Agricultural Productivity Growth in the Mediterranean and Tests of Convergence Among Countries*

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Abstract. *This paper measures agricultural productivity among a set of thirteen Mediterranean countries which includes two EU-15 countries (Greece and Spain), another two EU-25 (Cyprus and Malta) one country under accession negotiations (Turkey) and eight Middle East and North Africa (MENA) countries (Algeria, Egypt, Israel, Jordan, Libya, Morocco, Syria and Tunisia) from 1961 to 2002. The objective of the paper is twofold: Firstly, to analyse agricultural productivity growth in the Mediterranean countries by means of the sequential Malmquist Total Factor Productivity (TFP) index and secondly, to investigate whether this measure is converging among these countries. In terms of the first objective, TFP indices are decomposed into efficiency changes and technical changes, in an attempt to identify the best-practise countries and the overall effect of technological improvements. In terms of the second, both cross-section and time series tests of convergence are applied. The former include the conventional β- and σ-convergence tests, while for the latter, a new method proposed by Nahar and Inder (2002) that allows for country-specific estimates is used. Neither test finds evidence for unconditional convergence, but two distinctive periods, one prior and one after 1980 are recognized. The time series approach identifies four countries to be converging to the mean and another two to be diverging.*

Keywords: Productivity growth, sequential Malmquist TFP, convergence.

1. Introduction

This paper focuses on the study of agricultural productivity in a set of thirteen countries situated around the Mediterranean basin. It includes two EU-15 Member States (Greece and Spain), two EU-25 (Cyprus and Malta), one under accession negotiations (Turkey) and eight Middle East and North Africa (MEDA) countries in Asia and North Africa (Algeria, Egypt, Israel, Jordan, Libya, Morocco, Syria and Tunisia).

Within these countries, natural conditions and resources may vary significantly (i.e. land size, percentage of arable land, salinity and solidity, water and irrigation, agricultural population, input usage etc.)[1], thereby forming a rather heterogeneous group of countries with different backgrounds and development levels. Still, they all share one common characteristic, namely that their agricultural sectors are a vital component of their national economies, expressed in terms of share of Gross Domestic Product (GDP), exports and employment. Traditionally exporters of agricultural products, Mediterranean countries are now faced with new challenges within a global trading system that favours the abolishment of trade barriers and the liberalization of markets worldwide. Even the non-EU countries have bilateral and/or multilateral preferential trade agreements with the EU (i.e. Euro-Mediterranean Partnership)[2], whilst their agricultural sectors are undergoing serious structural changes (following the overall liberalising of their economies), as a means of meeting both EU qualifications, as well as WTO agreement provisions.

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[1] A more elaborate discussion on the situation of agricultural sectors in the Mediterranean countries can be found in Galanopoulos *et al.* (2006).
[2] Libya is the only country that has not signed the association agreement yet and has an observer status since 1999 (Lindberg and Surry, 2006)

Agriculture in the Mediterranean has exhibited considerable growth over the last four decades, especially during the Green Revolution era (late 1960s to early 1980s). In this sense, it is interesting to examine the sources of this agricultural productivity growth in each country and compare the growth patterns across the Mediterranean, given that differences in agricultural productivity levels and growth rates may help identify underlying factors that affect - positively or negatively – productivity growth (Wiebe *et al.,* 2000).

The issue of productivity growth has drawn considerable attention over the last few decades, as it is considered the major source of development for the agricultural sector, at a rate able to meet the demands for food and raw materials arising out of steady population growth. A country that falls short of achieving agricultural productivity growth may suffer a deterioration, either of the foreign exchange balance, or of the internal terms of trade against industry, thereby also hindering industrial production (Hayami and Ruttan, 1970; Coelli and Rao, 2003). In contrast, a country that best utilises its given resources within its agricultural sector may enjoy a significant comparative advantage in exporting markets.

Several studies have focused on this matter, using either Partial Factor Productivity (PFP) measures, most commonly labour productivity (e.g. Gutierrez, 2000; McErlean and Wu, 2003) or Total Factor Productivity (TFP) measures. The latter are typically analysed using either i) a production function approach (e.g. Hayami and Ruttan, 1970; Wiebe *et al.,* 2000), ii) an index number approach, usually Tornqvist index (e.g. Mukherjee and Kuroda 2003), or iii) a Data Envelopment Analysis (DEA) approach, the DEA-based Malmquist index (e.g. Coelli and Rao, 2003; Ludena *et al.,* 2005).

A common second step for studies measuring productivity growth is to test the convergence hypothesis, i.e. whether productivity levels have been converging across the sampled countries. Neoclassical growth theory suggests that the existence of decreasing returns and exogenous technological change generates in the long run a common convergence path even for economies with unequal initial states (Freeman and Yerger, 2001). On the other hand, the endogenous growth theory accepts structural differences across countries by treating technological change as endogenous, thereby allowing for permanent differences in productivity growth levels (Ludena *et al.,* 2005). This contradiction has triggered increased attention, making the testing of the convergence hypothesis a major issue in economic research over the last decades (Islam, 2003).

Within this conceptual framework, the objective of this paper is twofold: Firstly, to analyse agricultural productivity growth in the Mediterranean countries by means of Malmquist Total Factor Productivity (TFP) indices and secondly, to investigate whether TFP productivity is converging across the Mediterranean. Previous literature on TFP growth and convergence testing has been applied to a wide range of countries (i.e. OECD, Asia, Africa, EU, or a combination of countries). To the best of our knowledge, this is the first attempt to measure productivity growth and convergence solely across the Mediterranean basin.

