A Theoretical Development and Empirical Test on the Convergence of Agricultural Productivity in the USA

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Abstract

We find no support for the U.S. state level agricultural total factor productivity convergence; however, there seems to be some support for convergence at the regional level. Parametric and nonparametric models indicate significant role of human capital in explaining the regional discrepancies in agriculture productivity across states.

Keywords: agricultural total factor productivity, human capital, parametric and nonparametric models, U.S. States

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Growth theory and its concept of convergence or divergence has been a point of debate for a long time. The standard neoclassical growth model, as presented by Solow (1956), predicts technological change as an exogenous process that can be transferable from developed countries to developing countries. Ramsey (1928) and Samuelson (1958), and the followers of these two researchers further developed the concept of growth differences across countries and regions. Contrary to the neoclassical growth theory, new growth theory (also known as endogenous growth theory) lead by Romer (1986) and Lucas (1988) consider technological change as an endogenous process suggesting that growth could differ permanently across countries, reflecting differences in structural characteristics. This theory allows for the possibility of a sustained increase in the level of international or interregional inequality in terms of per-capita real income or productivity growth, arguing that there will be no convergence between rich and poor countries. With the appearance of this new growth theory, neoclassical growth theory lost its modesty of claiming to explain at most the growth process of industrialized capitalist countries (Wichmann 1996). However, Mankiw (1995) argued that when capital includes both physical and human capital, this would support convergence theory proposed by the neoclassical growth models.

The neoclassical growth model, predicts that differences in per-capita real incomes among economies with similar steady-state parameters, such as saving rates and human capital growth rates, must be transitory, which in long-run should lead to convergence of economies. In simple terms, we can say that there is a convergence in a given sample when the poorer economies in it grow comparatively faster than their industrialized (rich) neighbors. Convergence literature describes two types of convergence: absolute (unconditional) and conditional convergence. The absolute convergence tests whether per-capita real income (or total factor productivity) converges to a steady-state value, irrespective of other factors within a given country. Conversely, the conditional convergence allows each country to have a different level of per-capita real income towards which it is converging (Miller and Upadhyay 2002).

Literature

The emergence of new growth theory has lead to numerous studies in growth theory across countries; empirical tests of convergence hypothesis (e.g., Baumol, 1986; Barro, 1991; Barro and Sala-i-Martin, 1995; De Long, 1988; Islam, 1995; and Mankiw et al., 1992) had found absolute convergence only for the developed countries. These studies were based on two common assumptions: developing countries are not fundamentally different from industrialized countries and free world wide availability of technological knowledge. However, conditional convergence was found in some cases where sample consisted of both developed and developing countries.

Some of the studies focused on estimating convergence based on total factor productivity. Miller and Upadhyay (2002), studied convergence hypothesis for both real GDP per worker and total factor productivity for a pooled cross-section using time-series sample for developed countries. The authors found a strong evidence of convergence for total factor productivity than for real GDP, indicating that technological convergence as an important phenomenon. The results indicated a strong evidence of convergence of total factor productivity for low- and middle-income countries, and somewhat weaker evidence for higher-income countries. This indicates that technological innovations that increase total factor productivity, is a public good that can be transferred from one region to another, facilitating the convergence of total factor productivity (Miller and Upadhyay 2002).

There is a general belief that productivity grows less rapidly in agriculture than in manufacturing sector. Some of economists had found that transfer of improved agricultural techniques from the industrialized countries is a lengthy process. It is this notion of slow productivity growth in agriculture that has resulted in developing several theories and policies of economic development that favors the manufacturing sector. For example, Wichmann (1996) analyzed technology adoption in agriculture and convergence across economies and found that there exists an optimal technological gap between developed and developing countries, indicating full convergence never takes place between industrialized and developing countries. Contrary to this belief the empirical convergence literature is based on free transferability of technology. A study performed by Martin and Mitra (1999) on productivity growth and convergence in agriculture and manufacturing resulted in favor of agriculture sector. The authors found that at all levels of development, technical progress was faster in agriculture than in manufacturing. Moreover, they found a strong evidence of a rapid convergence in levels and growth rates of total factor productivity in agriculture, indicating relatively rapid transfer of technological innovations (knowledge) from one country to another.

