Agricultural Productivity Growth and Convergence among Countries

Luciano GUTIERREZ

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Luciano GUTIERREZ*

Croissance de la productivité agricole et convergence entre les pays

Résumé – La productivité de l'agriculture varie de façon considérable selon les différentes régions du monde. Au cours des dernières années, l'analyse des sources de la croissance a connu un regain d'intérêt et a donné lieu à de nouvelles recherches. Cet article s'intéresse à trois questions. Tout d'abord, la productivité du travail dans le secteur agricole a-t-elle convergé au cours des vingt dernières années ? Ensuite, quels facteurs influencent la croissance dans les secteurs agricoles ? Enfin, les pays membres de blocs régionaux commerciaux profitent-ils d'une croissance plus rapide due aux externalités spatiales et aux effets d'agglomération ? Nous mettons en évidence la présence d'une convergence conditionnelle pour un large échantillon de pays, mais le taux de convergence est très faible. Par contre, toutes choses étant égales par ailleurs, les pays qui disposent d'une grande quantité d'intrants techniques et d'un nombre important de personnes formées ont eu une croissance plus rapide. Nous montrons enfin que le processus d'unification de l'Europe a stimulé la productivité.

Mots-clés :
agriculture, croissance, productivité du travail, convergence

Agricultural productivity growth and convergence among countries

Summary *– Agriculture productivity varies dramatically in different regions of world. New intellectual interest has been shown and new efforts have been made to analyse the sources of agricultural growth in recent years. The article considers three questions. First, has labour productivity in the agricultural sector been converging in the last twenty years? Second, which factors influence growth in the agricultural sectors? Third, have member countries of regional trade agreements benefited from spillover or agglomeration effects by growing faster? We find evidence of conditional convergence for a broad sample of countries, but the convergence rate is very low. Other things being equal, countries with higher amounts of technical inputs and more educated people grow faster. There is evidence that the European Union has stimulated productivity.*

Key-words:
agriculture, growth, labour productivity, convergence

* *University of Sassari, Department of Agricultural Economics, Via E. De Nicola 1, Sassari 07100, Italy*
e-mail: lgutierr@ssmain.uniss.it

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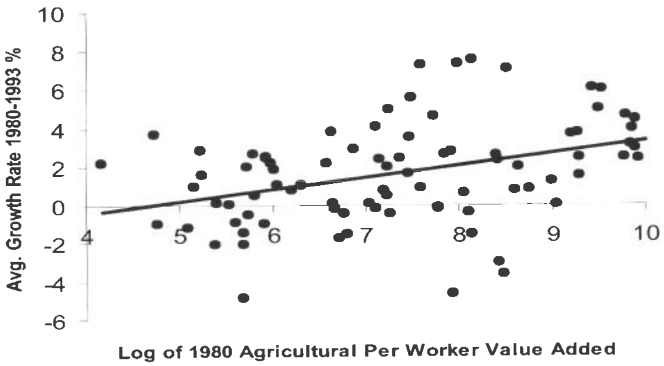
AGRICULTURE productivity varies dramatically in different regions of the world. In 1994, agricultural gross domestic product (GDP) per worker in the Netherlands was more than 100 times higher than agricultural GDP per worker in India. In other words, in just four days the average worker in the Netherlands produced as much as an average worker in India produced in one year. Explaining why such vast differences in economic performance continue is one of major tasks in our profession. During the last thirty years many studies have attempted to identify factors that determine differences in agricultural productivity in the developed and the less developed countries (see, for instance, Hayami, 1969; Hayami and Ruttan, 1970; Nguyen, 1979; Mundlak and Hellinghausen, 1982; Kawagoe and Hayami, 1985; Mundlak, 1997). By estimating the aggregate agricultural production function on cross-country data and looking at the estimates of production elasticities, these studies have highlighted the factors which explain the difference in labour productivity. Hayami's pioneering paper (Hayami, 1969, pp. 574-575) found that *"Differences in the inputs of modern man-made factors account more for the difference in productivity than differences in the endowments of original factors and that education and research are crucial in determining the productivity gap"*. Thirty years later little has changed and, using different methods and a larger data set, we reach the same conclusions as Hayami.

A primary concern of the paper is the analysis of the convergence rate for agriculture productivity across countries. Basing the analysis on Solow's (1956) and Swan's (1956) neoclassical growth models, Baumol (1986) and Barro and Sala-i-Martin (1990, 1992, 1995) stress that the per-capita growth rate tends to be inversely related to the starting level of output per person. If countries have similar preferences and technology, then poor countries tend to grow faster than rich countries. This negative relationship has been labelled *absolute convergence hypothesis*.

