Estimation of Agricultural Total Factor Productivity in China: A Panel Cointegration Approach

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Abstract: This paper uses panel cointegration approach to estimate the agricultural total factor productivity (TFP) from 30 regions from 1978 to 2004 in China. The results of panel unit root find that all inputs and output variables are nonstationary series. Pedroni (1999) panel cointegration tests present the evidence supporting the existence of the long run cointegration relationship. This paper finds the estimator of FMOLS is better than OLS and DOLS. Agricultural total factor productivity is estimated based on Kao and Chiang (2000) panel coefficients estimation.

Keywords: Total Factor Productivity; Panel Unit Root; Panel Cointegration; DOLS; FMOLS
JEL classification: C13, C23, Q00

1. Introduction

For more than a decade, a large number of theoretical and empirical studies have investigated the total factor productivity (TFP). While the origins of total factor productivity analysis can be traced back to the seminal paper by Solow (1957), developing a production function in which output growth is a function of capital, labor, and knowledge or technology. Technology is Harrod neutral and it is assumed to be exogenous and homogenous across countries. Recent years have seen a surge in both theoretical and empirical studies on TFP. In the economics literature, these studies used a variety of approaches including indexing approaches, data envelope analysis (DEA), stochastic frontier analysis (SFA), semi-parametric approach (Olley and Pakes, 1996; Levinsohn and Petrin, 2003) etc.

The majority of statistical agencies that produce regular productivity statistics use the indexing approach or Growth Accounting Techniques. For example, the Australian Bureau of Statistics calculates market sector multifactor productivity using the indexing approach based on a Törnqvist index, as does the US Bureau of Labor Statistics (Peter Mawson etc., 2003). The indexing approach is simple, while the difficulty is in determining what type of index to use, this problem by using prices (or output shares) to weight the various different kinds of outputs and the problem of the same period etc. There is a substantial body of literature measuring TFP using indexing approach (Hayami and Ruttan, 1985; Lin, 1992; Wen, 1993; Colby et al., 2000; Fan and Zhang, 2002).

Data Envelopment Analysis (DEA) is a “data oriented” nonparametric approach for evaluating the performance of a set of peer entities called Decision Making Units (DMU) which convert multiple inputs into multiple outputs. Agricultural TFP is estimated by DEA, e.g. David and Parker (1998), Mao and Won (1997) Li Jing and Lingjie Meng (2006), while the effect of stochastic distribution item is not taken into account. Stochastic Frontier Analysis (SFA) is a parametric approach. Aigner and Chu (1968) considered the estimation of a parametric frontier production function of Cobb-Douglas form. Fan (1991), Kalirajan et al. (1996) and Jianwei Mi et al. (2005) estimated the agricultural production function using SFA. But, the SFA approach does not take account of the endogeneity of independent variables, and there exists difficulty of estimation by maximum likelihood method. Jintian Wang et al. (2008) employed the semi-parametric Levinsohn-Petrin method to estimate the agricultural production function.

While, previous work on TFP has almost concentrated on level data, using indexing approaches, DEA, SFA and semi-parametric approach, this paper contributes to the literature in several key ways. Firstly, we focus on the problem about stationarity of data using panel unit root. Secondly, panel cointegration tests are applied to guard against spurious regression. Finally, we propose an estimation procedure on TFP based on OLS, DOLS and FMOLS.

This paper unfolds as follows. In the next section, we describe the model. In Section 3, we describe the econometric methodology. In Section 4, we report the data sources and the empirical estimation results. Finally, we conclude in Section 5.

