-1}^{-\rho}} \right] + \varepsilon_{it} - \varepsilon_{i,t-1} \qquad (21)$$

We carried out the same estimation procedure considering 3-period lags for the IV. The results of the Wald test allowed us to reject the null hypothesis of over-identified instrumental variables. The var-covar matrix was corrected for heteroscedasticity. In table 6 we present the estimation results for the sample of 17 countries and also for the group of the 4 poorest countries.

TABLE 6 – Results of the GMM panel estimation for the CES production function

		λ	ρ	δ	SEE
G17	L	-9,044	-0,040	0,899	
	(t)	(40,70)	(41,54)	(18,07)	0,023
G17	HL	-9,302	-0,039	0,964	
	(t)	(7,65)	(7,85)	(2,19)	0,023
G4	L	-8,350	-0,044	0,899	
	(t)	(17,96)	(19,08)	(10,70)	0,008
G4	HL	-8,581	-0,043	0,968	
	(t)	(58,87)	(60,28)	(16,34)	0,008

Note: G17 –sample of 17 countries, G4 – sample consisting of the 4 poorest countries (Iceland, Ireland, Portugal and Greece) , SEE – standard error of the estimation. t-statistic between brackets.

The estimate of ρ is negative in both samples. δ is significant in both cases and its estimated value is theoretically acceptable although a bit too high. Our results are opposite to those of Duffy and Papageorgiou (2000, p.99) - λ is too low while δ is too high.

Finally we would like to point out that the restriction v=1 should have been tested but estimating the model without imposing the coefficient restriction would lead to computational difficulties hard to overcome.

3.5 Estimation of Kmenta's log linearisation of the CES production function by GLS with panel data

We also estimated Kmenta's (1967) log linearisation of the CES production which allows us to indirectly determine ρ and δ .

We now estimate equation[11]:

$$\log y_{it} = \alpha + \lambda t + \beta_1 \log k_{it} + \beta 2\left[\log k_{it}\right]^2 + \varepsilon_{it} \qquad (22)$$

Using the results of our estimations it is then possible to compute the values of the CES production function parameters through,

$$\rho = -2\frac{\beta_2}{\beta_1(1-\beta_1)}$$
$$\delta = \beta_1 \qquad (25)$$
$$A_0 = e^{\alpha}$$

We can estimate equation (22) using two different methodologies: a) dynamic panel data techniques, or b) cointegration in panel data. Unfortunately using the Arellano and Bond (1991), Arellano and Bover (1995) and Doornik, Hendry, Arellano and Bond (2001) estimation procedures for dynamic panel data we obtained an estimated δ higher than one. This is the reason why we only present the results from the static panel data analysis using GLS[12].

TABLE 7 – Results from the estimation of Kmenta's log-linearisation of the CES production function through GLS

G17/G4	β_1	β_2	α	ρ	χ^2	SEE
G17 L	0,746	-0,0055	2,269	Comp.		
(t)	(8,21)	(0,801)	(4,83)	0,037	4394	0,047
G17 HL	0,499	0,0072	2,965			
(t)	(5,43)	(1,31)	(7,71)	-0,06	5281	0,042
G4 L	0,187	0,0276	4,652			
(t)	(1,65)	(4,67)	(8,62)	-0,362	2724	0,031
G4 HL	0,259	0,0231	3,834			
(t)	(2,39)	(3,28)	(9,37)	-0,241	3912	0,024

Note: G17 –sample of 17 countries, G4 – sample consisting of the 4 poorest countries (Iceland, Ireland, Portugal and Greece), SEE – standard error of the estimation. t-statistic between brackets. χ^2 –chi-square statistic values; Comp.- ρ was computed and not estimated.

[11] Variables measured in per worker units.

[12] Two stage estimate beginning with OLS.

We tested the suitability of the fixed effects specification (χ^2_{17} et χ^2_4). The results do not reject the presence of these effects. The trend coefficient is always significant. We also tested for the following error structure in all the equations: $\varepsilon_{it} = \varphi \cdot \varepsilon_{it-1} + \upsilon_{it}$. This seems a suitable specification to test for the stationarity of the error term.