Literature also emphasizes on convergence within a given country known as regional convergence. Garofalo and Yamarik (2001) estimated regional convergence by creating a state-by-state capital stock series. This study reconciled the growth empirics' technique of Mankiw, Romer, and Weil (1992) with the empirical results of Barro and Sala-i-Martin (1991) using the new database covering the 1977-96 period. The results indicated a convergence of 2 percent and suggested that the neoclassical growth model of Solow drives empirical results of Barro and Sala-i-Martin.

Modeling and testing convergence hypothesis is presently the topic of debate in convergence literature. Lichtenberg (1992) believes that the hypothesis of convergence and mean-reversion are not equivalent and shows that lowest initial productivity level tended to have the highest subsequent productivity growth does not automatically imply convergence. He shows that under certain conditions degree of convergence (σ convergence) does not depend at all on mean-reversion (β convergence), but under other assumptions it is a necessary condition but not a sufficient condition for convergence (σ convergence). He emphasizes that research should focus on σ convergence rather than β convergence. He proposes a convergence hypothesis that the variance of productivity across countries decreases overtime. If $y_t = \ln(Y_t)$, where Y_t is total factor productivity at time t, the convergence hypothesis model is as follows

$$\frac{d[\text{var}(y_t)]}{dt} < 0 \qquad (1)$$

where $\text{var}(y_t)$denotes the variance across economies. In case of only two time periods, indexed by beginning period (1) and ending period (T), the hypothesis is expressed as

$$[\text{var}(y_1)]/[\text{var}(y_T)] > 1 \qquad (2)$$

Mean-reversion as assumed by Lichtenberg is based on the following equation

$$y_T - y_1 = \beta y_1 + u \qquad (3)$$

the intercept is suppressed for simplicity. The equation is rewritten as

$$y_T = (1+\beta)y_1 + u \quad = \pi y_1 + u \tag{4}$$

where it is assumed that $-1 \leq \beta \leq 0$ and that $0 \leq \pi \leq 1$. According to Lichtenberg most of the previous studies have estimated equation (3) or (4) in order to test the hypothesis that $\beta<0$ or that $\pi<1$. This hypothesis is referred as mean-reversion hypothesis, which indicates that economies with lowest initial productivity level tended to have the highest subsequent productivity growth. Lichtenberg believes this is a necessary for convergence under certain assumptions but not a sufficient condition.

Lichtenberg's convergence hypothesis is as follows

$$\text{(Test Statistic)}T_1 = \frac{\text{var}(A_1)}{\text{var}(A_T)} = \frac{R^2}{(1+\beta)^2} = \frac{R^2}{\pi^2} \tag{5}$$

Lichtenberg believes that the test static indicated by equation (5) has an F distribution with N-2, N-2 degrees of freedom, where N is number of countries and R^2 is regression statistic. He employed this convergence hypothesis to test per capita output convergence for 22 OECD countries from 1960-85. The results indicated mean-reversion but showed no convergence.

Employing Lichtenberg's convergence hypothesis, McCunn and Huffman (2000) analyzed convergence in U.S. productivity growth for agriculture. They used State crop, livestock, and agricultural total factor productivity (TFP) data from 1950-82 to examine the convergence to a single TFP (σ convergence) or to a steady state rate of growth (β-convergence). By σ convergence authors mean that all states have the same steady state and TFP converges to the same level across all states. The β-convergence means each state converges to its own unique steady state. The result indicated no σ convergence but found β-convergence, which is in accordance with Lichtenberg's study.

Carree and Klomp (1996) analyzed and criticized Lichtenberg's (1994) convergence hypothesis test (T_1) that the variance of productivity across countries decreases overtime. Authors argue that Lichtenberg's idea that the ratio of the variance in the first time period to that in the last period of the sample time series as F-distributed, overlooking the dependency between the two variances, creates a probability of committing a type-II error of incorrectly rejecting the convergence hypothesis. The authors propose two alternate tests for testing the convergence hypothesis. The authors derived the first test statistic (T_2) using the likelihood-ratio principle and second statistic (T_3) by correcting distribution of Lichtenberg's test statistic (T_1). The three tests are formulated as follows

$$T_1 = \frac{\hat{\sigma}_{i1}^2}{\hat{\sigma}_{iT}^2} \tag{6}$$

$$T_2 = (N - 2.5)\ln\left[1 + \frac{1}{4}\frac{(\hat{\sigma}_1^2 - \hat{\sigma}_T^2)^2}{\hat{\sigma}_1^2\hat{\sigma}_T^2 - \hat{\sigma}_{1T}^2}\right] \tag{7}$$

$$T_3 = \frac{\sqrt{N}(\hat{\sigma}_1^2 / \hat{\sigma}_T^2 - 1)}{2\sqrt{1 - \hat{\pi}^2}} \tag{8}$$