The remainder of the paper is organised as follows: The following section briefly discusses some key methodological aspects and reviews basic approaches and models applied in the relevant literature. Next, the empirical framework of this study is defined, followed by a description of the variables and the data used for the construction of the model. Results are presented and discussed in the subsequent section, while some concluding comments are made in the final section.

2. Methodological aspects and literature review

DEA models are linear programming (LP) methods that calculate the frontier production function of the decision-making units (firms or countries) included in the sample. Those that operate on the frontier are technically efficient, whereas the degree of technical inefficiency of the rest is calculated on the basis of the Euclidian distance of their input/output ratio from the frontier (Coelli *et al.,* 1998). Applying DEA methodology, Färe *et al.,* (1992) extended the work of Caves *et al.,* (1982) and developed Malmquist productivity measures, which can be used in order to measure the productivity changes over time. Since then, the Malmquist TFP index has been applied in various studies, both in the industrial as well as the agricultural sector. For instance, Grifell and Sintas (1995) measured TFP change in the European textile industry, Färe *et al* (2001) calculated productivity growth in Taiwan's manufacturing industry, and Chen and Ali (2004) analyse the productivity in the computer industry. In the agricultural sector, Malmquist TFP indices have been used by Fulginity and Perrin (1997 and 1998), Suhariyanto and Thirtle (2001), Coelli and Rao (2003) and Ludena *et al.* (2005).

The popularity of Malmquist TFP indices is notably due to certain attractive features: Because it uses distance functions to measure the distance from a given input/vector to the technically efficient frontier, it does not impose any restrictive a priori assumptions on the production technology (unlike the production function approach). Moreover, it avoids the need for explicit information on input and output prices (as the Tornqvist index) by using implicit price information, as derived from the shape of the frontier. Furthermore, Malmquist TFP may not only be used in order to measure the productivity changes over time, but it can be also be further decomposed into two meaningful components, one measuring the technical change (TNCh) and the other the technical efficiency change (TECh). On the other hand, this approach is susceptible to data noise effects and to degrees of freedom problems when the sample is relatively small.

One issue arising when applying the Malmquist index is the choice of the reference subset: The original Malmquist TFP approach (Färe *et al.,* 1992) was based on the *contemporaneous* frontier approach, in which the frontier in each year is constructed based on the observations solely of the current year. Alternatively, one may choose to use the full dataset to construct a single *intertemporal* production set, or to accumulate all data until the present year, thereby constructing a *sequential* frontier (Tulkens and Vanden Eeckaut, 1995).

In most cases, the majority of Malmquist TFP applications in the relevant literature employ the contemporaneous frontier approach (see Coelli and Rao, 2003; Fulginiti and Perrin, 1998). Nevertheless, this approach may be inappropriate when the number of observations in the cross section is small relative to the total number of inputs and outputs, as is the case in this study. In such cases, the sequential frontier approach seems more appropriate, being more stable, but considerably more computationally demanding (see Suhariyanto and Thirtle, 2001; Thirtle *et al.,* 2003).

Given that TFP is the closest measure of technology, studies measuring productivity growth, often investigate also whether countries come closer in terms of TFP levels, i.e. whether countries with relatively low initial levels of productivity (defined as TFP) grow relatively faster than high productivity ones (Islam, 2003). In other words, the convergence hypothesis assumes that growth rates are likely to be inversely related to the initial level of productivity[3]. If this were the case, then there is a tendency for TFP growth rates to ultimately converge to the same level across all countries, as the less developed ones grow faster and 'catch up' with the developed economies (Lusigi *et al.,* 1998). This is the notion that rests behind the cross-section methods of testing convergence, pioneered by Barro and Sala-i-Martin (1992) which are used to test for β- convergence as well as for σ- convergence. The former holds if the coefficient of a regression of TFP growth rates on initial TFP levels is negative whilst the latter if the dispersion of the log of TFP, measured by its standard deviation decreases over time (Gutierrez, 2000).

These tests have been criticized by Evans and Karras (1996) on the grounds that the approach can only be valid if all economies have the same first-order autoregressive dynamic structures and all cross-country differences are controlled for. Moreover, with such models it may not be possible to distinguish between short-run dynamics and long-run steady state behaviour (Nahar and Inder, 2002). Especially regarding β-convergence tests, they can be sensitive to the choice of the initial period and β- convergence may be found even when some but not all the economies within the sample are converging (McErlean & Wu, 2003). Although β- convergence is a necessary, though not sufficient condition of σ- convergence, it does not necessarily imply that the cross-sectional dispersion in the growth rates does decrease. Still, β-convergence can be perfectly consistent with the absence of σ- convergence (Islam, 2003; Gutierrez, 2000).

[3] The convergence theory of neo-classical models was initially introduced as a concept of per capita income convergence, rather than productivity growth convergence. In the context of this paper, different concepts of convergence are affiliated for simplicity reasons.

Alternative approaches for testing convergence were introduced by Bernard and Durlauf (1995) and Evans and Karras (1996) that exploit the time variation of productivity levels[4]. Such time series tests (termed stochastic convergence) accept convergence if the long run forecasts of productivity differences tend towards zero and their concept is related to the unit root hypothesis; tests of stochastic convergence involve a regression of the augmented Dickey-Fuller test equation and cointegration tests.