TABLEAU 8 – Results from the estimation of the residuals for equations G17L, G17HL, G4L and G4HL

Residuals from equation:	HT	t_ρ	ρ_stat
G17 L	-0,042	661,1	0,06
(SL)	(0,48)	(0.0)	(0,48)
G17 HL	-0,042	680,4	0,06
(SL)	(0,48)	(0.0)	(0,48)
G4 L	0,022	639,7	0,03
(SL)	(0,49)	(0,0)	(0,49)
G4 HL	0,02	735,5	0,03
(SL)	(0,49)	(0,0)	(0,49)

Note – HT-Harris&Tzavalis-statistic values, SL – significance level, t_ρ and ρ_stat - Levis&Lin-statistic values.

The values of the HT-statistic allow us to accept the existence of a unit root. The Levis&Lin (1992) – statistic on the other hand contradicts this result. The first test leads us to reject the unit root hypothesis while the second test points to the presence of a unit root. This means that we cannot dismiss the spurious regression problem in all four equations. Nevertheless this is a quite important result since most empirical growth studies do not carry out a stationarity analysis of the series used within a panel data framework[13] thus its conclusions may not apply due to the spurious regression problem.

The results presented in table 7 state that for equation G17L it is not possible to reject the null hypothesis for the estimate of β_2, while in equation G17HL we can only accept this hypothesis for a 19% confidence level. This is not a very encouraging result. We still get a negative estimate of ρ in equation G17HL and for both equations in G4.

3.6 Estimation of Kmenta's log linearisation of the CES production function by panel cointegration methods

[13] In most growth studies the stationarity analysis is not even carried out within a time series framework.

We now estimate Kmenta's (1967) log linearisation of the CES production using cointegration techniques for panel data. The model estimated does not include an intercept,

$$\log y_{it} = \lambda t + \beta_1 \log k_{it} + \beta 2\left[\log k_{it}\right]^2 + \varepsilon_{it} \qquad (22.a)$$

First, we used Kao (99) tests and three Pedroni (99) test that test for the null hypothesis of no cointegration. In the former we used a one-period lag. The V-statistic is computed through the within estimation procedure and the ρ _stat is computed through the between estimation procedure.

TABLE 9 - COINTEGRATION TESTS BASED ON KAO'S AND PEDRONI'S METHODS APPLIED TO EQ. (22)

	G17L	G17HL	G4L	G4Hl
Kao99 DF ρ test	-0,49 (0,31)	-0,48 (0,31)	-1,82 (0,03)	-0,70 (0,24)
Kao99 DF t_ρ test	-0,93 (0,18)	-0,71 (0,24)	-1,10 (0,13)	-0,12 (0,45)
Kao99ADF(lag=1)	-1,86 (0,03)	-1,85 (0,03)	-1,76 (0,04)	-2,02 (0,02)
Pedroni99 t_stat	-477 (0,000)	-477 (0,000)	-100,84 (0,00)	-107,54 (0,00)
Pedroni99 V_stat	-3,49 (0,000)	-3,54 (0,000)	-1,47 (0,07)	-1,68 (0,05)
Pedroni99 ρ _stat	6,12 (0,000)	6,12 (0,000)	2,76 (0,00)	3,02 (0,00)

Note – The significance level of each statistic is presented in brackets.

In almost all cases the first two Kao's tests do not allow us to reject the null hypothesis of no cointegration, while all other tests do allow us to reject this hypothesis. Based on these results we proceed to the estimation of the cointegration relations for the four models.

We used the Kao and Chiang (2000) estimation procedure imposing an heterogeneous matrix of var-covar for the sample of 17 countries and an homogeneous matrix of var-covar for the sample of four countries[14]. We used a one-period lag and a one-period lead.