However the hypothesis does not hold when cross-country data are used. Figure 1 is a *convergence scatterplot*. As the figure shows, there is little evidence of convergence. The growth rate of agricultural GDP per worker is positively related to the starting level of agricultural GDP per worker for a sample of 85 countries for the period 1980-1993.

Figure 1. Agricultural productivity growth rate versus starting level labour productivity



Similar patterns have also been identified at aggregate level by other authors (Barro, 1991). The contrast between the empirical evidence and the theoretical predictions of the neo-classical growth model is one of the main objections raised against this literature. Another major criticism is that growth occurs only as a result of exogenously determined technological progress and population growth[(1)].

Lack of absolute convergence may be the result of different initial conditions or environment factors in the economies. These factors may be related to the resource endowments and geographical location of a country. Moreover, variable factors that can be influenced by government policy may affect the initial starting condition. It has been argued that if one subtracts what can be attributed to these differences in environment factors from the growth rates of GDP, then the hypothesis of poor countries growing more rapidly than rich countries is once again true. This hypothesis has been labelled *conditional convergence hypothesis*. In synthesis, the concept of conditional convergence asserts that the country that is itself proportionately far away from its own steady state will grow faster than a country that is proportionately closer to own steady state.

Empirical analysis usually shows evidence of conditional convergence at aggregate level, but focusing only on aggregate outcomes could mask important variations in sectoral productivity movements. Barro and Sala-i-Martin (1991) highlight that all US sectors converge at the same rate[(2)] but there are other studies which stress lack of convergence at the industry level (Galli, 1997 and Bernard and Jones, 1996). Our hypothesis is that, in the case of sector-specific technologies, convergence hypothesis should be tested at disaggregated level. New technologies may alter labour productivity in some sectors, giving rise to a diverging process, whereas other sectors may be influenced only after a certain time.

The article considers three questions. First, has labour productivity in the agricultural sector been converging in the last twenty years? Second, which factors influence growth in the agricultural sectors? Third, have member countries of regional trade agreements (RTAs) benefited from spillover or agglomeration effects, by growing faster?

We attribute great importance to the third question. Recent results (Vamvakidis, 1998) show that RTAs had no impact on growth and Henrekson *et al.* (1997) show that a dummy for participation in the European Union has a positive coefficient in cross-country regressions, but its significance is not always robust. Oskam and Stefanou (1997), reviewing the literature of the effects of CAP for the agricultural sector, conclude that "*... it seems probable that the CAP has on balance stimulated productivity growth in agri-*

[(1)] Differences between population growth rate and labour force growth rate affect the convergence parameter and this has been analysed in Gutierrez (2000a).

[(2)] Barro and Sala-i-Martin's study concentrated the analysis only on non agricultural sectors.

culture, although this conclusion is very weak". Our results indicate, after controlling for other variables and over the period 1980-1993, a significant effect of EU membership on agricultural labour productivity growth.

All the data in the article are from World Bank, FAO, and the Summers-Heston (1991) and Barro-Lee (1996) data sets. In each regression all the countries with available data have been included, giving a total sample of 85 countries. In section II, we review the cross-section methodologies. Section III discusses data and estimates the growth regressions. Finally, section IV concludes with some policy implications.

EMPIRICAL APPROACHES

Brief review of literature

Both the theoretical foundations[(3)] and the empirical implications of the neoclassical growth model developed by Solow (1956) and Swan (1956) have been widely investigated recently. On the theoretical front, Romer (1986), Lucas (1988), Grossman and Helpman (1991) and Aghion and Howitt (1998) *inter alia* have examined whether alternative models may explain observed growth experience better. Typically, these endogenous growth models relax the neoclassical assumption of diminishing returns to reproducible factors of production. If there are diminishing returns to capital, as in neoclassical models, the level of income per capita should converge toward its steady-state value, with the speed of convergence increasing with the distance from the steady state. By contrast, assuming constant returns, such as for the well-known AK[(4)] model in which the returns to capital are always constant, usually means that one would not expect to find convergence. An extensive empirical literature has developed on this issue. The debate depends heavily on the underlying structure of production. In an environment of increasing returns to scale at the firm level, as well as gains from a greater diversity of products, there may well be increasing or at least constant returns to the capital stock. In that setting endogenous growth models would depict the production technologies better than the neoclassical model. In this case we could expect to see divergence between rich and poor regions. If economies of scale are limited, we are more likely to see convergence but other factors must be taken into account.