One limitation of time series tests is that they are more appropriate when sampled economies are near their steady state equilibrium; if economies are in transition, moving towards a steady state, cross-section tests are preferable (Freeman and Yerger, 2001). On a different basis though, Nahar and Inder (2002) argue that the inappropriateness of time series tests may not be due to the underlying characteristics of the dataset but rather to an inconsistency of the tests conducted. They point out that the conventional time series tests that employ univariate and multivariate techniques are inappropriate with the definition of convergence: While the convergence hypothesis implies that the null hypothesis of a unit root in productivity differences should be rejected, i.e. productivity differences are stationary, there are non-stationary processes that meet the definition of convergence. In other words, stationarity of the productivity differences are not a necessary condition for the existence of convergence, since there are non-stationary series that may well meet the definition.

Instead, they proposed a new test (described in the subsequent section) that overcomes this problem and allows for non-stationary processes to converge. Moreover, another attractive characteristic of this method is that it focuses on each economy separately and tests its performance against the group's mean, thus allowing for country specific estimates of convergence and not just overall group convergence.

3. Empirical framework

This section describes the methodologies applied in the paper. Initially, the sequential Malmquist TFP approach is explained and compared to the contemporaneous one, followed by a brief presentation of the cross-section and time series tests that are used in order to test for convergence in agricultural productivity across the Mediterranean.

3.1 TFP growth

The Malmquist TFP index can be constructed with respect to the contemporaneous or the sequential frontier. Assuming there are *N* countries in the sample which use *K* inputs to produce *M* outputs, then the input matrix **X** ($K \times N$) represents all input data and the output matrix **Y** ($M \times$ N) all output of the *N* countries, while x_i and y_i represent the input and output vectors respectively, for country *i*.
In the manner of Färe *et al* (1992) a DEA-based, output-oriented Malmquist productivity change index (in time *t+1* and *t*) can be defined as follows:

$$M\left(y_{t+1}, x_{t+1}, y_t, x_t\right) = \left[\frac{D^t\left(x_{t+1}, y_{t+1}\right)}{D^t\left(x_t, y_t\right)} \; \frac{D^{t+1}\left(x_{t+1}, y_{t+1}\right)}{D^{t+1}\left(x_t, y_t\right)}\right]^{1/2} \tag{1}$$

where x_t is an input vector and y_t is an output vector for country *i* used in period *t*. In other words, this index measures the productivity of a country at the production (x_{t+1}, y_{t+1}) relative to (x_t, y_t) and it is the geometric mean of two (consecutive) Malmquist TFP indices, one using technology of period *t* and the other using technology of period *t+1*. Productivity may decline if the obtained value is less than one, remain unchanged if equal to one and improve if greater than one. The above equation can be further decomposed into two components, where the first measures the change in technical efficiency change (TECh) and the second measures the technical change (TNCh), i.e. the technology frontier shift between the two time periods:

[4] Bernard and Durlauf (1995) and Evans and Karras (1996) actually refer to per capita output convergence – see footnote 3.

$$M\left(y_{t+1},x_{t+1},y_t,x_t\right)=\underbrace{\left[\frac{D^{t+1}\left(x_{t+1},y_{t+1}\right)}{D^{t}\left(x_t,y_t\right)}\right]}_{TECh}\times\underbrace{\left[\frac{D^{t}\left(x_{t+1},y_{t+1}\right)}{D^{t+1}\left(x_{t+1},y_{t+1}\right)}\frac{D^{t}\left(x_t,y_t\right)}{D^{t+1}\left(x_t,y_t\right)}\right]^{1/2}}_{TNCh} \tag{2}$$

Unlike the contemporaneous Malmquist TFP[5] where the frontier in each period is constructed by enveloping the observations from the current period only, the sequential TFP, in the manner of Tulkens and Vanden Eeckaut (1995), accumulates and envelops all data until the present period. In this sense, under the contemporaneous DEA, Equation (2) is computed after solving through LP four distance functions. For instance, the LP for $D^t\ (x_t,y_t)$, assuming constant returns to scale (CRS) is:

$$\begin{aligned}&[D^t\ (x_t,y_t)]^{-1} = \max_{\varphi,\lambda}\ \varphi, && (3)\\ &\text{s.t. } -\varphi y_t + Y_t\lambda \geq 0,\\ &x_t - X_t\lambda \geq 0,\\ &\lambda \geq 0\end{aligned}$$

where λ is a vector the size of the number of units, φ is a parameter vector (N x 1) obtained by Equation (3) and $\mathbf{1/\varphi}$ represents technical efficiency (TE) ranging from zero to one. Alternatively, under the sequential DEA, the LP problem in (3) becomes:

$$\begin{aligned}&[D^t\ (x_t,y_t)]^{-1} = \max_{\varphi,\lambda}\ \varphi, && (4)\\ &\text{s.t. } -\varphi y_t + (Y_{t0}, Y_{t0+1}, \ldots, Y_t)\ \lambda \geq 0,\\ &x_t - (X_{t0}, X_{t0+1}, \ldots, X_t)\ \lambda \geq 0,\\ &\lambda \geq 0\end{aligned}$$

In other words, the fundamental difference among the two methods is the way the frontier is constructed and how technology is considered. The contemporaneous Malmquist index in any time *t* does not depend on data of the previous period and therefore the frontier may move towards, or away from the origin between two consecutive time periods, indicating technological regress or progress respectively. In contrast, the sequential Malmquist index, by enveloping all past observations, assumes that any technology available in the preceding periods is also available in the present, i.e. technical knowledge accumulates over time. Therefore, technological regress is not possible under the sequential frontier (Shestalova, 2003). Dealing with agricultural productivity in particular, there is no apparent reason to assume that the technology used in a previous period in agriculture will become infeasible in the next years. Technological regression in the agricultural sector is possible but not very likely. In addition, it is more reasonable to interpret any adverse effects of weather for instance, as deterioration in technical efficiency rather than technology regress, which is the case under the sequential Malmquist (Thirtle *et al.,* 2003).

