CONVERGENCE CLUBS OF STATE-LEVEL AGRICULTURAL PRODUCTIVITY IN THE U.S.A.

1. Introduction

The determinants and evolution of state-level agricultural productivity in the USA have been the focus of several empirical studies. Huffman and Evenson (1993), Alston *et al*. (1998), and Yee *et al*. (2002) used state-level data to examine the impact of public and private research, agricultural extension, and infrastructure on Total Factor Productivity (TFP); Huffman and Evenson (2001), and Ahearn *et al*. (2002) also used state-level data to investigate the relationship between structural change, R&D, and productivity growth; Ball *et al*. (1999) offered a decomposition of an aggregate (nationwide) TFP growth index to state-specific components, while Acquaye *et al*. (2003) accounted for changes in the composition of inputs and outputs over space and time and obtained new evidence on the evolution of TFP at state and national level.

The analysis of the performance of individual states relative to each other, however, has received much less attention. This despite the fact that convergence in productivity both between as well as within industries and countries has been a central topic in applied economic research since the mid-1980's[1]. McCunn and Huffman (2000) examined convergence in agricultural TFP levels for 42 states in the USA over the period 1950-82. They found no evidence of σ-convergence and of unconditional/absolute convergence. They could not, however, reject the hypothesis of conditional convergence[2]. Ball

[1] For a review of studies see Islam (2003).

[2] σ-convergence occurs when the dispersion of cross-section distribution of TFP levels diminishes over time; unconditional/absolute convergence occurs when there is *a unique* long-run equilibrium TFP level to which *all* states approach; conditional convergence occurs when each state approaches *its own* long-run equilibrium TFP level which may well be different from the long-run equilibrium TFP levels of the remaining states. For further details about the relationships among the alternative concepts of convergence see McCunn and Huffman (2000), and Islam (2003).

et al. (2004) investigated convergence in agricultural TFP levels for 48 states over the period 1960-99. They found that the coefficient of variation indicated some narrowing in the dispersion of the TFP levels with time. They (as McCunn and Huffman (2000)) also obtained evidence of conditional convergence.

The works of McCunn and Huffman (2000) and Ball *et al*. (2004) utilized the so called *formal cross-section approach* (Islam, 2003) which relies on the cross-section correlation between the initial TFP levels and the subsequent growth rates. A negative and statistically significant correlation coefficient is taken as an evidence of convergence because it implies that, on average, states with low initial TFP levels grow faster than states with high initial TFP levels. Several researchers (e.g. Quah, 1993, 1996 and 1997; Lichtenberg, 1994; Bernard and Durlauf, 1996), however, have shown that the formal cross-section approach (or Barro's regression) has many limitations and have seriously questioned its usefulness. Also, conditional convergence is considered to be the least interesting notion of convergence since, in principle, it allows for as many as long-run equilibrium TFP levels as the number of states under study. According to Baumol (1986), once the absolute convergence is rejected by the data the researcher should look for *convergence clubs*. The notion of club convergence is based on models (e.g. Azariades and Drazen, 1990) that yield *multiple equilibria*. Which of these different equilibria a state will reach, depends on its initial position or some other attribute. The states approaching a particular long-run equilibrium TFP level (because they share the initial condition or the attribute corresponding to that equilibrium) constitute a convergence club.

Although the need for endogenous selection of convergence clubs has been widely recognized from the very beginning of the convergence debate the issue has only recently received a systematic treatment. Bernard and Durlauf (1996) and Hobjin and Franses (2000) explored the relationships among different types of convergence and proposed clustering on the basis of common asymptotic behavior of the variables of interest (here, state agricultural TFP levels).

In this context, the objective of the present work is to identify potential convergence clubs (that is, number of clubs by type of convergence and number of states belonging to each club) in state-level agricultural productivity in the USA. There has been a number of studies on club convergence (e.g. Fare, Grosskopf, and Margaritis (2006) for labor productivity in E.U. manufacturing; Alexiadis and Tomkins (2004) for the regions of Greece; and Hobjin and Franses

(2000) for per capita income in a number of countries). To the best of my knowledge, however, there have been no empirical works on convergence clubs for agricultural TFP within a country. In what follows, section 2 contains a preliminary analysis of the data with emphasis on σ-convergence. Section 3 presents the analytical framework and section 4 the empirical results. Section 5 offers conclusions. A Technical Appendix contains the empirical values for all test statistics calculated in the process of the endogenous state clustering.

2. Investigation of σ-convergence

The data for this study come from the Economic Research Service (ERS) of the US Department of Agriculture (USDA). The ERS/USDA database contains TFP levels for 48 contiguous states over the period 1960-99 all expressed relative to the TFP level of Alabama in 1996. Exactly the same data have been used in the relevant study of Ball *et al*. (2004) and a full documentation is available in Ball *et al*. (2001)[3]. Given that the agricultural productivity is subject to random shocks due to adverse weather conditions or diseases, 3-year moving averages of TFP levels have been computed prior to the analysis in order to reduce random noise[4].