Where T_1 test statistic is F-distributed with N-2, N-2 degrees of freedom, T_2 test statistic has a χ^2(1)-distribution, and T_3 test statistic has a normal distribution with N-1 degrees of freedom, where N represents number of countries or regions in the sample. Carree and Klomp tested the convergence hypothesis employing these three tests for a data set of gross domestic per capita for 22 OECD countries for the 1950-1994, period. All the three test statistics indicated a decrease in variance of productivities. However, when authors employed the test statistics for the 1960-1985, period Lichtenberg's T_1 test statistic indicated no convergence of gross domestic product while the other two tests (T_2, T_3) indicated convergence. The authors also tested the convergence for short time periods by breaking the 1950-1994 periods in to four sub periods of 12 years. The T_2, T_3 test statistics for these sub periods indicated convergence of GDP while T_1 statistic found no convergence indicating that Lichtenberg's test statistic for shorter time periods has a large probability of committing type-II error.

As mentioned earlier McCunn and Huffman's employed Lichtenberg's test statistic to test for convergence in state agricultural TFP growth rates and as a result of which incorrectly rejected the convergence. This paper tries to test for convergence in state agricultural TFP growth rates employing the three test statistics mentioned earlier and validate the results presented by McCunn and Huffman.

The specific objective of this paper is to test for convergence in U.S state agricultural total factor productivity growth rates. This paper also tests for regional convergence of agricultural TFP in the United States. The study hypothesize that there is absolute convergence of U.S agricultural TFP towards a steady state.

Data

Data used for this study were obtained from United States Department of Agriculture, Economic Research Service. The estimates of TFP for the 48 contiguous States for 1960-96 were obtained. The TFP values were calculated taking Alabama 1996, as the base period. Table 1 illustrates ranking of states in terms of TFP during the initial and last period of the data set. Human capital data for the analysis were obtained from Barro and Sala-i-Martin (1995).

Methods

This study employs three models of convergence for testing the U.S. state agricultural TFP growth rate convergence. The first model is the one employed by Carree and Klomp. The model is as follows

$$y_{it} = \rho y_{i,t-1} + v_{it} \qquad \text{t =2,…,T, i =1,…..,N.} \qquad (9)$$

Where $y_{it} = ln(Y_{it})$, where Y_{it} is the productivity in state I at time t, and

$$\hat{\sigma}_t^2 = \frac{\Sigma_t (y_{it} - \bar{y}_t)^2}{N} \qquad (10)$$

Equation 10 represents the variance of y_{it} across states. The intercept in the equation 9 is suppressed. According to Carree and Klomp the null hypothesis of no convergence is equivalent to the parameter restriction $\rho^2 = 1 - \sigma_v^2 / \sigma_1^2$. Productivities converge overtime in case $\rho^2 < 1 - \sigma_v^2 / \sigma_1^2$. Test static T_2 (equation 7) is used to test the null hypothesis of no convergence for the convergence model specified in equation 9.

The second model employed is the one proposed by Lichtenberg. This equation is derived from equation 9.

$$y_{iT} = \pi y_{i1} + u_t \quad \text{i=1,….,N.} \qquad (11)$$

where $\pi = \rho^{T-1}$ and $u_i = \Sigma_{t=2}^{T} \rho^{T-1} v_{it}$. Lichtenberg proposed T_1 test statistic (equation 6) to test the null hypothesis of no convergence for the model in equation 11, where as Carree and Klomp argued that T_1 test statistic is not correct and proposed T_3 test statistic (equation 8) to test the convergence hypothesis for equation 11.

Third McCunn and Huffman approach is employed to test for unconditional convergence across geographic regions. The model is as follows

$$Var(\ln TFP_t) = \phi_1 + \phi_2 t + \varepsilon_t \quad (12)$$

the sufficient condition for convergence is that the cross-sectional dispersion in agricultural TFP decreases overtime which means that negative ϕ_2 that is significantly different from zero indicates unconditional convergence (McCunn and Huffman). The states are distributed in to regions as illustrated in table 2.