However, there is another practical reason why the sequential approach is preferred, relating to the degrees of freedom associated with DEA models: If the number of observations in the cross-section sample are small relative to the number of variables (inputs and outputs) used, then efficiency scores may be overestimated. A large number of countries will be (wronly) identified as technically efficient, technical efficiency change will be minimal, or even zero and productivity growth will be related only to technological change (Suhariyanto and Thirtle, 2001). In this paper, we use thirteen countries and six variables; hence the sequential approach seems more appropriate. Moreover, this approach generates a more stable frontier and are less sensitive to the presence or not of a particular observation in the sample, making the results generally more trustworthy (Shestalova, 2003).

[5] By the term contemporaneous (sequential) Malmquist index we refer to a distance function constructed with respect to the contemporaneous (sequential) frontier; hence it is actually contemporaneous (sequential) DEA. Still, this term is used most often in the literature.

3.2 Tests of convergence

As explained earlier, there are a number of alternative methods for testing the convergence hypothesis, broadly defined as cross-section and time series tests. This paper employs the time series approach proposed by Nahar and Inder (2002). The main underlying reason is that it allows for specific results to be generated for each particular country, thus highlighting different growth patterns and trends among the sampled countries, without making use of standard unit roots tests. However, in order to facilitate a comparison among alternative tests, results from cross-series tests are also shown. Because the former approach allows testing only for unconditional convergence, the same hypothesis is maintained also when testing for β- convergence and σ- convergence.

The conventional cross-section approach of regressing TFP growth rates on initial levels of TFP is used to test for unconditional β- convergence. In this respect, the following equation is used:

$$(y_{iT} - y_{i0}) = a - by_{i0} + u_{i0,T} \tag{5}$$

where y_{iT} and y_{i0} are the log of TFP for country i in years 0 and T respectively and $u_{i0,T}$ is an error term with mean zero. The estimated (implied) β-convergence coefficient may then be calculated using Equation (6). Significant estimates of β are obtained if the b-coefficient in (5) is itself significant. The convergence hypothesis is accepted if $\beta > 0$ (or $b < 0$); otherwise ($\beta < 0$ or $b > 0$) divergence is accepted. If the β- coefficient is insignificant, convergence (and divergence) is rejected (Gutierrez 2000; McErlean and Wu, 2003).

$$\beta = -\log(1+b)/T \tag{6}$$

Alternatively, the convergence test developed by Nahar and Inder (2002) is based on a regression of the squared demeaned TFP level on a time trend t, such as:

$$w_{it} = \theta + \theta_1 t + \theta_2 t^2 + \ldots + \theta_{k-1} t^{k-1} + \theta_k t^k + u_{it} \tag{7}$$

where, $w_{it} = (y_{it} - \overline{y}_t)^2$ with y_{it} being the log of TFP for country i in period t, $\overline{y}_t$ being the average TFP of the countries in the sample in period t (considered as the steady state information for all countries in t) and θ_i's parameters. Then, the convergence hypothesis can be tested by considering the average slope of Equation (7) which has to be negative and significant for convergence to hold, i.e.:

$$\frac{1}{T}\sum_{t=1}^{T}\frac{\partial}{\partial t}w_{it} = \theta_1 + \theta_2 r_2 + \ldots + \theta_k r_k < 0 \quad \text{where } r_k = \frac{k}{T}\sum_{t=1}^{T} t^{k-1} \tag{8}$$

Equation (7) can be estimated by ordinary least squares and the restriction on the parameters' vector by performing a t-test, where the null hypothesis is that it is greater than, or equal to zero, against the alternative that it is negative. Rejection of the null hypothesis is interpreted in favour of convergence.

Nahar and Inder (2002) also proposed a second procedure, by which the convergence hypothesis is tested in a similar manner to Equation (7), only not against the group mean, but rather against the group leader. In that manner, $d_{it} = y_{it} - y_{Ut}$ can be defined as the productivity gap of each other country in the sample from the leading one (with y_{Ut} being the productivity of the leading country – USA in their dataset) and suggest investigating whether this gap diminishes over time; if it does, then it would indicate convergence towards the group leader. They demonstrated the appropriateness of their methodology by testing for convergence in productivity growth among a set of 22 OECD countries. Nevertheless, this alternative procedure is only valid if the group leader's productivity is in each period higher than that of the rest of the countries, thus resulting always in negative values of d_{it}, i.e. for convergence to hold, the average slope of the estimated equation needs to be positive. In the dataset used in this paper however, no such country exists and the application of this latter method is meaningless.