(3) We do not attempt to review these theories here. On these themes the reader may consult among others, Fagerberg (1994), Barro and Sala-i-Martin (1995), Klenow and Rodríguez-Clare (1997), Durlauf and Quah (1998), Temple (1999) and Gutierrez (2000a).

(4) The acronym "AK" designates the typical endogenous growth model characterised by one input production function which is linear in the level of capital.

As previously noted, one hypothesis from the neoclassical model is absolute convergence or, as labelled by empirical analysis, β-convergence: countries where per worker output is lower typically grow faster and tend thereby to catch up with countries with a higher level of productivity. This hypothesis implies in our case that the average growth rate of agricultural labour productivity would tend to be inversely related to the level of labour productivity in the initial period of analysis. Usually data sets for a large set of countries reject the absolute convergence hypothesis. Thus, any hope of reconciling the convergence hypothesis with the data has to rely on the concept of conditional convergence. We have to examine the relation between the growth rate and the starting position after holding constant some variables that distinguish the countries. This latter form of convergence is definitely weaker than the former. It implies that countries will converge to different labour productivity steady states but that a country that is further below its own steady state will grow faster.

What does seem questionable in the empirical analysis on growth and convergence is that usually only aggregate data are examined. Bernard and Jones (1996) show that *"within sectors across countries there is evidence for convergence for some industries, but not for others. These differences across sectors account for convergence at national level"*. Boussemart and Robert (1999) show that, analysing the convergence process between France and Germany, some industries show convergence but, for other industrial sectors, they were able to depict only divergence. The same results were shown in Galli (1997), where she finds that, using data on EU countries, some sectors such as communications, distribution and non-market services, show strong evidence of convergence, while others, such as manufacturing, show substantial divergence. Gutierrez (2000a) tests for convergence of agricultural labour productivity for 50 US state and 11 EU countries. The results show absolute convergence for the US but only conditional convergence for EU countries. Finally, Gutierrez (2000b) finds only conditional convergence for a broad sample of countries.

Methods to estimate the rate of convergence

The cross-section approach attempts to estimate the rate of convergence by applying ordinary least squares to the following equation[5].

$$\gamma_i = \alpha + \beta y_{i0} + \delta' \mathbf{x}_i + \varepsilon_i , \qquad i = 1,2,\ldots,N \tag{1}$$

where γ_i is the average growth rate of per-worker output for economy i between periods 0 and T, y_{i0} is the logarithm of per-worker output for

[5] The reader may refer to Gutierrez (2000a) for a derivation of equation (1). A brief description of this equation's derivation is included in the appendix.

economy i in the period 0, $\mathbf{x}_i$ is a vector of observations on variables that control for cross-economy heterogeneity, α and β are parameters and δ is a parameter vector, and ε_i is an error term with a zero mean and finite variance. All the variables are observed for economies 1,2,...,N.

The neoclassical growth model asserts that countries that are relatively backward may learn from advanced producers and increase their productivity more rapidly. If this follows, we should see catch-up in the economy, proportional to the relative backwardness of technology in that country. In other words, the economies will converge in the sense that unexplained differences in period 0 tend to shrink in the next T periods. Then, after controlling for the mean differences associated with their **x**'s, according to equation (1) we should expect a negative β coefficient. Given β, it is simple to calculate the rate at which the economies will converge.

If, forgetting for a moment **x**'s and ε, we write equation (1) as

$$(y_{iT} - y_{i0})/T = \beta\, y_{i0}$$

or

$$y_{iT} = (1 + \beta T)\, y_{i0} \tag{2}$$

If $\beta = 0$, the economy will be along the balanced growth path, *i.e.* per-capita variables will be constant in the steady state whereas the level variables will grow at a rate given by the sum of the exogenous labour force and technology growth rate. Consider now a country which is one unit above the balanced-growth path in period 0. Looking at equation (2) after T periods it will reach a value of $(1 + \beta T)$ units above its balanced-growth path. Naturally, if the countries all converge toward their parallel balanced-growth path, $(1 + \beta T)$ will equal, by definition, $(1 - r)^T$, where r is the convergence rate. Consequently

$$r = 1 - (1 + \beta T)^{1/T} \tag{3}$$

The less negative β is, the slower the convergence will be. Alternatively, convergence is analysed by looking at the temporal dispersion of per worker outputs: a decreasing dispersion may be interpreted as evidence of convergence and has been labelled as σ-convergence.