As mentioned in the Introduction, Ball *et al*. (2004) by using the coefficient of variation (CV) concluded that there has been some narrowing in the range of TFP levels across states with time. The evolution of the CV statistic (defined as the ratio of the cross-section standard deviation to the cross-section average), however, is

[3] The 48 contiguous states considered in this study are AL: (Alabama), AR (Arkansas), AZ (Arizona), CA (California), CO (Colorado), CT (Connecticut), DE (Delaware), FL (Florida), GA (Georgia), IA (Iowa), ID (Idaho), IL (Illinois), IN (Indiana), KS (Kansas), KY (Kentucky), LA (Louisiana), MD (Maryland), MA (Massachusetts), ME (Maine), MI (Michigan), MN (Minnesota), MO (Missouri), MS (Mississippi), NC (North Carolina), ND (North Dakota), NE (Nebraska), NH (New Hampshire), NJ (New Jersey), NM (New Mexico), NV (Nevada), NY (New York), OH (Ohio), OK (Oklahoma), OR (Oregon), PA (Pennsylvania), RI (Rhode Island), SC (South Carolina), SD (South Dakota), TN (Tennessee), TX (Texas), UT (Utah), VT (Vermont), VA (Virginia), WA (Washington), WV (West Virginia), WI (Wisconsin), and WY (Wyoming).

[4] This implies that TFP level associated with the year 1961 is actually the average of the TFP levels in 1960, 1961, and 1962 and so on. We note that moving averages have been also employed in the works of Ball *et al*. (2001) and Ball *et al*. (2004).

not a really good indicator of whether the range has been narrowing or widening. The reason is simple. The CV may remain constant or even decrease over time in the presence of a widening in the range of TFP levels provided that the cross-section average (M) increases at least as fast as the standard deviation (SD). Figure 1 suggests that this has been precisely what happened with the state-level agricultural productivity in the USA. Over the period under study, both the cross-section average and the cross-section standard deviation have doubled leaving the CV fairly constant.

To pursue this issue a bit further, we use here two alternative tests. The first, is a Likelihood Ratio (LR) test proposed by Carree and Klomp (1996). The second, is a test for the presence of a monotonic trend in dispersion proposed by Brillinger (1989). The test statistic for the former is

$$\Phi = (N - 2.5)\ln[1 + 0.25\frac{[(\hat{\sigma}_1^2 - \hat{\sigma}_T^2)]^2}{(\hat{\sigma}_1^2\,\hat{\sigma}_T^2 - \hat{\sigma}_{1T}^2)}] \quad (1)$$

where N is the number of states, $\hat{\sigma}_1^2$ and $\hat{\sigma}_T^2$ are the variances in the initial and the final year (respectively), and $\hat{\sigma}_{1T}$ is the covariance between the cross-section TFP levels in years 1 and T. Under the null hypothesis ($\hat{\sigma}_1^2 = \hat{\sigma}_T^2$) the statistic follows the χ^2 distribution with 1 degree of freedom. Table 1 presents the test results. The constancy of variance over the total period is rejected. Indeed, the test offers strong

TABLE 1 - *The Results of the LR Test for the Constancy of Variance*

Period	$\hat{\sigma}_1^2$	$\hat{\sigma}_T^2$	Φ-value
1961-98	0.011	0.038	26.785*
1961-70	0.011	0.013	1.112
1970-79	0.013	0.016	2.297
1979-88	0.016	0.027	12.563*
1988-98	0.027	0.038	4.062*

* Statistically significant at the 5 percent level or less. The 5 percent critical value is 3.84.

evidence that there has been a widening in the range of TFP levels. The picture, however, is not uniform since the constancy cannot be rejected for the sub-periods 1961-70 and 1970-79. It appears, therefore, that the increase in the dispersion occurred largely after the early 1980s.

The LR test considers only two years (1 and T). Thus, the test results may be highly dependent on the choice of these time

points which is typically imposed by the available data. Brillinger's test weighs the cross-section variances by a linear combination that induces a strong temporal contrast between the initial and the final period. Under the null hypothesis the cross-section variance is constant ($\sigma_t^2 = \mu$, for every t) while under the alternative it follows a monotonic stochastic trend ($\sigma_t^2 = \mu_t = \varepsilon_t$), where μ_t denotes the level and ε_t is a stationary and strictly invertible zero mean process. The relevant test statistic is

$$\tau = \frac{\sum_{t=1}^{T} w_t \sigma_t^2}{s_L^2 \sum_{t=1}^{T} w_t^2}. \qquad (2)$$

The weights, calculated as $w_t = [(t-1)(1-\frac{t-1}{T})]^{0.5} - [t(1-\frac{1}{T})]^{0.5}$, are such as that $w_{T-j} = -w_{j+1}$ (hence $\sum_t w_t = 0$); s_L^2 is a consistent estimate of the long-run variance of the residuals of the OLS regression of σ_t^2 on a deterministic linear trend[5]. Here we adopt the Newey-West (1987) estimator of the long-run variance

$$s_L^2(l) = \hat{\gamma}(0) + 2\sum_{\tau=1}^{m}(1-\frac{l}{m+1})\hat{\gamma}(l) \qquad (3)$$

which is based on a Bartlett's window with truncation parameter l and $\hat{\gamma}(l)$ is residual autocovariance at lag l[6].