4. Data description

The empirical analysis of this study has been conducted by constructing a model comprised of one output and five inputs, involving a set of thirteen Mediterranean countries (Morocco, Algeria, Tunisia, Libya, Egypt, Israel, Jordan, Syria, Turkey, Cyprus, Malta, Greece and Spain). The period under investigation was 1961-2002, while all required data were taken from the Food and Agriculture Organisation (FAO) database. More specifically, the variables are defined as follows:

Value of agricultural produce (y): Agricultural produce volume in 1989-91 international dollars ('000).
Land (x_1): Arable land, permanent crops and permanent pastures, in hectares ('000)
Labour (x_2): Economically active population employed in agriculture ('000).
Fertilisers (x_3): The sum of nitrogenous, phosphate and potash fertilisers ('000 MT)
Machinery (x_4): Number of agricultural tractors in use.
Livestock capital (x_5): Number of animals in cows equivalent, as expressed by Hayami & Ruttan (1970).

Table 1 presents brief descriptive statistics of the variables used in the model. Unambiguously, these FAO data have certain shortcomings, acknowledged by other researchers that have also used them (see for instance Wiebe *et al.,* 2000; Suhariyanto and Thirtle, 2001) but they are still the most comprehensive data source available for such studies and this is the reason why most of similar studies make use of these data (Coelli and Rao, 2003).

[Table 1]

5. Results

The evolution of agricultural TFP growth in the Mediterranean is discussed in subsection 5.1. Results of the convergence tests are presented in subsection 5.2. It should be stressed that although the dataset begins in 1961, the starting period for efficiency calculations is 1966. Data from 1961 to 1966 were pooled so as to reach 78 observations in the initial year and overcome problems generated by the large number of variables compared to the number of countries included (see Thirtle *et al.,* 2003).

5.1 Productivity changes-Malmquist TFP indices

Table 2 summarises the main findings of the empirical analysis regarding Malmquist indices and productivity growth rates in the Mediterranean countries. The average technical efficiency of the Mediterranean countries in the base period is quite low (66%), notably due to three countries (Algeria, Libya and Tunisia) that are exceptionally inefficient (i.e. TE scores below 36%). In contrast, only two countries, Israel and Malta, appear to be technically efficient, whereas the degree of technical inefficiency for the rest of the countries ranges from 14% to 40%.

[Table 2]

In the period 1966-2002, the MEDFROL countries show on average an annual 0.14% improvement in the technical efficiency of their agricultural sectors. Morocco, Greece and Libya exhibit the highest efficiency gains (1.1%, 0.9% and 0.7% respectively). Only Algeria exhibits a significant efficiency regress (0.9%), while the other three countries with efficiency regression (Cyprus, Malta and Syria) show only minor changes (less than 0.2%), similar to the remaining countries with positive efficiency changes.

Given that the sequential TFP does not allow for technological regression, it is evident that the distinction is made only on the grounds of progression and stagnation: Syria, Greece, Jordan and Turkey are more or less stagnant (with an annual growth rate of TNCh no more than 0.3%), whereas Cyprus, Libya and Spain exhibit the highest technological changes (more than 1%).

The evolution of TFP changes in the period under study shows that on average, there is a 0.7% productivity growth in the Mediterranean countries. Libya (1.7%), followed by Morocco, Cyprus, Greece and Spain - all above 1% annual increases - are the leading countries in productivity growth rates. All the remaining countries, with the exception of Algeria, show positive productivity changes, ranging from 0.3-0.8% per annum. Algeria in fact exhibits high TFP growth rates in the last two periods, being well above the average, but its growth rates were quite low prior to 1980. It is evident that out of the four leading countries, all but Cyprus, are also identified as the ones that exhibit the highest TECh. Israel, which is the only fully efficient country throughout the sampled period, naturally shows no efficiency gains and its productivity growth rates are entirely attributable to technological improvements. Greece, Israel, Malta and Morocco are the only countries that maintain positive productivity growth rates throughout the sampled period, while Spain, exhibits productivity losses only in the initial decade.

Turning to the next columns of Table 2, the evolution of TFP and its components are broken down into different time periods so as to highlight differences in growth patterns. In the first period 1966-70, TEChs and TFP changes are both negative (-3.9 and -2.9% respectively), while there significant technological improvements (1.1%). In the following two decades however, the rate of technological improvements falls sharply to 0.5% and 0.3%, only to rise again in the final period 1990-2002 to 0.7%. In the same periods, a sharp increase in the efficiency changes for the Mediterranean countries is noticed, to as much as 0.9% annually in the periods 1971-80 and 1991-2002 and 0.6% in the period 1981-1990, thereby generating increasing TFP growth rates of 1.5% and 0.9% respectively.

These findings are sustained by the fact that whilst in the first period there are eight countries with productivity losses, they are subsequently reduced to two in the following two decades and to only one (Tunisia) in the final period. The same holds when examining efficiency changes: The nine countries with efficiency losses are reduced to three in the two decades 1971-1990 and four in the final period. Consequently, it seems reasonable to argue that in the first decades of the period under study (coinciding with the Green Revolution era) most of the Mediterranean countries gained primarily from technological innovations adopted in their agricultural sectors. In the last years though, it is evident that it is the efficiency changes that affect productivity growth rates, because the rate of TNCh has slowed down. This finding is in accordance with the results obtained by Suhariyanto and Thirtle (2001) who examined agricultural productivity growth in Asia and concluded similar findings. They also cite Byerlee (1987) who suggests that traditional technological innovations (i.e. new varieties, fertiliser use) may have been already substantially exploited and therefore there is a need for other innovations such as better information and training of the farmers in order to adopt advanced management and input usage techniques (i.e. water management, precise planting methods, use of micro-nutrients etc.).