Many criticisms have been levelled at the view of cross-section convergence, pointing out that it is perfectly consistent with the absence of σ-convergence, (Quah, 1993). I share Sala-i-Martin's (1994) view of these criticisms. Our results show that poor countries will be poor for a long time. Knowing whether the overall world dispersion is falling or not is of secondary importance. Lee *et al.* (1995) stress that the cross-section estimated coefficient on initial income may be biased and inefficent and Dowrick and Nguyen (1989) argue that there is some doubt whether the apparent convergence of labour productivity may not be the result of biases in the data used for international comparisons and in the selection of both the sample of countries and historical periods.

In order to take account of these criticisms, we use the White's method (1980) which corrects the estimates for an unknown form of heteroskedasticity. Secondly, we are confident that our independent **x** variables account for a great share of cross-sectional heterogeneity. Finally our results are robust to changes in the sample of countries and in the period of estimation.

To complete this short discussion on the methods used to study growth, we will pay attention on panel data and time series techniques[6]. Many studies have been proposed in recent years (among others Caselli *et al.* (1996), Evans and Karras (1996), Islam (1995), and Loayza (1994)) which attempt to study growth and convergence by using panel data techniques. The mainly advantages are firstly that they permit for omitted variables that are persistent over time to be controlled for, and secondly that they allow one to use lags of the regressors as instruments, reducing measurement error and endogeneity biases. However some worries remain. The standard transformation for output such as first differences when adopting the usual fixed effects or within groups specifications, reintroduces the problem of measurement errors, giving rise to a fall in precision because the between-country variation is thrown away. Second, when using dynamic panel estimation, as in Caselli *et al.* (1996), we run into the problem that the finite properties of most estimators are not yet well understood and different estimators perform well in different situations, so introducing indeterminacy about the best choice (Temple, 1999). When using time series techniques[7], we are able to estimate parameters for countries individually, leaving aside any assumption of parameter homogeneity as in cross-section or panel data estimations. The problems here are first that we need long time series, which is usually not available, especially for variables collected from census data, and secondly the low quality of the data for most of developing countries.

EMPIRICAL RESULTS

We now estimate the cross-country growth equation (1) that allows for the possibility of catching-up effects. Specifically we estimate a model of average annual growth of agricultural labour productivity during the period 1980-1993 on agricultural labour productivity levels in 1980. We test whether labour productivity growth is affected negatively (in the case of convergence) or positively (in the case of divergence) by the initial labour productivity level. We test also if other factors connected to resource endowment, technical inputs and education, holding constant initial labour productivity, may influence productivity growth.

[6] Fuss (1999) is a useful reference for a review of the literature on tests of convergence.

[7] See Bernard and Durlauf (1996)) on how cross-section and time series techniques perform when testing for convergence hypothesis.

Data issues

As previously noted, agricultural productivity may depend on resource endowment. Surprisingly, almost none of the cross-studies introduce variables such as climate, water availability and soil fertility. An exception is Mundlak et *al.*'s (1997) study, which includes indicators for biological productivity and water availability when studying cross-country agricultural production function. From this study it emerges that biological productivity, measured as "potential dry matter", is not correlated with agricultural output but water availability is positively correlated. As it will be seen, we introduce water availability in the regression, finding a positive relationship with agricultural labour productivity growth. Soil fertility and climate may influence productivity. In our study, a soil fertility index has been built using the FAO Digital Soil Map of the World (1995) and average temperature in each countries during the period of analysis have been inserted as additional potential indicators. Both variables, albeit positively correlated with agricultural labour productivity, were found not significant and thus excluded from regressions. In the first case, the result may be attributed to fertiliser use, which can substitute poor fertility in the soil. In the second case, the result may be related to the use of the average annual temperature whereas a better indicator could be the average temperature during the growing seasons.

Use of fertilisers is usually seen as a proxy for the use of a large set of technical inputs. Antle (1983) shows a strong correlation between research and use of fertilisers, probably connected to the relationship between agricultural research, or using Hayami's (1997) expression "science-based agriculture", and the introduction of modern inputs. As it will be seen, use of fertilisers for unit of land is positively related to the growth of agricultural labour productivity.

In the last ten years a broad consensus has emerged between endogenous as well as neoclassical growth researchers that one of the key variables that explains growth is the increase in the quantity of human capital per person. The effective use of new technologies requires high levels of education or accumulation of human capital. Education interacts with new technologies in two different ways. First, higher levels of education are fundamental for the vast majority of innovations. Second, the effective use of new technologies often requires highly skilled individuals to use modern sophisticated machinery, for example. Moreover, health care may contribute to the growth of agricultural productivity through improvements in the farmers' productive capacity. Both effects are taken into account in the empirical analysis by introducing education and life expectancy variables.