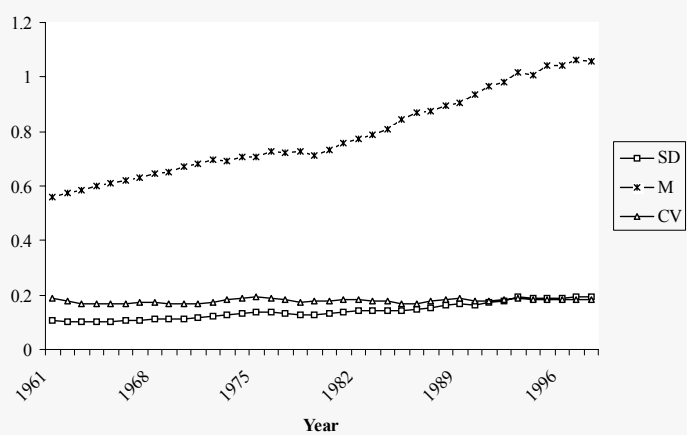
The null distribution of τ can be approximated by the standard normal. For σ-convergence the case of interest is an one-sided test against a monotonically decreasing alternative (i.e. $\mu_t \leq \mu_{t-1}$, with strict inequality for some t). The empirical value of the test statistic turned out to be equal to 116.7 which is by no means significant against the one-sided alternative of the negative tail suggesting that the cross-section TFP variance has not been not decreasing (or even remained constant) but it has exhibited a very strong positive trend. Therefore, the results of the two tests support the visual evidence of Figure 1 (no σ-convergence for all the 48 states) and are in agreement with those by McCunn and Huffman (2000) for 42 states in the period 1950-82.

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[5] The "long-run variance" is defined as the $\lim_{T\to\infty} T^{-1}E(s_T^2)$ where s^2 stands for the residual variance. The s_L^2 is used instead of s^2 to account for possible autocorrelation and heteroscedasticity.

[6] The truncation parameter l has been set equal to 3 which is the integer part of $[4(T/100)^{2/9}]$ as suggested by Newey and West (1994).

FIGURE 1 - *The Evolution of the Standard Deviation, the Average, and the Coefficient of Variation*



3. THE ANALYTICAL FRAMEWORK

Let i and j two states with productivity levels at time t equal to TFP_{it} and TFP_{jt}, respectively. Let also $DL_t = \ln(TFP_{it}) - \ln(TFP_{jt})$ be the difference (contrast) in the natural logarithms of productivity levels at t. For Bernard and Durlauf (1996) and Hobjin and Franses (2000) the TFP levels of the two states converge stochastically when the following condition is satisfied

$$\lim_{k\to\infty} E(DL_{t+k}) = \delta_0 \tag{4}$$

where δ_0 is a constant. In words, stochastic convergence is interpreted to mean that the contrast is always stationary (it contains no deterministic trends or unit roots). On the basis of the value of δ_0, Bernard and Durlauf (1996) and Hobjin and Franses (2000) distinguish between two types of stochastic convergence, namely, the *asymptotically relative* and the *asymptotically perfect*. The former occurs when DL_t is level stationary (that is, when $\delta_0 \neq 0$). Asymptotically relative convergence for *all* states is consistent with a constant dispersion of the TFP distribution in the long-run. The perfect convergence occurs when DL_t is zero-mean stationary (that is, when $\delta_0 = 0$) suggesting that regardless of the initial conditions we expect the TFP levels of the two states to ultimately become equal. The asymptotically perfect (another name for unconditional/absolute convergence) for *all* states is consistent with a zero dispersion of the TFP distribution in the long-run. As far as the relationship between

the two types of convergence is concerned, the asymptotically relative is necessary but not sufficient condition for perfect[7].

The existence of stochastic convergence can be established by carrying out stationarity tests on the relevant contrasts; these tests can be illustrated with reference to a restricted version of the local linear trend model

$$\begin{aligned} DL_t &= \delta_t + \varepsilon_t \\ \delta_t &= \delta_{t-1} + \eta_t, \quad t=1,2,.....,T \end{aligned} \tag{5}$$

where δ_0 is not stochastic, $E(\varepsilon_t)=0$ and $\text{var}(\varepsilon_t)=\sigma^2_\varepsilon$, $E(\eta_t)=0$ and $\text{var}(\eta_t)=\sigma^2_\varepsilon$ and η_t and ε_t are stationary and independent random variables. In particular, for asymptotic relative convergence we are interested in testing the null hypothesis $\sigma^2_\eta=0$ (meaning that $DL_t=\delta_0+\varepsilon_t$) against the alternative $\sigma^2_\eta>0$ (meaning that DL_t is a pure random walk). The test statistic for the problem is

$$\xi_\mu = \frac{\sum_{t=1}^{T} S_t^2}{T^2 s_L^2} \tag{6}$$

where S_t is the partial sum of the residuals of the OLS regression of DL_t on a constant only, and s^2_L is an estimate of the long-run variance (defined in section 2). Critical values for ξ_μ are provided by Kwiatkowski *et al*. (1992). For asymptotic perfect convergence we are interested in testing that DL_t is zero mean stationary (meaning that $DL_t=\varepsilon_t$) against the alternative that DL_t is a pure random walk (with value at t=0 equal to zero). The relevant test statistic (termed as ξ_0) takes exactly the same form as ξ_μ but with S_t being the partial sum of DL_t values and s^2_L being the long-run variance of DL_t. Critical values for ξ_0 are provided by Nabeya and Tanaka (1988).