2. Model Description

The measurement of total factor productivity in China requires the estimation of a Cobb-Douglas production function specification from:

$$Y_{it} = A_{it} X_{1it}^{\beta_1} X_{2it}^{\beta_2} X_{3it}^{\beta_3} X_{4it}^{\beta_4} X_{5it}^{\beta_5} X_{6it}^{\beta_6} X_{7it}^{\beta_7} \tag{1}$$

where Y_{it} is Gross Output of Farming, Forestry, Animal Husbandry in region i at time period t, X_{1it} is Total Number of Employed Persons of Primary Industry, X_{2it} is Total Power of Agricultural Machinery, X_{3it} is Irrigated Area, X_{4it} is Consumption of Chemical Fertilizers, X_{5it} is Electricity Consumed in Rural Area, X_{6it} is Total Sown Area, X_{7it} is Large Animals at Year-end. $\beta_i\left(i=1,\cdots,7\right)$ are parameters. A_{it} is a technology parameter and can be defined as follows:

$$A_{it} = e^{TFP_{it}+\varepsilon_{it}} \tag{2}$$

Where TFP_{it} is total factor productivity, $\varepsilon_{it} \sim i.i.d.\left(0,1\right)$.

Rewriting Eqs. (1) in natural logarithms yields the following:

$$y_{it} = \ln TFP_{it} + \beta_1 x_{1it} + \beta_2 x_{2it} + \beta_3 x_{3it} + \beta_4 x_{4it} + \beta_5 x_{5it} + \beta_6 x_{6it} + \beta_7 x_{7it} + \varepsilon_{it} \tag{3}$$

Where the lowercase of variables is natural logarithms form.

Therefore, the TFP is estimated as follows:

$$TFP_{it} = e^{y_{it} - \hat{\beta}_1 x_{1it} - \hat{\beta}_2 x_{2it} - \hat{\beta}_3 x_{3it} - \hat{\beta}_4 x_{4it} - \hat{\beta}_5 x_{5it} - \hat{\beta}_6 x_{6it} - \hat{\beta}_7 x_{7it}} \tag{4}$$

3. Method

Avoiding to the spurious regression and the bias of OLS, we firstly employ the panel unit root test. Testing for unit roots in time series studies is now common practice among applied economics fields. However, panel unit root tests are adopted recently, see Levin & Lin (1992), Im, Pesaran & Shin (1997), Harris & Tzavalis (1999), Maddala & Wu (1999), Choi (1999a), and Hadri (1999) (Badi H. Baltagi and Chihwa Kao, 2000). At the same time, Bharagava et al. suggested a modified Durbin-Watson (DW) statistic based on fixed effects residuals and two other test statistics based on differenced OLS residuals. Breitung & Meyer (1994) proposed various modified DF test statistics to test for panel unit root tests. Quah (1994) suggested a test for unit root in a panel data model without fixed effects where both N and T go to infinity at the same rate such that N/T is constant.

Kwiatkowski et al. (1992) stationarity tests point at the nonstationarity of the variables. Under the nonstationarity, three methods are suggested in panel data models. Firstly, Kao (1990) presents two types of cointegration tests in panel data, the Dickey-Fuller (DF) and augmented Dickey-Fuller (ADF) type tests by assuming the null hypothesis that is the absence of cointegration. The DF_ρ and the DF_t statistics are computed under the assumption of stong exogeneity of regressors and errors. Alternatively, the DF_ρ^* and the DF_t^* statistics are based on the endogenity between the regressors and errors. With the null of no cointegration, an ADF-type test will converge to a standard normal distribution N (0,1). Secondly, Pedroni (1995) proposes a test of cointegration in heterogenous panels that can be viewed as extensions of no cointegration of the single-equation test. The proposed statistics test the null hypothesis of no cointegration versus the alternative of cointegration. Finally, McClskey and Kao (1998) derive a residual-based LM tests for the null hypothesis of cointegration. This paper will employ the Pedroni panel unit root to test whether the cointegration relationship exists or not.

Under the framework of heterogeneous panels, this paper employs the Dynamic Panel OLS (DOLS), Full Modified OLS (FMOLS) methods to estimate cointegration vector β if the cointegration relationship exists.

4. Estimation Results

4.1 Data Collection

The data used in the estimation of the reference model, summarized in equation (3) are drawn from China Compendium of Statistics 1949-2004, Agriculture Statistic Data of 50 Years Since the Founding of New China and Rural Statistical Year Book of China etc. The data sets are yearly and cover the period from 1978 to 2004, for 30 provinces, municipalities, and autonomous regions in China, The data for Chongqing municipality was subtracted from Sichuan Province, from which is split to become a separate region in 1997. Therefore, this paper does not take account of Chongqing. All Samples is 810.