TABLE - 10 Results from the estimation of Kmenta's log-linearisation of the CES production function using panel cointegration techniques

	λ	$\beta_1(=\delta)$	β_2	ρ	$\overline{R}^2$
G17L	0,0806	0,0580	0,0372		
(t)	(65193)	(7,97)	(5,73)	-1,36	0,57
G17HL	0,0144	0,0338	0,0361		
(t)	(18387)	(1,42)	(3,34)	-2,2	0,57

[14] The coefficients and the adjusted R squared thus are not comparable.

G4 HL		0,2590	0,0533		
(t)		2,43	3,34	-0,55	0,98

For the sample of the 4 poorest countries it was never possible to reject the null hypothesis of no trend. In the models with L δ is negative.

With the exception of G4HL, the estimated values of $\beta_1(\delta)$ are very low and ρ is negative. Nevertheless the estimated ρ with human capital is quite lower than in the model without human capital.

CONCLUSION

The main goal of this paper was to distinguish between the potential sources of growth and convergence for the Portuguese economy within Europe. We followed the methodology of Duffy and Papageorgiu (2000) developing a little further their econometric analysis. It is important to determine whether the most suitable specification of the aggregate production function is a CES technology or a Cobb-Douglas technology since this distinction has important implications for growth. For instance, if the elasticity of substitution between inputs is greater than one ($\sigma>1$) then the economy is characterised by endogenous growth (see Jones and Manuelli (1990), Rebelo (1991)). If ($\sigma<1$) on the other hand, Azariadis (1993, 1996, 2001) shows that the economy can converge to different steady-states depending on its initial conditions.

From our econometric analysis we concluded that $\rho<0$, i.e., the CES technology is the one that best describes the technology used in each of the seventeen countries in our sample. This result supports that of Duffy and Papageorgiou (2000) and implies the development of growth models without balanced growth.

As far as convergence is concerned the implications of our analysis are derived from the results in tables 6 and 7 (estimated values of ρ, δ and β_1) through the analysis of the sample of 17 countries and the sample of the 4 poorest countries.

According to the results in table 6 we get a higher value of ρ for the G4 sample whatever the model consider. This result means that there will not be convergence between the economies in our sample since the higher ρ is (in absolute value) the lower the difference between the terms $sA\delta^{-1/\rho}$ and $n+\mu$ for the G4 in comparison with the same difference for the G17. The growth rate of the G4 will thus be lower than the growth rate of the G17 in the transition period. This conclusion is further reinforced by the fact that in the model with labour force the estimated value of δ is the same for both samples[15] - everything else equal, economies with a higher value of δ, will have a higher income per capita growth rate. In the model with human capital adjusted labour force, the estimated value of δ is higher for the G4 but only 0.004 higher than for the G17, which is a very small difference. If we focus on the results for the first model then we conclude that there will be no convergence between the G4 and the G17. If we focus on the results for the human capital adjusted model although there is convergence it proceeds at a very low speed. Both results are not encouraging for the G4 economies.

According to table 7, the estimated values of ρ and δ in the human capital adjusted model point to the rejection of the convergence hypothesis between the G4 and the G17- the estimated value of ρ is higher for the G4 while the estimated value of δ is lower for this sample. Again convergence proceeds at a very slow pace.

The main contributions of our empirical analysis are the following. First, by considering the potential value of GDP and not its effective value we are able to overcome the endogeneity problem. Second, the conclusions of the conventional empirical growth studies are not valid in the presence of non-stationary series. This is why we tested all the series for stationarity both in a time series and in a panel data framework. In all the estimations carried out (ML, GMM, static panel) we devoted a considerable amount of time to the stationarity analysis of the series used and of the residuals of the estimated equations. We also tested for cointegration relationships. Despite this careful analysis some of the estimated coefficients present values that are not easily justified. This is a possibility for future research since it calls for the analysis of non-linear cointegration relations within a panel data framework.

[15] Although the estimated value of δ is a little too high, nevertheless it is significant and supported by the theoretical model.

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