Figure 1 illustrates the differences noticed in Mediterranean agriculture during and after the Green Revolution, by plotting the evolution of the cumulative indices of TECh, TNCh and TFP: Technical change is higher than TFP growth until 1984. From 1985 onwards though, efficiency changes increase sharply, thereby generating a TFP growth rate higher than TNCh. Generally, technical change exhibits a sharp increase until 1973 but remains relatively stagnant for more than two decades (until 1995) only to increase during the last decade. On the other hand, TE changes are regressing sharply until 1979, but exhibit a steady growth pattern ever since, turning positive only in 1985.

[Figure 1]

5.2 Convergence

Estimates of the unconditional β- convergence were obtained by estimating Equation (5) and substituting in Equation (6). Results are reported in Table 3, which shows that for the entire period 1966-2002 convergence (and divergence) of agricultural TFP across the Mediterranean countries cannot be accepted; the implied β- estimator is negative (indicating divergence), but the b- coefficient is insignificant. Still, by breaking down the full period into two sub-periods, 1966-1980 and 1981-2002, it is possible to highlight differences among the Green Revolution period and the Post-Green Revolution period. During the first period, divergence is pronounced, as shown by the negative sign of the implied β- estimator and the significance of the b- coefficient. In contrast, during the latter period, the implied β- estimator has the desired sign (indicating convergence), but the b- coefficient is insignificant.

[Table 3]

In other words, these results suggest that although agricultural productivity does not appear to exhibit signs of convergence across the Mediterranean region, divergence was more obvious during the Green Revolution period. During this period, some countries managed to make better use of new available technologies, thus reaching far greater productivity levels than others. These findings can be related to the evolution of the decomposed cumulative Malmquist TFP index presented in the previous section. During the first years, TECh (or 'catch-up') was declining, indicating that the gap between productive and less-productive countries was widening. In the same time, TNCh (or 'frontier shift') was increasing, further widening the gap. In the latter years though, TECh turned positive, i.e. catching-up was occurring, while the frontier shift remained stagnant.

Evidence from the plot of cross-sectional standard deviations of TFP growth rates further sustains the above arguments. Figure 2 shows a steady increase in the dispersion of the cross-sectional standard deviations of the log of TFP until 1979 and then reduces slightly; in 1979 the standard deviation reached 0.307 (from 0.151 in 1966), to drop to 0.249 in 2002.

[Figure 2]

The results of the Nahar and Inder (2002) methodology do not vary largely from the outcomes of the cross-sectional convergence tests. Nevertheless, as indicated earlier, this method focuses on country-specific estimates of convergence (rather than overall group convergence), thereby allowing for more in-depth and analytical insights on the group of countries under investigation. Results are reported in Table 4.

Based on the average slope estimates of the squared demeaned TFP levels, convergence cannot be accepted for the majority of the Mediterranean countries. In fact, only four countries, Egypt, Greece, Spain and Tunisia appear to be converging to the mean, while the coefficient for Turkey is only marginally not significant. Tunisia is converging to the mean at a rate of 0.73% per annum, and Egypt at a rate of 0.15%. Spain and Greece show a much more modest convergence pattern (0.04% and 0.01% respectively). On the opposite, two countries - Israel and Malta - have positive average slopes with significant values, suggesting a divergence from the mean. These two countries had the highest initial efficiency levels, but still their estimated slope suggests a divergence at moderate rates of merely 0.02% and 0.01% annually. For the remaining five countries tests are inconclusive, although they all have the desired (negative) sign, with the exception of Morocco.

[Table 4]

Generally, it is evidenced that agricultural productivity growth does not appear to be converging across the Mediterranean countries. It is not unusual for studies testing the convergence hypothesis to derive this conclusion; several other studies have also failed to accept convergence – particularly unconditional – in the agricultural productivity growth. Suhariyanto and Thirtle (2001) rejected convergence among a set of eighteen Asian countries, as did Ludena *et al.* (2005) regarding ruminant production among developed and less-developed countries. In a similar manner, Gutierrez (2000) investigating agricultural productivity in the EU, McErlean and Wu (2003) analysing regional agricultural labour productivity in the Chinese provinces and Mukherjee and Kuroda (2003) examining growth rates among the Indian states, all rejected convergence. The latter three studies, found evidence only for conditional convergence, after the inclusion of auxiliary variables in order to control for socio-economic and/or spatial differences among the countries.

6. Conclusions

This paper has investigated the levels and growth patterns in agricultural productivity in the Mediterranean countries. For this purpose, the sequential Malmquist approach was employed in order to calculate TFP indices. Results show that the average growth rate of agricultural productivity reached 0.7% per annum in the period 1966-2002. Efficiency changes contributed by a mere 0.1% while the rest 0.6% was provided by technical change. Nevertheless, TFP grew at considerably higher rates in the later years, reaching 1.5% in the period 1991-2002, with efficiency changes contributing consistently more than technical change. This suggests that during the Green Revolution, the rate of technology adoption was not uniform across the Mediterranean region, but as the diffusion of technology gradually spread, it allowed low performing countries to narrow the gap with high performing ones. This process however, was not strong enough to generate a complete catching-up, given that eventually, for the whole period, the frontier shifts was greater than the movements towards the frontier.