4.2 Empirical Results

Table 1 and Table 2 presents the results of panel unit root test. Through the estimation, we find that all variables are I (1). Under the level data sets, LLC, IPS, ADF-fisher and PP-fisher test are almost nonstationary series except the Total Number of Employed Persons of Primary Industry, but we think that it is acceptable because that IPS and ADF-fisher no reject the unit root null hypothesis. Under the difference form, all variables reject the unit root null hypothesis.

TABLE 1—Panel Unit Root Tests (Level)

Variable	Method	Statistic	Prob.**	sections	Obs.
Y	LLC t*	1.49905	0.9331	30	750
	IPS W-stat	6.70690	1.0000	30	750
	ADF - Fisher Chi-square	8.03412	1.0000	30	750
	PP - Fisher Chi-square	6.77357	1.0000	30	780
X1	LLC t*	-4.02238	0.0000	30	750
	IPS W-stat	-0.82715	0.2041	30	750
	ADF - Fisher Chi-square	73.7172	0.1098	30	750
	PP - Fisher Chi-square	82.7913	0.0273	30	780
X2	LLC t*	10.5310	1.0000	30	750
	IPS W-stat	17.2400	1.0000	30	750
	ADF - Fisher Chi-square	7.38507	1.0000	30	750
	PP - Fisher Chi-square	8.99179	1.0000	30	780
X3	LLC t*	1.55961	0.9406	30	750
	IPS W-stat	3.31637	0.9995	30	750
	ADF - Fisher Chi-square	46.8838	0.8917	30	750
	PP - Fisher Chi-square	44.7665	0.9288	30	780
X4	LLC t*	0.31630	0.6241	30	750
	IPS W-stat	4.26043	1.0000	30	750
	ADF - Fisher Chi-square	35.0301	0.9959	30	750
	PP - Fisher Chi-square	64.2877	0.3289	30	780
X5	LLC t*	11.1686	1.0000	30	750
	IPS W-stat	17.5662	1.0000	30	750
	ADF - Fisher Chi-square	1.60595	1.0000	30	750
	PP - Fisher Chi-square	0.93887	1.0000	30	780
X6	LLC t*	1.08445	0.8609	30	750
	IPS W-stat	2.70244	0.9966	30	750
	ADF - Fisher Chi-square	60.8555	0.4449	30	750
	PP - Fisher Chi-square	62.0462	0.4031	30	780
X7	LLC t*	-0.09251	0.4631	30	750
	IPS W-stat	3.35513	0.9996	30	750
	ADF - Fisher Chi-square	40.6052	0.9741	30	750
	PP - Fisher Chi-square	28.4922	0.9998	30	780

Note: Levin, Lin & Chu t- Null: Unit root (assumes common unit root process), Im, Pesaran and Shin W-stat, ADF - Fisher Chi-square, PP - Fisher Chi-square- Null: Unit root (assumes individual unit root process).

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

TABLE 2—Panel Unit Root (1st order difference)