Some questions have been asked, (Ben-David, 1998), about the incidence of reduction in income gaps among countries at different levels of development. There is some evidence of "convergence clubs", especially among the world's poorest countries. We do not address the problem but, as it will be seen, we test for differences in the rate of agricultural labour productivity growth between low, lower-middle income and wealthier countries.

Finally, the effect of RTA on agricultural labour productivity growth is examined. Shortly, the main reason advanced for the role that RTA may play in heightening growth has been connected to the removal of trade barriers. Trade competition induces exporters and importers to learn and utilise better technologies and secondly helps the dissemination of ideas (Coe and Helpman, 1995; and Grossman and Helpman, 1991). Many works have analysed the issue of relationship between growth, convergence and RTAs in recent years. Ben-David (1993) highlights that EU trade agreements have resulted in the convergence of its members, while Vamvakidis (1998) does not find any significant relationship, after controlling for openness and other independent variables, between a sample of five RTAs, included EU, and per capita income growth. Henrekson *et al.* (1997) find that a dummy for participation in the EU has a positive coefficient in cross-country regressions, but its significance is not always robust. While all these works analyse the effects of RTAs on per capita or per worker GDP growth, in our paper we focus the analysis on agricultural productivity growth. As it will be seen, our results show that EU agreements spurred agricultural labour productivity for member countries, while no effect is reported for the other RTAs analysed.

The data for agricultural output and inputs comes from World Bank and FAO's data sets. We construct our labour productivity measure as the ratio of gross value added in the agricultural sector at market prices expressed in constant 1987 US dollars[(8)], *i.e.* a measure of real output in agriculture, to full-time equivalent employment in the agricultural sector. Both series are provided by World Bank Development Indicators. The data are available for most countries in the world from 1980 to 1993. Agricultural land comes from FAO as well as other measures of agriculture capital, the number of livestock, the number of machines and the consumption of fertilisers. Livestock of different kinds are aggregated using the weights from Hayami and Ruttan (1970). Fertilisers are measured as metric tons of nitrogenous, potash, and phosphate fertilisers, and water availability is taken from the FAO data set. Finally, human capital is represented by the percentage of "average years of secondary schooling" in the total population and by the percentage of "average years of higher schooling" in the total population, for the population aged 15 and over (Barro and Lee, 1996).

[(8)] Since the agricultural sector mainly involves production of traded goods, market exchange rates seem more appropriate than the purchasing power parity exchange rates (PPP), because PPP is fundamentally designed to deal with differences in consumer prices as well as volumes of consumption.

Econometric results: presentation and discussion

We start the analysis by estimating the regression which we label the *basic convergence equation*. We regress the average labour productivity growth over the period 1980-1993 on the log of agricultural GDP per worker in 1980 and a constant. The total number of countries in the sample is 85[(9)]. Regression (1) of Table 1 shows the results. At the end of the table, we present standard regression statistics as the coefficient of determination R^2, the F-statistic for the test that all coefficients are zero, the Lagrange Multiplier test for the null hypothesis of residuals normality and Breusch-Pagan test for the null hypothesis of residual homoskedasticity. As it will be seen, all regressions reject the hypothesis of homoskedasticity. Heteroskedasticity is not unusual when using cross-sectional data on a number of units such as countries. In this case, as it is well known, the least square estimators are still unbiased but inefficient and the estimates of the variances are biased, thus invalidating the tests of significance. In the absence of any prior knowledge concerning the form of heteroskedasticity we leave this important issue to further research. In any case, asymptotically invalid t-statistics on coefficients significance can be avoided by using White's (1980) consistent covariance matrix estimator. This is why t-statistics based on White's heteroscedastic consistent standard errors are reported in parentheses.

The estimated coefficient for the log of productivity is positive and strongly significant. As previously mentioned, this result shows the lack of absolute convergence hypothesis, *i.e.* countries do not converge to the same steady-state level of agricultural labour productivity.

In order to take account of differences in resource endowments, we introduce in the basic regression the ratio of fertiliser consumption and the ratio of water availability to total agricultural area (see regression (2) in the table). Both coefficients are positive and significant at the usual 5% confidence level, which means that a higher use of fertiliser and water availability increases the GDP growth rate. We also introduced the total number of machines and livestock per unit of land in the regression but neither coefficient was significant and have been excluded from regression. The coefficient on initial GDP is still positive and significant, showing no convergence in agricultural per worker GDP.