4. The empirical results

The fact that asymptotically relative convergence is necessary but not sufficient condition for asymptotically perfect convergence suggests a possible way of going about the identification of convergence clubs. That is, the search for clubs of relative convergence comes

[7] When the notion of relative convergence is viewed in a cointegration framework it is consistent with a cointegrating vector for $\ln(TFP_{it})$ and $\ln(TFP_{jt})$ equal to (1, δ_0, -1), while the perfect with a cointegrating ector equal to (1, -1).

first and follows the search for clubs of prefect convergence *within* each relative convergence club.

The definition of stochastic convergence is unambiguous for a two-state situation. This is not so when convergence is considered in a sample of more than two states. In empirical works, however, researchers typically take contrasts from a *benchmark/reference* state as a measure of convergence. In some works (e.g. Bernard and Jones, 1996a and 1996b) the benchmark is the *leading* state (the one with the highest productivity over the sample period). In others (e.g. Alexiadis and Tomkins, 2004; Nahar and Inder, 2002) is the *average* state. Here, we follow Bernard and Jones (1996a and 1996b) by using as benchmark the leading state and the steps of the clustering algorithm become:

1) Select the leading among N states and test the level contrasts with the rest;
2) If the null of asymptotically relative convergence cannot be rejected for all contrasts conclude that all N states belong to the same relative convergence club with the leading and go to (5);
3) If for only k<N-1 contrasts relative convergence cannot be rejected conclude that the k states belong to the same club with the leading one, while the remaining N-k belong to one or more different relative convergence clubs.
4) Select the leading among the N-k and repeat steps (1) to (3) as many times as required to allocate each of the 48 states to an asymptotically relative convergence club (or to classify it as a separate state)[8].
5) For every relative convergence club repeat steps (1) to (4) as many times as required to allocate each of the 48 states to a club of asymptotically perfect convergence (or to classify it as a separate state)[9].

Table A.1 in the Technical Appendix provides details on the clustering algorithm for asymptotically relative convergence along

[8] The separate states are single-member clubs.

[9] The clustering algorithm relies on the theoretical property of *transitivity (triangular consistency test)* according to which if states *i* and *j* converge with the leading, then states *i* and *j* also converge to each other. Because convergence is a long-run notion while the time horizon of most available data sets is relatively short, the triangular consistency test may fail sometimes. Proietti (2005) using GDP levels from 20 Italian regions, found that the transitivity property was not supported by the data for a handful of cases. The same is true for this study as well. We note, however, that transitivity cannot be imposed *a priori* on the data and all empirical works on convergence make use of this property explicitly or implicitly.

with the empirical values of the test statistics, and Table 2 presents the suggested relative convergence clubs. There are four clubs of this type involving 26, 7, 11, and 3 members, respectively, while WY appears to be a separate state. The presence of multiple clubs of relative convergence indicates that the dispersion of the cross-section TFP distribution in the long-run is not constant something which is in agreement with the empirical results on σ-convergence in section 2.

TABLE 2 - *Asymptotically Relative Convergence*

Club No	States Belonging to a Club
1.	CA, AL, CT, DE, FL, GA, IA, ID, IN, KS, KY, LA, MA, MD, ME, MN, ND, NE, OH, PA, RI, SC, SD, UT, VA, WV
2.	NC, AR, MI, MS, OR, TN, WA
3.	AZ, MT, NH, NJ, NM, NV, NY, OK, TX, VT, WI
4.	CO, IL, MO
	Separate States
	WY

Table A.2 in the Technical Appendix provides details on the clustering algorithm for asymptotically perfect convergence along with the empirical values of the test statistics, and Table 3 presents the suggested perfect convergence clubs. There are eleven clubs of this type involving from a minimum 2 to a maximum 6 members, while 14 states appear as separate.

Several researchers have argued in the past that, if convergence is plausible at all, it is surely more likely to be true across regions *within* a country because the flow of factors is easier and such regions are subject to similar policy and technological constraints (e.g. Barro and Sala-i-Martin, 1991; Button and Pentecost, 1993). McCunn and Huffman (2000), however, emphasize that agriculture production is one of biological process and strongly influenced by geoclimatic conditions rendering, thus, unconditional/absolute convergence highly unlikely. Moreover, land (a major production factor) is immobile. The large number of separate states and the relative small number of members in each club indicate that perfect convergence is not very common phenomenon in the US agriculture.