Human capital has been described as the contributor of growth in Mankiw, Romer and Weil (1992), Lucas (1988), and Shultz (1961a, 1961b). Recent researches on total factor productivity convergence are emphasizing the needs for including human capital into TFP model to test for convergence. For example, Miller and Upadhyay (2002) found that human capital has a significant impact on output when it is included as a factor production. Human capital when considered as an input lowers the elasticity of output with respect to labor when compared to the production function without human capital. The authors estimated total factor productivity including human capital as an input and tested for convergence of total factor productivity for OECD countries and found strong evidence of convergence for low- and middle-income countries, and somewhat weaker evidence of convergence for high-income countries. The authors believe that accumulation of human capital through education and training programs are most beneficial for economic performance (Miller and Upadhyay, 2002).

Similar findings were shown in a study done by Coulombe and Tremblay (1998). Their analysis indicated that in an open economy with perfect capital mobility, the dynamics of human capital accumulation is the driving force of economic growth. According to them in the process of convergence, physical capital accumulation is driven by accumulation of human capital, and per capita income disparities across economies are explained by disparities in human capital stock. The results indicated that advance education indicator (human capital) explains roughly 70% of the relative evolution of per-capita income since 1951 across the Canadian provinces.

Maudos, Pastor, and Serrano (1999) developed Malmquist indices of productivity including human capital as an additional input. Their results indicated the existence of a significant effect associated with human capital and its importance for an accurate measurement of TFP.

Following the concept of human capital's impact on growth as described by the earlier researchers, we explore if human capital can describe the disparities in agricultural total factor productivity differences across states over time. The following panel data formulation is used to explore the relationship between human capital and total factor productivity in both parametric and nonparametric specifications

$$TFP_{it} = f(H_{itk}) + u_{it} \qquad (13)$$

Here, TFP is total agricultural factor productivity, H is human capital, u is error term. If the functional form f(H) is specified, it is a parametric model. Our parametric model has linear specification between TFP and H. The number of states (i = 48) and time period (t = 4) for the data are appropriately recognized. The structure of the error term determines whether model should be estimated as fixed or random effect. We estimated fixed effect and random effect models in parametric specifications. Further, error term specification in parametric model varied from i.i.d. to autoregressive and moving average forms. In a nonparametric form, we do not know the functional form between human capital and TFP. Parametric panel data models are estimated using PROC TSCSREG option where as nonparametric model is estimated using PROC LOESS option in SAS version 9.0 developed by the SAS Institute.

Results

To test the convergence of total factor productivity, the data were analyzed using all the three methodologies discussed earlier in the paper. The results using Lichtenberg's approach are presented in Table 3. The results show that the aggregate U.S agriculture sector doesn't show any evidence of convergence across the states based on the total factor productivity.

The results obtained by using Carree and Klomp approach are presented in Table 3. The results suggest that though the approach in testing the convergence hypothesis varies the end result is the same for the data analyzed in this study. We fail to reject the null hypothesis of no convergence using this approach. Conclusion from this approach is similar to the above approach that there exists no convergence in the U.S agricultural sector at the aggregate state level.

McCunn and Huffman's approach results are presented in Table 4. The results show that there exists no evidence of convergence at the aggregate level, as we fail to reject the null hypothesis of no convergence. But when we look at region wise data there seems to be some evidence against the null hypothesis of no convergence in these particular regions. The negative value of ϕ_2 indicates unconditional convergence. The results show Cornbelt and Lakestates having a negative and statistically significant parameter estimate for time variable 't' suggesting convergence is taking place in these regions. We estimated parametric panel data model to determine if human capital can sufficiently explain the differences in total factor productivity across states and times. Results from panel data model is shown in Table 5. We estimated fixed effect one way and fixed effect two way models. In fixed effect one way model, we assume that agricultural productivity differences is caused by state heterogeneity. The result from fixed effect model indicates that human capital does play a significant role in determining the total factor productivity. The coefficient associated with human capital in this model is significant at 1 percent level. R^2 from the model is 97% indicating that human capital is able to explain most of the difference in productivity difference. Hausman test indicated that we fail to reject the state level homogeneity in agricultural total factor productivity. The coefficients associated with each state were found to be significant. The highest coefficient is associated with the state of Florida. The results from the two way fixed effect model indicated the similar results also the coefficient associated with human capital is found to be insignificant. Hausman test statistics rejects the homogeneity of the state specific parameters in the model. Results from the random effect models (both one way and two way) also show coefficient associated with human capital to be significant. The M-test indicates that we are unable to reject the random effect in the models.