[(9)] The countries included are: Algeria, Argentina, Australia, Austria, Bangladesh, Barbados, Belgium, Benin, Bolivia, Botswana, Brazil, Bulgaria, Cameroon, Canada, Chile, China, Colombia, Congo Dem. Rep., Congo Rep., Costa Rica, Cyprus, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Fiji, Finland, France, Gambia, Germany, Ghana, Greece, Guinea-Bissau, Guyana, Honduras, India, Indonesia, Iran, Italy, Jamaica, Japan, Kenya, Korea Rep., Kuwait, Lesotho, Madagascar, Malawi, Malaysia, Mali, Mauritius, Mexico, Mozambique, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Norway, Pakistan, Panama, Paraguay, Peru, Philippines, Rwanda, Senegal, Sierra Leone, South Africa, Spain, Sri Lanka, Sudan, Swaziland, Sweden, Syria, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, United Kingdom, United States, Uruguay,Venezuela, Zambia, Zimbabwe.

Table 1. **Cross-section regressions**

	Regression			
Variables	(1)	(2)	(3)	(4)
Constant	-0.0303 **	-0.018 **	-0.1307	-0.071
	(-2.832)	(-1.683)	(-1.268)	(-0.645)
Log productivity [1], 1980	0.006 **	0.0038 **	-0.0043 *	-0.0063 **
	(4.399)	(2.308)	(-1.673)	(-2.188)
Water [2], 1980		0.68E-6 **	0.61E-6 **	0.58E-6 **
		(4.131)	(3.020)	(2.755)
Fertiliser [2], 1980		0.12E-3 **	0.99E-4 **	0.72E-4 *
		(3.027)	(2.569) **	(1.738)
Life expectancy, 1980			0.47E-1 *	0.36E-1
			(1.855)	(1.415)
Secondary education [3], 1980			-0.64E-2 *	-0.35E-2
			(-1.886) *	(-1.054)
Higher education [4], 1980			0.33E-2 *	0.35E-2 *
			(1.894)	(1.880)
Dummy for RTA:				
EU				0.017 **
				(2.688)
ASEAN				-0.97E-3
				(-0.1069)
ANCOM				-0.79E-2
				(-0.660)
CACM				0.54E-2
				(0.546)
Dummies for:				
Low Income Countries			-0.023 **	-0.026 **
			(-2.000)	(-1.988)
Medium Income Countries			-0.015	-0.014
			(-1.858)	(-1.600)
Implied ß:	-0.006 **	-0.004 **	0.004 *	0.006 **
	(-4.561)	(-2.360)	(1.798)	(2.268)
Number of observations	85	85	85	85
R^2	0.14	0.27	0.38	0.42
F-test	13.261 **	10.161 **	5.732 **	3.71 **
LM normality test [5]	0.941 (5.99)	2.586 (5.99)	5.872 (5.99)	4.660 (5.99)
Breusch-Pagan test [6]	99.50 (3.84)	107.94 (7.81)	94.19 (12.60)	79.78 (12.60)

Notes: The dependent variable is the average annual growth rate of labour productivity for 1980-1993. White's (1980) t-statistics based on heteroscedastic-consistent standard errors are in parentheses.
[1] Log 1980 GDP per worker.
[2] Ratio of variable to total agricultural area.
[3] Log average years of secondary schooling in the total population.
[4] Log average years of higher schooling in the total population.
[5] LM test on the null hypothesis that the errors are normally distributed.
It follows a chi-square distribution with two degrees of freedom. In parentheses 5% critical values.
[6] Breusch-Pagan test on the null hypothesis that the errors are homoskedastic. It follows a chi-square distribution with s degrees of freedom, where s is the number of variables included in the auxiliary regression. In parentheses 5% critical values.
**,* Estimated coefficients statistically significant for a level of 5 and 10% respectively.
Source: Author's calculations.

In the equation (3) we introduce proxies for human capital given by life expectancy, and years of secondary and higher education. Life expectancy is entered as a proxy for features other than good health. For example, higher life expectancy may go along with better work habits and higher level of skills. The years of secondary and higher education are proxies for investment in human capital. The hypothesis is that for a given starting value of per capita GDP, a country's subsequent growth rate is positively related to these measures of initial human capital. To sum up, a poor country will grow faster if its human capital exceeds the amount that typically accompanies the low level of per capita income. The results show positive coefficients, albeit only marginally significant, for life expectancy and for years of higher education, but a negative coefficient has been estimated for the secondary education variable[(10)].

We also introduce two dummy variables for the set of countries labelled as low-income countries and lower-middle income countries in the 1980 report by The World Bank. The estimated coefficients are both negative but only the estimate for low-income countries is significant at the usual 5% confidence level for a two-sided test. Note that now the coefficients on initial GDP become negative and significant at the 10% confidence level, showing a negative relationship between growth rate and initial conditions in the sector.