TABLE 3 - *Asymptotically Perfect Convergence*

Club No	States Belonging to a Club
1.	CA, FL
2.	DE, IA
3.	ID, KS, NE
4.	ND, SD
5.	LA, IN, MD, MN, SC
6.	KY, AL, ME, PA, RI, UT
7.	CT, OH, MA, VA
8.	MI, TN
9.	NV, NY
10.	TX, OK
11.	VT, MN, NJ, NM
	Separate States
	GA, WV, NC, WA, AR, MS, OR, AZ, WI, NH, CO, IL, MO, WY

As noted in the Introduction, club members are likely to share an initial condition and/or an attribute corresponding to a particular equilibrium. It is interesting, therefore, to identify attributes that may be related to club membership. In this work (and constrained by the lack of other potentially relevant information) we consider two attributes. Namely, the state location and the state research profile (which, in turn, reflects output priorities).

To examine the role of location we make use of the so called Old ERS grouping (a purely geographical one involving ten farm production regions made up of contiguous states)[10]. With that grouping in mind, we observe that the asymptotically perfect converge club no 1 consists of states (CA and FL) which belong to different ERS regions. The same is true for clubs no 2 (DE, and IA), no 5 (LA, IN, MD, MN, and SC), no 8 (MI, and TN), and no 9 (NV, NY). However, club no 10 consists of two states (TX, and OK) which form the ERS group "Southern Plains". Also, the

[10] In the Old grouping, the regions follow state boundaries. Recently, a New grouping has been developed by ERS where farm production regions are made up of counties which may belong to different states (see ERS, 2005). The New grouping is likely to represent more accurately the geographic distribution of the US farm production. It cannot, however, be utilized here since the TFP data are state-level ones.

two members of club No 4 (ND, and SD) belong to the ERS group "Northern Plains". Moreover, two (KS, and NE) out of the three members of club no 3 belong to the ERS group "Northern Plains", three (ME, PA, and RI) out of the six members of club no 6 belong to group "Northeast", two (CT, and MA) out of the four members of club no 7 belong to group "Northeast", and two (VT and NJ) out of the four members of club no 11 also belong to group "Northeast". Overall the comparison of the clubs obtained here with the ERS grouping appears to provide some evidence that location may play a role in perfect convergence of productivity[11].

To examine the role of state research profile we use the results of the study by the National Research Council (NRC, 1995) on colleges of agriculture and land grand universities. That study relied on cluster analysis to classify State Agricultural Experimental Stations (SAES's) into 9 commodity groups on the basis of the allocation of their research expenditure[12]. With the NRC grouping in mind, we observe that the perfect converge clubs no 2, 6, 8, 9, 10, and 11 consist of states which belong to different NRC clusters. However, the two members of club no 1 (CA, and FL) form the NRC cluster "Vegetables, Citrus, and Other Fruits", the three members of club no 3 (ID, KS, NE) belong to the NRC cluster "Beef Cattle, Wheat, and Vegetables", and the two members of club no 4 (ND, and SD) also belong to the NCR cluster "Beef Cattle, Wheat, and Vegetables". Moreover, three (CT, OH, and MA) out of the four members of club no 7 belong to the NRC cluster "Dairy, Vegetables, and Poultry". Overall the comparison of the clubs obtained here with the NRC clusters appears to provide some evidence that the research profile (reflecting output priorities) may play a role in perfect convergence of productivity.

5. Conclusions

The objective of the present study has been to investigate empirically the existence of convergence clubs in state-level

[11] We note that McCunn and Huffman (2000) found σ-convergence within the regions Central (ERS "Corn Belt"+ERS "Lake" states), Southeast (ERS "Southeast"+ERS "Appalachian" states), and "Pacific" states.

[12] See Figure 7.4 in the NRC report. The states in the NRC clusters are non-contiguous.

agricultural productivity of the USA. This have been pursued using data from 48 contiguous states over the period 1960-99 and time series methods which endogenously allocate states to clubs on the basis of the long-run behavior of the respective TFP levels.

According to the results, there is no unique steady state to which all states converge. Instead, there are multiple equilibria each of them attracting a rather small number states. Moreover, the agricultural productivity levels of almost 1/3 of states approach their own long-run values giving, thus, rise to a considerable number of single-member clubs. A possible explanation of the empirical results lies in nature of agricultural production (a biological process, highly dependent geoclimatic conditions) which makes unconditional convergence unlikely even within the borders of a country.

The New Growth Theory suggests that convergence stems from similarities in initial conditions or in attributes. In this work an attempt has been made to relate the endogenously selected perfect converge clubs with state location and state agricultural research profile. Both attributes appear to play a certain role which is, however, by no means decisive. Given that a single state often encompass different soils and typography which are associated with different agricultural production patterns more detailed information on TFP (possibly at county level) is necessary to draw solid conclusions about the relation between convergence and geographical location.