Not surprisingly, tests of unconditional convergence of agricultural TFP across the Mediterranean countries failed to find evidence of diminishing disparities. Both cross-sectional as well as time series tests were applied in order to facilitate comparison among alternative methods. The former reject the convergence (and divergence) hypothesis throughout the period under investigation, while strong evidence of divergence is provided for the first period until 1980. Since then, disparities appear to be lessening, but at an insignificant rate. Coelli and Rao (2003) measuring agricultural TFP growth in a set of 93 countries worldwide, despite not testing for convergence, also note that in the period 1980-2000 there is a reversal in the tendency of a widening gap in productivity levels between high- and low-performing countries, that was recorded in the prior period.

A new time series test of unconditional convergence proposed by Nahar and Inder (2002) that overcomes problems of standard unit root test and enables country-specific estimates of convergence to a common steady state was also applied. Again, there is little proof that countries with low initial productivity levels manage to grow faster than others with a higher productivity level. Only for four countries (Egypt, Greece, Tunisia and Spain) is there strong evidence of convergence to the group mean, whereas another two (Israel and Malta) are clearly diverging. The test is inconclusive for the remaining seven countries, although for all but Morocco the estimated coefficient has the desired sign.

Failure to accept unconditional convergence is not uncommon in the literature. In this case, it appears that the group of Mediterranean countries included in the study, is so diverse and heterogeneous that perhaps it is necessary to control for these differences and test whether each country has its own steady state. Further research could be extended by introducing also additional variables (i.e. land quality, irrigation, rainfall etc) that could capture terms of agricultural production in the Mediterranean presently not included.

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Table 1: Descriptive statistics of the variables

	Mean	St. Error	St Dev.	Min	Max
y	4,554,049.6	265,836.4	6,211,703.8	28,484.	25,506,622
x_1	14,343.4	616.3	14,401.7	9	45,471
x_2	6,003.4	327.8	7,660.7	6	26,720
x_3	350,373.4	23,840.0	557,061.2	282	2,367,000
x_4	105,467.4	8,822.5	206,151.4	86	970,083
x_5	4,309,086.9	232,039.6	5,421,987.3	23,068	23,357,790

Table 2: Decomposition of agricultural TFP growth rates in the Mediterranean countries

	1966-2002				1966-70			1971-80			1981-90			1991-2002		
	TE*	TECh	TNCh	TFP	TECh	TNCh	TFP	TECh	TNCh	TFP	TECh	TNCh	TFP	TECh	TNCh	TFP
Algeria	0.357	0.991	1.004	0.995	0.904	1.021	0.923	0.979	1.003	0.982	1.011	1.000	1.011	1.023	1.000	1.023
Cyprus	0.687	0.999	1.013	1.012	0.969	1.032	1.000	1.019	1.018	1.037	0.997	1.001	0.998	0.997	1.011	1.008
Egypt	0.863	1.001	1.008	1.008	0.993	1.000	0.993	1.005	1.000	1.005	1.011	1.003	1.013	0.993	1.022	1.014
Greece	0.703	1.009	1.002	1.011	1.007	1.009	1.016	0.996	1.004	1.001	1.009	1.000	1.009	1.020	1.000	1.020
Israel	1.000	1.000	1.007	1.007	1.000	1.006	1.006	1.000	1.006	1.006	1.000	1.008	1.008	1.000	1.008	1.008
Jordan	0.843	1.002	1.003	1.005	0.870	1.000	0.870	1.031	1.010	1.041	1.023	1.000	1.023	1.020	1.001	1.021
Libya	0.265	1.007	1.012	1.019	0.933	1.026	0.958	1.010	1.010	1.021	1.022	1.005	1.027	1.024	1.015	1.039
Malta	1.000	0.999	1.004	1.003	1.000	1.002	1.002	1.000	1.001	1.001	1.000	1.002	1.002	0.998	1.009	1.007
Moroco	0.586	1.011	1.006	1.017	1.022	1.000	1.022	1.020	1.000	1.020	1.007	1.014	1.021	1.000	1.009	1.009
Spain	0.792	1.000	1.010	1.010	0.969	1.012	0.981	1.008	1.006	1.014	0.996	1.009	1.005	1.010	1.014	1.024
Syria	0.593	0.998	1.001	0.999	0.939	1.003	0.942	1.035	1.001	1.036	0.961	1.000	0.961	1.027	1.000	1.027
Tunisia	0.292	1.001	1.004	1.005	0.962	1.007	0.969	1.034	1.011	1.045	1.013	1.000	1.013	0.980	1.000	0.981
Turkey	0.601	1.001	1.003	1.004	0.937	1.019	0.954	0.988	1.001	0.989	1.024	1.000	1.024	1.023	1.000	1.023
Average**	0.660	1.001	1.006	1.007	0.961	1.011	0.971	1.009	1.005	1.015	1.006	1.003	1.009	1.009	1.007	1.015

* TE refers to the base period (1961-1966)
** Average TE is arithmetic mean, whereas average TECh, TNCh and TFP are geometric means

Table 3: Cross-section estimates of β- convergence in Mediterranean agricultural TFP