In the absence of any assumption related to functional form between total factor productivity and human capital, we should estimate the nonparametric model. Nonparametric model showed that smoothing parameter value equaling to 0.809 should be used to study the relationship. Figure 5 shows the prediction using nonparametric model. The figure also shows the 90% confidence interval of the predicted value. The nonparametric model has very good fit as indicated by the residual sum of square from the prediction model.

Conclusions

The study tested the evidence of total factor productivity convergence in the U.S agriculture sector using a state level panel data. The empirical investigation carried out in this paper did not find any evidence of convergence while looking at the U.S state agricultural TFP at aggregate level. However, we did find the support for convergence at the regional level. Attempt to explain agricultural productivity differences across states with human capital in both parametric and nonparametric models support the idea that higher human capital index means higher agricultural productivity. This finding is consistent with earlier findings in human capital model describing it as a determining factor for regional differences in growth and economic development.

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Table 1. States Ranked by 1996 Level of Productivity

State	1996 Rank	1996 Level	1960 Rank	1960 Level	Avg. annual growth of productivity 1960-96 Rank	Avg. annual growth of productivity 1960-96 Growth
CT	1	1.509	20	0.549	2	0.0284
FL	2	1.504	2	0.701	17	0.0212
GA	3	1.398	14	0.560	6	0.0254
NC	4	1.386	22	0.522	3	0.0271
IA	5	1.299	1	0.712	37	0.0167
WA	6	1.287	19	0.554	10	0.0234
ID	7	1.218	21	0.525	11	0.0234
SD	8	1.213	6	0.613	27	0.0190
ME	9	1.208	11	0.593	22	0.0198
DE	10	1.197	10	0.595	24	0.0194
AR	11	1.184	29	0.484	7	0.0249
KY	12	1.181	27	0.496	9	0.0241
CA	13	1.146	7	0.612	35	0.0174
WI	14	1.137	3	0.684	42	0.0141
MN	15	1.132	12	0.592	32	0.0180
NE	16	1.122	17	0.557	23	0.0195
PA	17	1.112	25	0.500	13	0.0222
VT	18	1.102	15	0.560	28	0.0188
SC	19	1.100	36	0.456	8	0.0244
IL	20	1.093	9	0.599	38	0.0167
CO	21	1.083	4	0.654	43	0.0140
NJ	22	1.080	13	0.581	36	0.0172
LA	23	1.074	46	0.386	1	0.0284
NY	24	1.042	8	0.603	39	0.0152
IN	25	1.040	24	0.510	21	0.0198
MS	26	1.034	44	0.398	4	0.0265
MA	27	1.033	33	0.477	15	0.0215
KS	28	1.032	5	0.636	45	0.0134
AL	29	1.000	23	0.511	29	0.0186
ND	30	1.000	40	0.437	12	0.0230
OR	31	0.990	31	0.479	19	0.0202
MI	32	0.981	47	0.384	5	0.0261
NM	33	0.969	37	0.450	16	0.0213
MD	34	0.954	34	0.468	20	0.0198
MO	35	0.933	26	0.498	34	0.0174
AZ	36	0.925	18	0.556	41	0.0142
NH	37	0.924	39	0.442	18	0.0205
VA	38	0.916	43	0.423	14	0.0215
UT	39	0.913	30	0.480	33	0.0179
OH	40	0.884	35	0.460	31	0.0181
NV	41	0.855	16	0.559	46	0.0118
RI	42	0.851	41	0.424	25	0.0193
TX	43	0.778	32	0.478	44	0.0135
TN	44	0.775	45	0.387	26	0.0193
MT	45	0.707	42	0.423	40	0.0143
OK	46	0.699	28	0.490	47	0.0098

Source: USDA/ERS 2003 State Productivity Data.

Table 2. Distribution of States in to Regions

Regions	States
Northeast	New York, New Jersey, Pennsylvania, Delaware, Maryland.
Lake States	Michigan, Minnesota, Wisconsin.
Corn Belt	Ohio, Indiana, Illinois, Iowa, Missouri.
Northern Plains	North Dakota, South Dakota, Nebraska, Kansas.
Appalachia	Virginia, West Virginia, Kentucky, North Carolina, Tennessee.
Southeast	South Carolina, Georgia, Florida, Alabama.
Delta States	Mississippi, Arkansas, Louisiana.
Southern Plains	Oklahoma, Texas.
Mountain States	Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada.
Pacific States	Washington, Oregon, California.