With regard to agricultural research, it is widely recognized that productivity catching-up is determined not only by the effort undertaken within a state but also by the ease by which scientific information is transferred and exchanged. As noted by McCunn and Huffman (2000) in the USA agricultural research spillins are currently determined by two forces. The Federal Technology Transfer Act, which allows cooperative research agreements between federal laboratories, private laboratories, and universities, promotes greater sharing of new technologies across geographical areas. The strengthening, however, of the intellectual property rights (IPRs) and the increase in the share of agricultural R&D undertaken by the private sector appears to provide forces pulling in the opposite direction which can slow technology sharing.

Panos Fousekis

Department of International European Economic and Political Studies, University of Macedonia, Thessaloniki, Greece

REFERENCES

Acquaye, A., J. Alston and G. Pardey (2003), "Post-War Productivity Patterns in US Agriculture: Influence of Aggregation Procedures in State-Level Analysis", *American Journal of Agricultural Economics*, 85: 59-80.

Ahearn, M., J. Yee and W. Huffman (2002), *R&D, Productivity, and Structural Change in US Agriculture, 1960-96*, paper presented at the NBR Summer Institute Conference on Income and Wealth, Cambridge, Massachusetts, July 29-31.

Alexiadis, S. and J. Tomkins (2004), "Convergence Clubs in Regions of Greece", *Applied Economics Letters*, 11: 387-91.

Alston, J., B. Craig and P. Pardey (1998), "Dynamics in the Creation and Depreciation of Knowledge, and Returns to Research", EPDT Discussion Paper No. 35, International Food and Policy Research Institute: Washington D.C.

Azariades, C. and A. Drazen (1990), "Threshold Externalities in Economic Development", *Quarterly Journal of Economics*, 105: 501-26.

Ball, E., F. Gollop, A. Kelly-Hawke and G. Swinand (1999), "Patterns of State Productivity Growth in the US Farm Sector: Linking State and Aggregate Models", *American Journal of Agricultural Economics*, 81: 164-79.

Ball, V.E., J-P. Butault and R. Nehring (2001), "US Agriculture, 1960-96. A Multilateral Comparison of Total Factor Productivity", Technical Bulletin No 1895, May.

Ball, E., C. Hallahan and R. Nehring (2004), "Convergence in Productivity: An Analysis of the Catch-up Hypothesis Within a Panel of States", *American Journal of Agricultural Economics*, 86: 1315-21.

Barro, R. and X. Sala-i-Martin (1991), "Convergence across States and Regions", *Brooking Papers on Economic Activity*, 1: 107-82.

Baumol, J. (1986), "Productivity Growth, Convergence and Welfare: What the Long-run Data Show", *American Economic Review*, 76: 1072-86.

Bernard, A. and S. Durlauf (1996), "Interpreting Tests of Convergence Hypothesis", *Journal of Econometrics*, 71:161-73.

Bernard, A. and C. Jones (1996a), "Productivity across Industries and Countries: Time Series Theory and Evidence", *Review of Economics and Statistics*, 78: 135-46.

Bernard, A. and C. Jones (1996b), "Comparing Apples to Oranges: Productivity Convergence and Measurement across Industries and Countries", *American Economic Review*, 86: 1216-38.

Brillinger, R. (1989), "Consistent Detection of Monotonic Time Trend superposed on a Stationary Time Series", *Biometrica*, 76: 23-30.

Button, K. and E. Pentecost (1993), "Regional Service Sector Convergence", *Regional Studies*, 27: 623-36.

Carree, M. and L. Klomp (1996), "Testing the Convergence Hypothesis: a Comment", *Review of Economics and Statistics*, 79: 683-86.

ERS/USDA (2005), "Research Emphasis. Harmony Between Agriculture and the Environment: Current Issues", http://www.ers.usda.gov/emphases/harmony/issues

Fare, R., S. Grosskopf and D. Margaritis (2006), "Productivity Growth and Convergence in the E.U.", *Journal of Productivity Analysis*, 25: 111-136.

Hobjin, B. and P. Franses (2000), "Asymptotically Perfect and Relative Convergence in Productivity", *Journal of Applied Econometrics*, 15: 59-81.

Huffman, W. and E. Evenson (1993), Science for Agriculture, Iowa State University, Ames, Iowa.

Huffman, W. and E. Evenson (2001), "Structural and Productivity Change in US Agriculture, 1950-82", *Agricultural Economics*, 24: 127-47.

Islam, N. (2003), "What have we learned from the Convergence Debate?", *Journal of Economic Surveys*, 17: 309-62.

Kwiatkowski, D., P. Phillips, P. Schimdt and Y. Shin (1992), "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root", *Journal of Econometrics*, 54: 179-78.

Lichtenberg, F. (1994), "Testing the Convergence Hypothesis", *Review of Economics and Statistics*, 76: 576-79.

McCunn, A. and W. Huffman (2000), "Convergence in US Productivity Growth for Agriculture: Implications of Interstate Spillovers for funding Agricultural Research", *American Journal of Agricultural Economics*, 82: 370-88.

Nabeya, S. and K. Tanaka (1988), "Asymptotic Theory of a Test for a Constancy of Regression Coefficients against the Random Walk Alternative", *The Annals of Statistics*: 16: 218-35.

Nahar, S. and B. Inder (2002), "Testing Convergence in Economic Growth for OECD Countries", *Applied Economics*, 34: 2011-2022.

