Is Productivity Growth Slowing in China and the U.S. Farm Sectors[1]?

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Abstract

This paper provides estimates of relative levels of farm sector productivity for China and the United States, spanning the 1985-2013 period. Using bilateral total factor productivity (TFP) estimates we apply time series analysis techniques that allow for multiple structural breaks at unknown points in time and in various forms to test the productivity slowdown hypothesis. The results show that while TFP growth has been the major driver of the U.S. agricultural output growth, input growth has played a much more important role in China's agricultural growth, especially during the early period. While the U.S. farm sector has a higher productivity level, China's agricultural productivity has grown much faster than the U.S., on average, over the study period. As a result, the gap between China and the U.S. TFP levels has shrunk over time, indicating a productivity catch-up effect. On the other hand, test results of the productivity slowdown hypothesis indicate that there is no statistical evidence of an agricultural productivity slowdown in the post-1985 period in either country.

Key words: Total Factor Productivity (TFP), bilateral productivity, Törnqvist index, U.S. agricultural productivity, China agricultural productivity, structural break test

I. Introduction

China and the United States are two major producers and consumers in the world food market. Sustained agricultural productivity growth in these two countries is critical for global food security. China has experienced fast economic growth since it implemented a series of rural reforms and open policies after 1978. Given that China and the U.S. are in different development stages measuring the relative productivity levels and comparing the sources of agricultural growth of these two countries can inform agricultural policy decisions. In addition, soaring food prices in the 2000s and stagnant public agricultural R&D investment in recent years for many developed countries have raised concerns about agricultural sustainability and a possible systematic productivity slowdown in global agricultural sector (see for examples, Fuglie (2008), Alston and Pardey (2009), James et al. (2009) Wang, Schimmelpfennig, and Fuglie (2012), Ball, Schimmelpfennig, and Wang (2013), and Trindade, F. and L.E. Fulginiti (2015)). Slower productivity growth has strong policy implications as it may result in higher food prices if productivity growth cannot keep pace with increasing global food demand, and/or damage our environment as nutrient and chemical runoff or erosion can impair water and land quality when farmers intensify use of agricultural chemicals and land.

The objectives of this paper are: first, comparing relative levels of total factor productivity in China and the U.S. farm sectors; second, identifying sources of agricultural growth in these two countries; and third, we revisit the slowdown hypothesis to investigate if productivity growth has slowed in China and the U.S. over the study period.

II. Methods

[11] The views expressed are those of the authors and do not necessarily reflect the positions of the USDA or ERS.

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Total Factor Productivity Measurement

Total factor productivity (TFP) index is an aggregate measure that accounts for all inputs' contribution to the sector's output growth. The TFP measurement is based on a translog transformation frontier model that relates the growth rates of multiple outputs to the cost-share weighted growth rates of labor, capital, land, and intermediate goods. The rates of productivity growth are constructed using the Törnqvist index approach. The TFP growth over two time periods is defined as:

$$\ln\left[\frac{TFP_t}{TFP_{t-1}}\right] = \sum\left[\frac{R_{it}+R_{i,t-1}}{2}\right]\ln\left[\frac{Y_{it}}{Y_{it-1}}\right] - \sum\left[\frac{W_{jt}+W_{j,t-1}}{2}\right]\ln\left[\frac{X_{jt}}{X_{jt-1}}\right] \quad (1)$$

where Y_i are individual output, X_j are individual input, R_i are output revenue shares, the W_j are input cost shares, and t and $t-1$ are time subscripts.

Bilateral TFP measurement

In order to measure the relative levels of output, input, and TFP between China and the U.S. farm sectors we estimate prices of output and input for China farm sector relatively to the U.S. agriculture under a purchasing power parity concept (e.g., see Eichhorn and Voeller (1983), and Jorgenson and Nomura (2007)). We then obtain indexes of relative real output and relative real input between the two countries by dividing the nominal value of output and input with relative output price and input price, respectively.

In the farm sector, land is a productive asset and its quality can be distinct from one region to another. In this study we adjust for relative land quality differences between the two countries based on hedonic shadow value approach (Ball et al. (2016). The land quality estimate of China relatively to the U.S. is estimated using the shadow values of land attributes from the U.S. estimates and China's land characteristics data.

We draw data from various sources for China and the US agricultural output and input (see details in Wang et al. (2013) for China estimates, and Ball et al. (2016) for U.S. estimates), spanning the 1985-2013 period.