Finally regression (4) is similar to equation (3) except for the presence of four dummy variables. To test the impact of RTAs on labour productivity growth, we introduce agreements in force during the 1980s and continued in the following years. The RTAs[(11)] are: European Union (EU), Andean Common Market (ANCOM), Association of South East Asian Nations (ASEAN) and Central American Common Market (CACM). Dummy variables are included for countries that were members of any of the four RTAs in the 1980. In the regression only the estimated coefficient for the EU is positive and statistically significant, at

[(10)] The puzzling finding that the initial levels of secondary education tend to enter negatively in the growth-rate equations is not new in the empirical literature on growth, see Pritchett (1997).

[(11)] The following table defines the four RTAs:

Regional Trade Agreements

Agreement	Year created	Member countries (*)
European Union, EU	1958	Belgium, France, Germany, Italy, Luxembourg, the Netherlands
Andean Common Market, ANCOM	1969	Bolivia, Colombia, Ecuador, Peru, Venezuela
Association of South East Asian Nations, ASEAN	1967	Indonesia, Malaysia, Philippines, Singapore, Thailand
Central American Common Market, CACM	1960	Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua

(*) Countries are restricted only to founder members.

5% level, while all other RTAs have no impact on labour productivity growth. Thus our results show that EU trade agreements have had a positive effect on the agricultural productivity growth.

The remaining variables inserted in the regression (4) show coefficient values similar to those estimated in regression (3). Water and fertilisers still have a positive impact on productivity growth, albeit that now only the estimated coefficient for irrigated area is significant at 5% confidence level, whereas the estimate for fertilisers is only marginally significant. Note that estimates for years of education show values similar to those estimated in regression (3) while secondary education and life expectancy are not significant. Finally, looking at the statistics at the end of table, we note that the regressions do not reject the null hypothesis of normal errors distribution but all regressions reject the hypothesis of homoskedasticity[(12)].

We can calculate the relative importance of irrigated area and fertilisers by showing the effect of one-standard-deviation increase of the variables for the GDP growth, *i.e.* by analysing the well known beta coefficients (Maddala, 1977, p. 119). The estimated coefficients for the 1980-1993 sample mean that a one-standard-deviation increase in the use of fertilisers raises the growth rate of agricultural labour productivity by 0.53 percentage points per year, whereas a one-standard-deviation increase in irrigated area raises the growth rate by 0.40 percentage points per year. Finally, we can calculate that a one-standard deviation increase in higher education raises the growth rate by 0.51 percentage points per year.

Using the estimation results, we can now see that there is an inverse relationship between the initial agricultural per worker GDP and the net (from exogenous **x** factors) growth of per worker GDP. Thus, the hypothesis of conditional convergence holds if we subtract from the growth rates that can be explained by a country's particular environmental factors. Finally, using the coefficient on initial GDP in the regression (4) and equation (3), we can compute the speed of convergence. This value is approximately equal to 0.006. That is to say, each year there is a reduction equivalent to approximately 0.6 percentage points in a country's own agricultural per worker GDP gap. These results are lower than those estimated at aggregated level, where the 2 percent convergence parameter has usually been estimated.

To sum up, the results confirm those of Hayami's pioneering paper (Hayami, 1969): differences in the inputs of modern man-made factors and human capital are important in determining the productivity gap.

[(12)] In order to compute the Breusch-Pagan test, the square of all variables used in the original regression has been inserted in the auxiliary regression.

The results highlight that, during the period 1980-1993, economies with a relatively larger stock of technical inputs and higher level of human capital grew on average faster annually than economies with a relatively larger stock of resource endowments, if all other factors remained constant. So agricultural technical inputs and education are important determinants of labour productivity growth. This implies that resource endowments must be used efficiently and therefore policies facilitating access to these factors will facilitate growth. Second, we find that in the past only the European Union's regional trade agreements had some effect on agricultural productivity growth.

CONCLUSION

There was new interest in the problem of economic growth in the 1980s and 1990s. The new growth literature, by contrast with the neoclassical literature of the 1960s, sees empirical studies as important, paying close attention to data and the real world experience of countries world-wide. The agricultural sector is not exempted from this new intellectual interest and new efforts to analyse the sources of agricultural growth have been made in recent years (see Mundlak, 1997).