Table 3. Values Obtained From Three Test Statistics

Test Statistic	Test Value	Critical Value
T_1	0.78	2.12
T_2	0.59053	3.84
T_3	1.04742	1.645

Table 4. Regression of Cross-Sectional Variance of TFP on Trend, United States and by Regions, 1960-1996.

Reference Area/Coefficient	Estimates	t-values
All States (forty eight states)		
Φ_1	0.033	19.44
Φ_2	0.0002	2.37
R^2	0.14	
Appalachia (five states)		
Φ_1	0.1007	14.8
Φ_2	0.001	3.26
R^2	0.23	
Cornbelt (five states)		
Φ_1	0.026	12.31
Φ_2	-0.0003	-3.81
R^2	0.29	
Deltastates (three states)		
Φ_1	0.007	4.81
Φ_2	-0.00004	-0.53
R^2	0.007	
Lakestates (three states)		
Φ_1	0.0707	16.65
Φ_2	-0.0022	-11.65
R^2	0.079	
Mountainstates (eight states)		
Φ_1	0.0112	3.26
Φ_2	0.0007	5.01
R^2	0.41	
Northeast (five states)		
Φ_1	0.019	9.8
Φ_2	-0.0105	-1.19
R^2	0.03	
Nothernplains (four states)		
Φ_1	0.019	3.07
Φ_2	-0.0003	1.08
R^2	0.032	
Pacificstates (three states)		
Φ_1	0.013	3.07
Φ_2	-0.00004	1.08
R^2	0.008	
Southernplains (two states)		
Φ_1	0.0001	0.11
Φ_2	0.0001	3.47
R^2	0.23	
Southeast(four states)		
Φ_1	0.035	8.64
Φ_2	0.00012645	0.67
R^2	0.12	

Table 5. Effect of Human Capital on Total Factor Productivity in U. S. Agriculture

Dependent Variable	**One way fixed effect**	**Two way fixed effect**	**One way random effect**	**Two way random effect**
Human Capital Index	3.02** (0.2328)	-0.217 (0.2225)	0.78** (0.0264)	0.70** (0.0672)
F-value or M-value	5.26*	25.94*	93.89**	11.65**
R-square	0.98	0.99	0.82	0.36

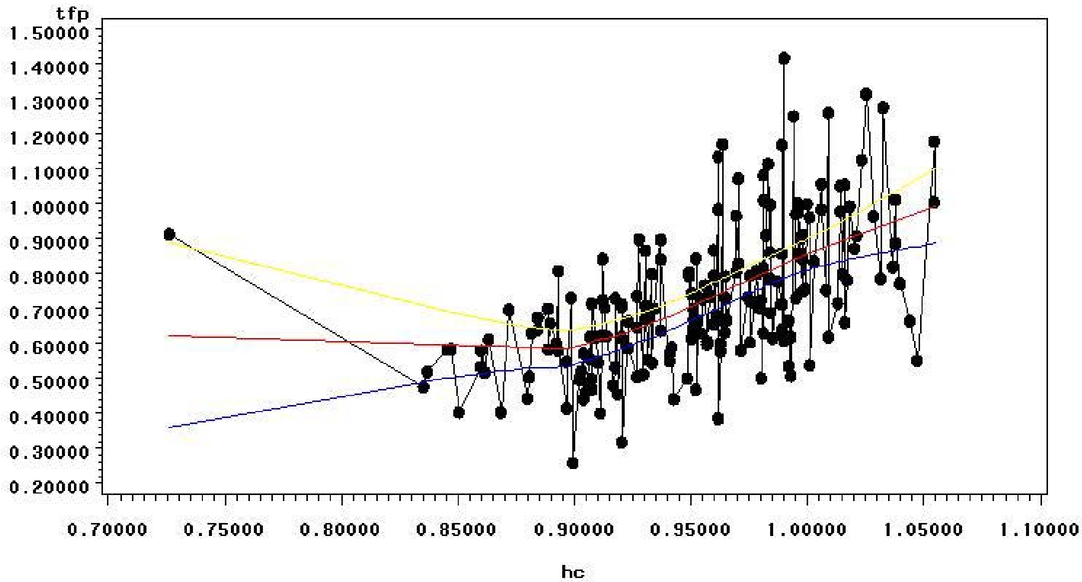

Figure 1. Prediction of total factor productivity in agriculture as a function of human capital index using a nonparametric regression (Note: Red line is the predicted value, yellow line is the upper confidence interval, purple line is the lower confidence interval)