Newey, K. and D. West (1987), "A simple Positive-Semidefinite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix", *Econometrica*, 55: 703-8.

Newey, K. and D. West (1994), "Automatic Lag Selection in Covariance Matrix Estimation", *Review of Economic Studies*, 61: 631-53.

National Research Council (1995), "Colleges of Agriculture at the Land Grand Universities: A Profile", Committee on the Future of the Colleges of Agriculture in the Land Grand University System; National Academy Press: Washington D.C.

Proietti, T. (2005), "Convergence in Italian Regional per-capita GDP", *Applied Economics*, 37: 497-506.

Quah, D. (1993), "Empirical Cross-Section Dynamics in Economic Growth", *European Economic Review*, 37: 426-34.

Quah, D. (1996), "Regional Convergence Clusters across Europe", *European Economic Review*, 40: 951-58.

Quah, D. (1997), "Empirics for Growth and Distribution: Stratification, Polarization, and Convergence Clubs", *Journal of Economic Growth*, 2: 27-59.

Yee, J., W.E. Huffman, M. Ahearn and D. Newton (2002), *Sources of Agricultural Productivity Growth at State Level, 1960-93*, in: Ball E. and Norton G.W. (Eds.), Agricultural Productivity: Measurement and Sources of Growth, 184-212, Kluwer Academic Publishers: Norwell, Massachusetts.

TECHNICAL APPENDIX

Estimation Results

TABLE A.1 - *Tests for Asymptotically Relative Convergence**

Leading State: CA

AL=0.222	AR=**0.647**	AZ=**0.695**	CO=**0.655**	CT=0.397	DE=0.250
FL=0.188	GA=0.433	IA=0.457	ID=0.284	IL=**0.477**	IN=0.209
KS=0.456	KY=0.197	LA=0.347	MA=0.147	MD=0.388	ME=0.368
MI=**0.827**	MN=0.395	MO=**0.528**	MS=**0.470**	MT=**0.614**	NC=**0.568**
ND=0.098	NE=0.205	NH=**0.469**	NJ=**0.624**	NM=**0.557**	NV=**0.865**
NY=**0.653**	OH=0.145	OK=**0.934**	OR=**0.635**	PA=0.195	RI=0.071
SC=0.194	SD=0.377	TN=**0.759**	TX=**0.607**	UT=0.379	VA=0.435
VT=**0.604**	WA=**0.779**	WI=**0.681**	WV=0.260	WY=**0.904**	

Leading State: NC

AR=0.351	AZ=**0.887**	CO=**0.903**	IL=**0.889**	MI=0.140	MO=**0.847**
MS=0.429	MT=**0.935**	NH=**0.933**	NJ=**0.900**	NM=0.853	NV=**0.880**
NY=**0.872**	OK=**0.870**	OR=0.262	TN=0.116	TX=**0.942**	VT=**0.985**
WA=0.176	WI=**0.882**	WY=**1.003**			

Leading State: AZ

CO=**0.555**	IL=**0.618**	MO=**0.705**	MT=0.061	NH=0.428	NJ=0.399
NM=0.249	NV=0.387	NY=0.172	OK=0.278	TX=0.420	VT=0.213
WI=0.145	WY=**0.848**				

Leading State: CO

IL=0.366	MO=0.199	WY=**0.961**

*The 5 percent critical value is 0.463. Bold characters indicate statistical significance at the 5 percent level (or less).

TABLE A.2 - *Tests for Asymptotically Perfect Convergence**

A.2.1: *Test Statistics for States Belonging to Same Asymptotically Relative Convergence Club with California*

Leading State: CA

AL=**261.2**	CT=**121.6**	DE=**32.2**	FL=0.926	GA=**24.4**	IA=**28.1**
ID=**63.3**	IN=**167.1**	KS=**28.5**	KY=**649.1**	LA=**11.5**	MA=**286.2**
MD=**270.3**	ME=**236.4**	MN=**178.4**	ND=**106.1**	NE=**106.3**	OH=**518.3**
PA=**558.6**	RI=**126.7**	SC=**434.9**	SD=**54.9**	UT=**167.9**	VA=**49.7**
WV=**1316.4**					

Leading State: GA

AL=**267.7**	CT=**164.4**	DE=**2.61**	IA=**5.81**	ID=**72.06**	IN=**107.3**
KS=**7.51**	KY=**266.1**	LA=**205.6**	MA=**177.3**	MD=**54.2**	ME=**114.7**
MN=**57.9**	ND=**39.3**	NE=**45.5**	OH=**304.5**	PA=**312.6**	RI=**42.1**
SC=**250.7**	SD=**22.2**	UT=**94.2**	VA=**621.7**	WV=**801.8**	

Leading State: DE

AL=**32.4**	CT=**25.4**	IA=0.81	ID=**2.28**	IN=**23.1**	KS=**2.42**
KY=**37.5**	LA=**26.8**	MA=**93.3**	MD=**56.9**	ME=**100.4**	MN=**20.4**
ND=**5.17**	NE=**3.14**	OH=**78.2**	PA=**49.1**	RI=**26.4**	SC=**27.1**
SD=**5.98**	UT=**66.3**	VA=**50.9**	WV=**244.6**		