One of the most crucial empirical questions discussed by growth researchers has been the convergence hypothesis, *i.e.* the negative relationship between the growth rate and the initial level of income. As pointed out by endogenous growth researchers, the neoclassical hypothesis of diminishing returns to capital implies that the rate of returns to capital is negatively related to the stock of capital, which means that countries with low amounts of capital are predicted to grow faster.

Using Summers and Heston's data set (1991), they were able to show that the point estimate of a regression of growth on initial level of income was positive and this was taken as evidence against neoclassical models in favour of alternative theories that stress the absence of diminishing returns, *i.e.* endogenous growth theories.

In this article we have explicitly examined the presence of convergence of agricultural labour productivity for a large sample of countries over the period 1980-1993. We have found evidence of conditional convergence and not absolute convergence. This means that countries differ in their levels of technology, resource endowments, etc., so they will approach different steady-state levels of agricultural productivity. Secondly, our estimation of the speed of convergence differs remarkably from other data sets. We find a value of 0.6 percent per year. Thus, the lesson is that the process of convergence to the steady-state path is quite slow. The results highlight the fact that poor countries will be poor for a long time, and so current productivity disparities are of importance, and decisive intervention policies must be used in order to reduce these disparities.

We introduce variables in the growth regression proxy which take account the availability in countries of resource endowments, technical inputs and human capital. We found that technical inputs and education have a positive effect on agricultural labour productivity growth. Other things being equal, countries with higher amounts of technical inputs and more educated people grow faster and will reach a higher steady-state level of labour productivity. Resource endowment variables have a positive but lesser effect on determining the country productivity growth. A consistent picture emerges from the paper. Using Fagerberg's (1994, p. 1171) words *"...The potential for "catch-up" is there, but is only realised by countries that have a sufficiently strong "social capability ". e.g. those that manage to mobilise the necessary resource (investments, education, etc.). The results also indicate that many of these factors should be seen as complements rather than substitutes in economic growth"*.

Finally, we test for the impact of regional trade agreements (RTAs) on labour productivity growth. We find evidence that among RTAs only the EU trade agreement has stimulated productivity. Indeed our results indicate, after controlling for factor inputs variables, a significant effect for the EU regional trade agreement on labour productivity growth over the period 1980-1993. This does not mean that new RTAs or, for example, enlargement of the European Union to Central East countries, will have some impact on agricultural productivity growth. Recent studies by Vamvakidis (1998) stress that countries neighbouring open, large and more developed economies grow faster than those neighbouring closed, smaller, and less developed economies. It may be that future integration will foster the growth of agricultural productivity of Central East countries, but to verify this further research is necessary.

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APPENDIX

Derivation of expression (1)

Assume for simplicity a Cobb-Douglas production function

$$y = k^{\alpha} \quad \text{(A1)}$$

where both output y and capital k are defined in term of unit per worker and α is the elasticity of output per worker with respect to capital per worker. The dynamics equation for capital per worker is given by

$$dk = sy - (n + \delta)k \quad \text{(A2)}$$

where dk is the change of the physical capital per worker at any point in time, s is the share of output dedicated to the accumulation of capital, n is the growth rate of employment in the sector and finally δ is the capital depreciation rate.

From (A1) output per worker growth rate can be written as

$$\gamma_y = \alpha \, \gamma_k \quad \text{(A3)}$$

where $\gamma_y = dln(y)/dt \approx dy/y$ and $\gamma_k = dln(k)/dt \approx dk/k$.

Using (A3) and (A2), and taking the first-order Taylor expansion around the logarithm steady-state value of k we end with the following expression

$$\gamma_y = -(1 - \alpha)\,(n + \delta)\, ln(y/y^*) \quad \text{(A4)}$$

where $(1 - \alpha)\,(n + \delta)$ indicates how rapidly output per worker y approaches its steady state or equilibrium value y^*.

Equation (A4) is a linear differential equation and has a very simple solution which, after subtracting $ln(y_0)$, *i.e.* the log of output per worker at the time 0, and dividing both sides by the number of years T that correspond to the period analysed, may be written as

$$ln(y_T/\, y_0)/T = c - [(1 - exp(- r'T))/T]\; ln(y_0), \quad \text{(A5)}$$

where $c = [(1 - exp(- r'T))/T]\; ln(y^*)$ and $r' = (1 - \alpha)\,(n + \delta)$. Note that $r' \approx r$, *i.e.* the convergence parameter r in the equation (3) is a discrete approximation for r'. Finally, if we insert on the right side of the equation (A5) the vector of other determinants $\boldsymbol{x}$ which influence the output per worker growth rate between the period 0 and T, we find the equation (1) used in the empirical analysis.