Variable	Method	Statistic	Prob.**	sections	Obs.
ΔY	LLC t*	-2.72587	0.0032	30	720
	IPS W-stat	-8.04257	0.0000	30	720
	ADF - Fisher Chi-square	169.401	0.0000	30	720
	PP - Fisher Chi-square	156.231	0.0000	30	750
ΔX1	LLC t*	-6.23259	0.0000	30	720
	IPS W-stat	-7.15366	0.0000	30	720
	ADF - Fisher Chi-square	159.163	0.0000	30	720
	PP - Fisher Chi-square	291.306	0.0000	30	750
ΔX2	LLC t*	-0.19542	0.4225	30	720
	IPS W-stat	-1.78098	0.0375	30	720
	ADF - Fisher Chi-square	82.2297	0.0300	30	720
	PP - Fisher Chi-square	142.822	0.0000	30	750
ΔX3	LLC t*	-10.7195	0.0000	30	720
	IPS W-stat	-12.3432	0.0000	30	720
	ADF - Fisher Chi-square	265.915	0.0000	30	720
	PP - Fisher Chi-square	410.757	0.0000	30	750
ΔX4	LLC t*	-3.56724	0.0002	30	720
	IPS W-stat	-10.0851	0.0000	30	720
	ADF - Fisher Chi-square	225.531	0.0000	30	720
	PP - Fisher Chi-square	408.016	0.0000	30	750
ΔX5	LLC t*	-1.64049	0.0505	30	720
	IPS W-stat	-5.26448	0.0000	30	720
	ADF - Fisher Chi-square	156.812	0.0000	30	720
	PP - Fisher Chi-square	310.404	0.0000	30	750
ΔX6	LLC t*	-6.24841	0.0000	30	720
	IPS W-stat	-9.86926	0.0000	30	720
	ADF - Fisher Chi-square	212.837	0.0000	30	720
	PP - Fisher Chi-square	384.600	0.0000	30	750
ΔX7	LLC t*	-6.58258	0.0000	30	720
	IPS W-stat	-9.74365	0.0000	30	720
	ADF - Fisher Chi-square	211.760	0.0000	30	720
	PP - Fisher Chi-square	318.514	0.0000	30	750

This paper employs the Pedroni (1999) panel cointegration test. The cointegration relationship is existed through the estimation of panel statistics (within) and group statistics (between) in Table 3. The seven statistics all reject the no cointegration relationship null hypothesis at a significance level. That is to say, there exists the long run relationship of the inputs and output of agricultural production function.

TABLE 3—Panel Cointegration Test (Pedroni, 1999)

Method	Statistics	Prob.
Panel Statistics (within)		
v	109.47204	0.00000
ρ	-72.100032	0.00006
t (nonparametric)	-6.15667	0.00122
t (parametric)	-37.70661	0.00000
Group Statistics (between)		
ρ	-72.10032	0.00004
t (nonparametric)	-6.15667	0.00041
t (parametric)	-5.93569	0.00119

We employ Kao and Chiang (2000) panel coefficient estimation by OLS, DOLS, and FMOLS approach. Table 4 presents that the estimated coefficients are significant except the Large Animals at Year-end. In the same time, we find that the results of estimated coefficients about OLS and DOLS is almost the same, see Figure 1 and Figure 2, while the estimator of OLS is bias, Therefore, we have priority to use FMOLS to estimate the agricultural TFP, see Figure3 and Figure 4. The sum of the all coefficients is almost 1, this shows that Cobb-Douglas production function is feasible.

TABLE 4—Kao and Chiang (2000) Panel Coefficient Estimation

	OLS				DOLS				FMOLS			
	Coefficients	Statistics	Prob.(t)	Prob.(N)	Coefficients	Statistics	Prob.(t)	Prob.(N)	Coefficients	Statistics	Prob.(t)	Prob.(N)
β1	0.1273	4.8382	0.0000	0.0000	0.1118	4.2293	0.0000	0.0000	0.2069	7.8516	0.0000	0.0000
β2	0.5265	28.1308	0.0000	0.0000	0.4805	25.5498	0.0000	0.0000	0.4192	22.3695	0.0000	0.0000
β3	-0.1270	-4.2211	0.0000	0.0000	-0.1162	-3.8438	0.0000	0.0000	-0.1043	-3.4607	0.0000	0.0000
β4	0.2655	16.9811	0.0000	0.0000	0.2900	18.4620	0.0000	0.0000	0.3493	22.3158	0.0000	0.0000
β5	0.0980	16.7813	0.0000	0.0000	0.0975	16.6242	0.0000	0.0000	0.1024	17.5218	0.0000	0.0000
β6	0.0821	2.2076	0.0138	0.0136	0.1135	3.0373	0.0012	0.0012	-0.0774	-2.0787	0.0190	0.0188
β7	0.0012	0.0855	0.4659	0.4659	-0.0095	-0.6910	0.2449	0.2448	-0.0040	-0.2904	0.3858	0.3857
SUM	0.9736				0.9676				0.8921			
	R square = 0.8541				R square = 0.9619				R square = 0.8466			
	Adjusted Rsquare = 0.8529				Adjusted Rsquare = 0.9606				Adjusted Rsquare = 0.8529			

Note: DOLS is estimated under the heterogeneous covariance structure.