Leading State: ID

AL=**80.9**	CT=**138.1**	IN=**65.3**	KS=0.439	KY=**52.8**	LA=**22.4**
MA=**88.6**	MD=**9.5**	ME=**50.2**	MN=**16.6**	ND=**1.86**	NE=0.161
OH=**120.4**	PA=**124.2**	RI=**15.7**	SC=**39.8**	SD=**4.26**	UT=**57.8**
VA=**181.4**	WV=**712.2**				

Leading State: ND

AL=**28.5**	CT=**25.7**	IN=**14.8**	KY=**75.2**	LA=**8.54**	MA=**27.9**
MD=**4.28**	ME=**35.3**	MN=**9.61**	OH=**73.1**	PA=**54.4**	RI=**11.8**
SC=**13.3**	SD=1.109	UT=**29.6**	VA=**42.9**	WV=**492.9**	

Leading State: LA

AL=**8.61**	CT=**11.9**	IN=0.77	KY=**18.8**	MA=**19.1**	MD=0.801
ME=**10.5**	MN=0.46	OH=**47.79**	PA=**20.8**	RI=**5.32**	SC=1.526
UT=1.526	VA=**30.2**	WV=**492.9**			

Leading State: KY

AL=0.533	CT=**2.03**	MA=**2.55**	ME=0.673	OH=**6.94**	PA=0.256
RI=1.12	UT=1.13	VA=**5.99**	WV=**307.1**		

Leading State: CT

OH=0.236	MA=0.161	VA=0.098	WV=**142.4**

* The 5 percent critical value is 1.656. Bold characters indicate statistical significance at the 5 percent level (or less).

A.2.2: *Test Statistics for States Belonging to Same Asymptotically Relative Convergence Club with North Carolina*

Leading State: NC

AR=**5.49**	MI=**243.6**	MS=**19.24**	OR=**78.9**	TN=**190.8**	WA=**1.790**

Leading State: WA

AR=**2.12**	MI=**1122.3**	MS=**53.2**	OR=**776.7**	TN=**270.3**

Leading State: AR

MI=**448.8**	MS=**24.6**	OR=**173.8**	TN=**417.7**

Leading State: MS

MI=**288.2**	OR=**204.8**	TN=**108.5**

Leading State: OR

MI=**102.7**	TN=**171.6**

Leading State: MI

TN=0.189

* The 5 percent critical value is 1.656. Bold characters indicate statistical significance at the 5 percent level (or less).

A.2.3: *Test Statistics for States Belonging to Same Asymptotically Relative Convergence Club with Arizona*

Leading State: AZ

MT=**207.8**	NH=**92.3**	NJ=**485.9**	NM=**651.8**	NV=**27.4**	NY=**79.2**
OK=**18.8**	TX=**41.2**	VT=**86.5**	WI=**269.1**		

Leading State: NV

MT=**37.8**	NH=**32.2**	NJ=**49.8**	NM=**49.4**	NY=0.869	OK=**1.74**
TX=**2.08**	VT=**22.9**	WI=**14.2**			

Leading State: TX

MT=**38.3**	NH=**87.8**	NJ=**53.2**	NM=**25.2**	OK=0.370	VT=**28.2**
WI=**2.15**					

Leading State: TX

MT=**24.5**	NH=**17.3**	NJ=**66.3**	NM=**46.8**	VT=**11.6**

Leading State: WI

MT=0.315	NH=**6.84**	NJ=0.261	NM=0.296

A.2.4: *Test Statistics for States Belonging to Same Asymptotically Relative Convergence Club with Colorado*

Leading State: CO

IL=**10.81**	MO=**245.1**

*The 5 percent critical value is 1.656. Bold characters indicate statistical significance at the 5 percent level (or less).

ABSTRACT

The objective of the present study is to investigate empirically the existence of convergence clubs in state-level agricultural productivity of the USA. This is pursued using Total Factor Productivity (TFP) data from 48 contiguous states over the period 1960-99 and time series methods which endogenously allocate states to clubs on the basis of the long-run behavior of the respective productivity levels. According to the results, there are multiple equilibria each of them attracting a rather small number states, while a large portion of states form single-member clubs.

Key Words: Convergence, Productivity, USA

JEL Classification: C22, D24

RIASSUNTO

Convergence clubs della produttività agricola a livello di stato negli USA

L'obiettivo di questo studio è analizzare empiricamente l'esistenza di club di convergenza nella produttività agricola degli U.S.A. a livello di ciascuno stato. A tal fine si utilizzano i dati della produttività totale dei fattori (FTP) relativi a 48 stati contigui nel periodo 1960-1999 con analisi di serie temporale che endogenamente collocano gli stati in club sulla base dell'andamento di lungo periodo dei rispettivi livelli di produttività. I risultati mostrano l'esistenza di equilibri multipli che attraggono un numero di stati piuttosto basso, mentre numerosi stati generano club "mono-membro".