	1966-2002		1966-1980		1981-2002	
	Parameter	*t*-value	Parameter	*t*-value	Parameter	*t*-value
Constant	0.3304	4.49	0.1394	11.82	0.3473	4.62
b	0.2629	0.59	0.2023	4.22	-0.3649	-0.80
Implied β	-0.0063	-0.66	-0.0123	-4.62	0.0206	0.64
R^2	0.031		0.057		0.056	
F-test	0.351		17.819		0.647	

Table 4: Time series estimates of convergence (Average slope)

	Squared demeaned TFP		
	Polynomial order	Average slope	*t*-value
Algeria	6	-0.00010	-0.11
Cyprus	5	-0.00028	-0.68
Egypt	6	-0.00146	-5.60*
Greece	3	-0.00011	-2.00*
Israel	4	0.00017	3.60**
Jordan	6	-0.00003	-0.02
Libya	9	-0.00006	-0.08
Malta	5	0.00013	2.57**
Moroco	5	0.00074	1.31
Spain	8	-0.00038	-2.44*
Syria	10	-0.00147	-1.07
Tunisia	6	-0.00728	-4.79*
Turkey	5	-0.00037	-1.74

* Convergence, significant at the 5% level

** Divergence, significant at the 5% level

The polynomial order for each equation was selected by using the Akaike Information Criterion (AIC)

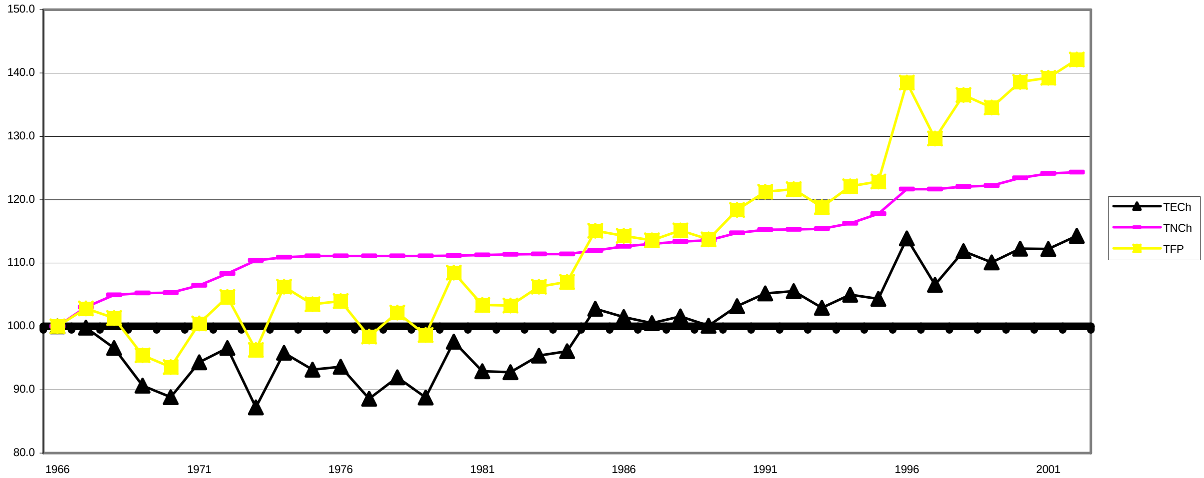

Figure 1: Decomposition of cumulative TFP (TECh, TNCh)

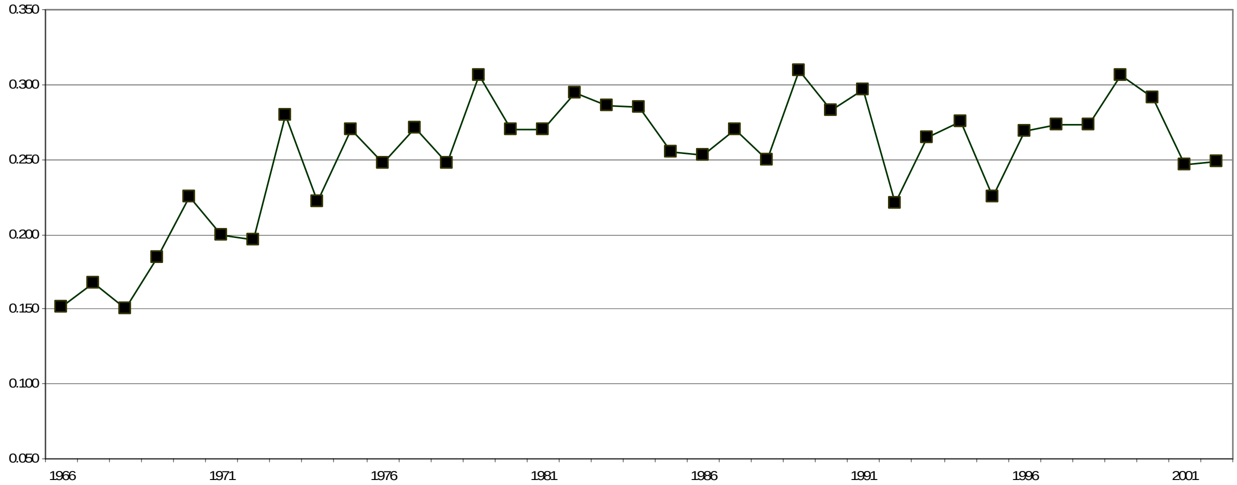

Figure 2: Standard deviation of log TFP, 1966-2002