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Testing the convergence hypothesis: a new approach

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Abstract

This paper uses a non-constant returns Cobb–Douglas production function to assess the relative roles of stages of economic development, the degree of returns to scale and capital deepening in explaining productivity growth differences in agriculture across countries. © 1999 Elsevier Science S.A. All rights reserved.

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1. Introduction

This short paper demonstrates how to assess the relative roles of stages of economic development (convergence/divergence), the degree of returns to scale and capital deepening in explaining productivity growth differences in the agricultural sector of 101 countries.

The outline of the paper is as follows. In Section 2 the model (and its variants) is discussed. Section 3 briefly discusses the data used. In Section 4 the results obtained, their limitations and economic implications are discussed. Finally Section 5 contains concluding remarks.

2. The model

The Cobb–Douglas production function on which the productivity growth equation used (see below) is based is assumed to be of the form

$$Q_{it} = \Pi_i(t) K_{it}^{\beta_1} L_{it}^{\beta_2} \tag{1}$$

where Q_{it}, K_{it} and L_{it} are output, capital and labour in country i at time t, respectively. β_1 and β_2 are

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scale elasticity parameters and $(\beta_1 + \beta_2)$ may differ from unity (i.e. non-constant returns to scale may prevail). $\Pi_i(t)$ is level of technology in country i at time t and its growth rate (π_i) is discussed below.

It is easy to show that dividing both sides of Eq. (1) by L_{it}, taking the natural logs and appropriately rearranging gives:

$$\ln Y_t = \ln \Pi_i(t) + \beta_1 \ln \left(\frac{K_{it}}{L_{it}}\right) + \varphi \ln L_{it} \tag{2}$$

where Y_t is the labour productivity level in year t and $\varphi = (\beta_1 + \beta_2 - 1)$, that is to say, φ measures the deviation of degree of returns to scale from unity (i.e. $\varphi < 0$, $\varphi > 0$ and $\varphi = 0$ implies decreasing, increasing and constant returns to scale, respectively).

Differentiating Eq. (2) with respect to time, t, yields the non-constant returns to scale version of the Cobb–Douglas growth equation, namely:

$$y_i = \pi_i + \beta_1(k_i - l_i) + \varphi l_i \tag{3}$$

where lower case letters denote the natural growth rate of the relevant variables.

It is worthwhile to emphasise that as $\varphi <> 0$ the role of labour in productivity growth could be positive, negative or nil depending upon the degree of returns to scale. However, the role of capital deepening is always positive as long as $\beta_1 > 0$.

Turning next to the exact specification of the rate of technical progress, π_i, the following specifications will be tested:

$$\pi_i = \alpha_0 \tag{4}$$

$$\pi_i = \alpha_0 + \alpha_1 Y_{0i} \tag{5}$$

$$\pi_i = \alpha_0 + \alpha_1 Y_{0i} + \alpha_2 Y_{0i}^2 \tag{6}$$

where $Y_{0i} = (Q_{i0}/L_{i0})$, namely, Y_{0i} is the labour productivity level at the initial year in country i.

Therefore, Eq. (4) assumes π_i is constant and identical for all countries. On the other hand, Eq. (5) assumes that the rate differs from country to country due to the technological gap. It is expected that $\alpha_1 < 0$ — that is to say, productivity growth across countries is inversely related to their initial productivity levels, thereby setting a tendency towards convergence (see inter alia, Dowrick and Nguyen (1989) and Bernard and Jones (1996)). Eq. (6) relaxes the assumption of linear divergence/convergence and explicitly tests for non-linearities in π_i.

3. The data

The agricultural output and labour data used are from Prasada Rao (1993) and cover 101 countries in 1970 and 1990. The relevant output data is the nominal value of final agricultural output.[1] It is recognised that differences in non-agricultural inputs, such as fertiliser, are not accounted for. The

[1] That is to say, net of output used in agricultural production — seeds, feed, etc.

1990 output data was converted to 1970 dollars using implicit price deflators given in the report.[2] The choice of price deflator does not qualitatively affect any of the results reported in this paper.

For measures of the capital stock, there are no value data available for most of the countries under consideration. Here, number of tractors and the amount of agricultural machinery (in metric tonnes) are used as proxies for capital stock.[3] These data are from the FAOSTAT database.

Finally, the growth rates in output, capital and labour are averages of log growth rates from 1970 to 1990. That is to say:

$$x = (\ln X_{i,90} - \ln X_{i,70})/20$$

4. Results

Stochastic versions of Eq. (3), using Eqs. (5) and (6) as the technical progress function, are estimated and reported in Table 1.