Test for the slowdown hypothesis

Productivity slowdown hypothesis has been oftentimes tested by partitioning the sample into two sub-periods and comparing the resulting mean rates of growth in the literature. However, the breakdate must be known a priori under such approach. Since short-term fluctuations in weather events and macroeconomic movements may affect agricultural TFP estimates the mean productivity growth rate can be sensitive to the selected period of time. To avoid "uninformative" or "misleading" rest results (Hanson (2001)) we follow Ball, Schimmelpfennig, and Wang (2013) to test the slowdown hypothesis by conducting structural trend break test with unknown break dates. We posit a simple trend model:

$$\ln TFP = c_0 + \tau_0 t + \varepsilon_t \quad (2)$$

and test the null hypothesis of a stable linear model against the alternative of "breaks" in the parameters in the trend regression. We take the first derivative of (1) with respect to time t yields:

$$\frac{d \ln TFP}{d\, t} = \tau_0 \quad (3)$$

where τ_0 is the rate of productivity growth over time. Once the unknown break date is identified we conduct the Elliott and Müller (2006) "quasi-Local Level" (qLL) test to determine if the time series has been free of structural breaks during the study period after the identified trend break is included in the regression model specification as equation (4).

$$\ln TFP = c_0 + c_1 D_{B_1} t + \tau_0 t + \varepsilon_t \quad (4)$$

However, this qLL test does not provide information on the timing of the structural break if the results indicate there are still unknown breakdate need to be accounted for. This suggests that different breakdates may exist for intercept or trend. Accordingly, we estimate equation (5) with alternative intercept shifts sequentially.

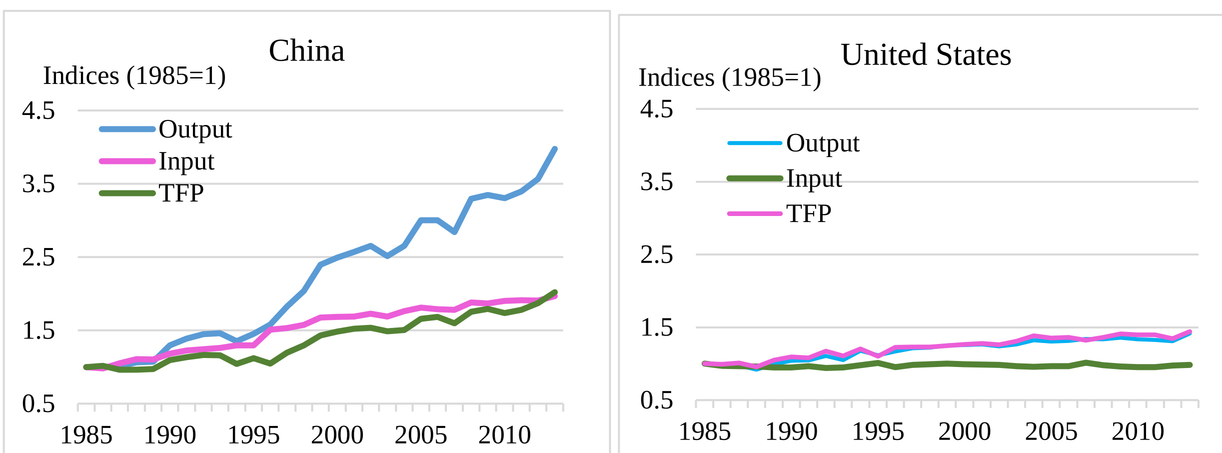
$$\ln TFP = c_0 + c_1 D_{B_1} t + \tau_0 t + \tau_1 D_{B_2} + \varepsilon_t \quad (5)$$

We plot the residual variances as a function of individual intercept breakdates. The sum of squared errors will have a minimum near the true breakdate. We then conduct qLL test to examine if the time series has been free of structural breaks.

III. Patterns of growth in agricultural output, input, and TFP in China and the United States

In 2013 China's agricultural production was nearly four times its 1985 level, and grew at an average annual rate of 4.9%. With input growing at an average rate of 2.4% per year, the average annual rate of TFP growth in China is 2.5% during 1985-2013, which has surpassed the U.S. TFP growth rate of 1.31% per year over the same period of time. Distinctly, while both input and TFP have grown strongly in China's farm sector input growth has declined by 0.07% per year on average in the U.S. that TFP growth accounts for most of output growth in the U.S. farm sector (figure 1).