Then, agricultural TFP is estimated based on OLS, DOLS and FMOLS according to the Kao and Chiang (2000) panel coefficients estimation and equation (4).

Figure 1, Figure 2, Figure 3 and Figure 4 present that the agricultural TFP change little from 1978 to 1992 because the restriction of market and Structural Contradiction, while great changes have taken place from 1993-1996 because of the Economic System Reform and Policy Adjustment, agricultural TFP changes downward from 1997 to 2004. Results are the same to Chen Weiping (2006) etc.

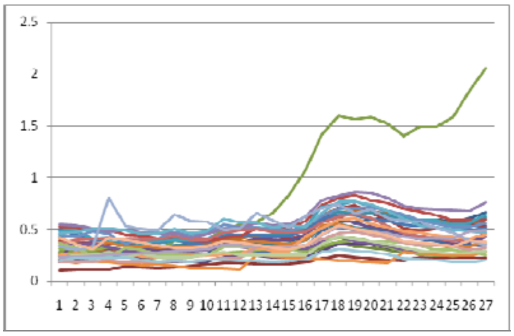

FIGURE 1—Agricultural TFP Based on OLS

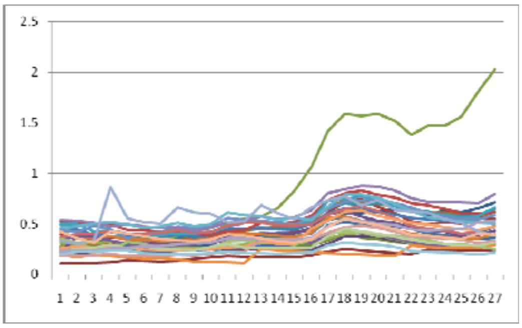

FIGURE 2—Agricultural TFP Based on DOLS

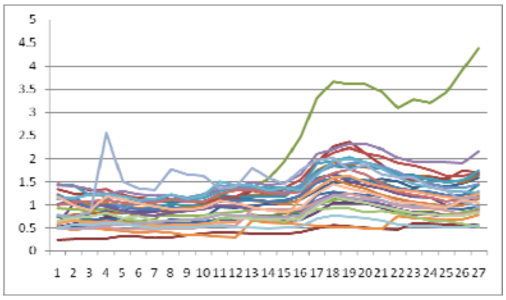

FIGURE 3—Agricultural TFP Based on FMOLS

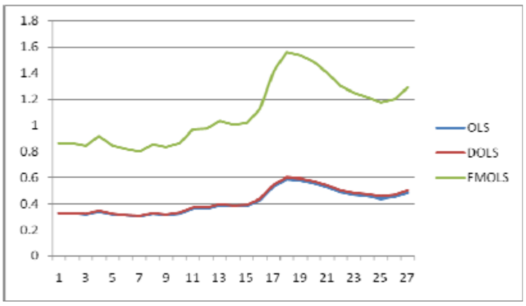

FIGURE 4—Average of Agricultural TFP

5. Conclusions

This paper empirically estimates the agricultural TFP using panel cointegration for 30 regions in China. Based on LLC, IPS, ADF-fisher and PP-fisher panel unit root, we find that all variable are I (1) series. Therefore we perform the panel cointegration test and estimation, and find the existence of the cointegration relationship. In addition, we find that the selection of Cobb-Douglas production function is suited. The analysis of the results of OLS, DOLS and FMOLS, we find the estimator of FMOLS is better than OLS and DOLS. Finally, we estimate the agricultural TFP Based on panel coefficients estimation.

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