The first two columns in Table 1 are the OLS estimates of labour productivity growth regressed against the rate of technical progress (from Eqs. (5) and (6)). The first equation in the table reveals

Table 1
Estimated agricultural growth equations, 1970–1990[a]

Parameter/ statistics	Equation number:					
	(I)	(II)	(IIIa)	(IIIb)	(IVa)	(IVb)
α_0	−0.036	−0.142	−0.130	−0.137	−0.026	−0.025
	(−3.93)	(−3.24)	(−3.35)	(−3.44)	(−0.77)*	(−0.75)*
α_1	0.009	0.042	0.035	0.037	0.011	0.010
	(6.21)	(3.12)	(2.94)	(3.06)	(1.05)*	(1.05)*
α_2	–	−0.002	−0.002	−0.002	−0.0006	−0.0006
		(−2.46)	(−2.13)	(−2.27)	(−0.84)*	(−0.86)*
β_1	–	–	0.177	0.160	0.103	0.102
			(5.32)	(4.69)	(3.62)	(3.68)
φ	–	–	–	–	−0.665	−0.694
					(−7.38)	(−7.94)
$\bar{R}^2$	0.273	0.308	0.459	0.431	0.651	0.653
LLF	260.56	263.59	276.53	273.93	299.23	299.44
RESET(2)	6.07	9.17	1.02	0.73	0.18	0.12
$\beta_1 + \beta_2$	–	–	1.00	1.00	0.335	0.306

[a] Data source: see Section 3.

Notes: in Eqs. (IIIa) and (IVa) the proxy for capital stock is number of tractors whereas in Eqs. (IIIb) and (IVb) metric tonnes of machinery is the proxy. Figures in parentheses are t statistics (* indicates that the estimated coefficient is not statistically significantly different from zero at the 0.05 test level). $\bar{R}^2$, LLF and RESET(2) are adjusted coefficient of determination, the log of likelihood function and RESET(2) statistic, respectively.

[2] For converting between currencies, Prasada Rao used price parities calculated for the agricultural sector.

[3] There is a high degree of correlation between the number of tractors and other forms of agricultural capital, such as the number of combine harvesters.

that $\alpha_1 > 0$ and is statistically significant. This suggests that, assuming linear convergence/divergence, there exists significant divergence among the 101 countries under consideration. However, the second equation in Table 1 shows that this divergence is non-linear (quadratic). That is to say, labour productivity growth rates across countries are directly related to their initial productivity levels, thereby setting a tendency in agriculture towards divergence but at a decelerating rate. However, these two simple equations fail the RESET test, hence suggesting misspecification or omitted variables.

A remedy to this problem is to estimate the constant and non-constant returns production functions to assess the role of capital deepening and economies of scale in productivity growth. Consequently Eq. (3) is estimated using Eq. (6) as the appropriate technical progress function. These results are also reported in Table 1. Before we examine the results it is important to emphasise that both capital proxy measures discussed in the previous section (number of tractors and amount of agricultural machinery in metric tonnes) give very similar, if not identical, results.

Turning to the econometric and economic interpretation of these estimates, taking capital deepening into account significantly improves the results, even with the assumption of constant returns to scale. Likelihood ratio, $\bar{R}^2$ and RESET tests show that this is a statistically significantly better result than the first two equations in the table that hypothesise that differences in productivity growth rates are solely due to the level of economic development (proxied by the initial productivity level). Nonetheless, the constant returns to scale production function still shows statistically significant divergence.

However, once the constant returns to scale assumption is relaxed, it is apparent from the last two columns that this is the ‘best’ specification. As can be seen from the table, estimates (IVa) and (IVb) do not suffer from misspecification problems. Furthermore, appropriate likelihood tests would show that these equations are statistically significantly better than those in the first four columns of the table.

These last two equations, therefore, are the appropriate ones to interpret. They show that the differences in labour productivity growth among the countries are solely due to different rates of capital deepening and labour input growth. These generate differing adverse effects on agricultural productivity growth rates. It can be seen from the unconstrained production function in Section 2 that these adverse effects are generated by huge and statistically significant diseconomies of scale in agriculture ($\beta_1 + \beta_2 = 0.335$ in (IVa) and $\beta_1 + \beta_2 = 0.306$ in (IVb) in the table).

Finally, it should be emphasised that once diseconomies of scale and the role of capital deepening are taken into account, the role of convergence/divergence is statistically insignificant in explaining different productivity growth rates among the countries considered.

5. Concluding remarks

This paper has shown how to use a non-constant returns Cobb–Douglas production function to assess the role for the stage of economic development and the convergence/divergence hypothesis in explaining productivity growth differences among countries.

The results obtained from cross-country agricultural data show that when non-constant returns to scale is taken into account, convergence/divergence is not important and productivity growth differences can be solely explained by diseconomies of scale and differences in capital deepening among countries under consideration.

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