Figure 1. Agricultural output, input, and TFP growth in China and the United States



Panel A. Panel B.

Source: Authors' calculation

IV. Sources of Agricultural Growth in China and the U.S. Farm Sectors

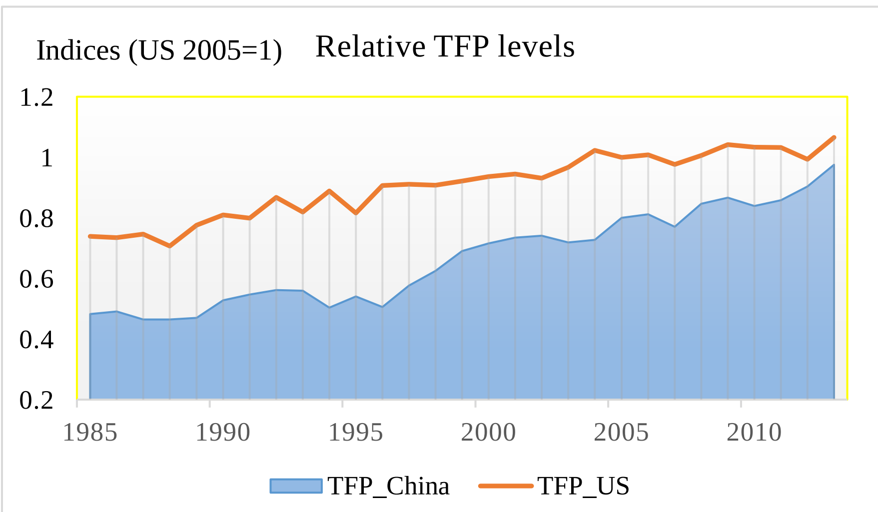
While aggregate input use continues to grow in China and continues to be flat or decline in the U.S. labor use has declined in both countries. Intermediate goods growth is the main contributing factor to the strong input growth in China's farm sector over the entire study period (table 1). However, in the latter period (1996-2013) the major source of China's agricultural output growth has shifted from input growth to TFP growth (table 1). Using U.S. TFP in 2005 as the base the trend growth of the relative TFP levels in these two countries show that the TFP gap has shrunk over time, which is consistent with the "catch-up" hypothesis (figure 2).

Table 1 Sources of Agricultural Output Growth

	China			U.S.		
	1985-2013	1985-1995	1996-2013	1985-2013	1985-1995	1996-2013
Output growth	4.93%	3.74%	5.43%	1.24%	1.08%	1.13%
Sources of growth						
Input growth	2.42%	2.60%	1.56%	-0.07%	0.09%	0.19%
Labor	-0.33%	0.25%	-0.68%	-0.28%	0.08%	-0.36%
Capital (excluding land)	0.18%	0.07%	0.24%	-0.20%	-0.62%	0.03%
Land	0.21%	-0.09%	-0.12%	-0.02%	-0.04%	-0.02%
Intermediate goods	2.36%	2.37%	2.11%	0.44%	0.67%	0.55%

Source: Authors' calculation

Figure 2. Bilateral TFP estimates in China and the U.S. farm sectors



Source: Authors' calculation

V. Is Agricultural Productivity Growth Slowing in China and the U.S.?

To test for the productivity slowdown hypothesis we first conduct Supremum Wald test for a structural break at an unknown break date for equation (2) using symmetric trimming of 20%. The results (table 2) indicate that we reject the null hypothesis of no structural break at the 1% level for both China and the U.S. TFP time series. The estimated break date is 1996 for U.S. TFP and is 1999 for China TFP series. We then conduct qLL tests to examine if the revised regression model (equation (4)) is free of structural break after including the trend break in the model specification. The results of qLL test indicate that there is no further structural break in China's TFP series while we reject the hypothesis of no further break for the U.S. series. We estimate equation (5) for the U.S. TFP regression model with alternative intercept shifts sequentially. We identify an intercept break in 1990 as that break date has a minimum sum of squared errors. We conduct the qLL test with both intercept break and trend break afterwards. The result indicates the time series has been free of structural breaks. Therefore, according to the test results and the regression model estimate there is no evidence of a productivity slowdown in both China and the U.S.

farm sectors in the post-1985 period. In fact, China has experienced a 0.3 percentage point higher growth rate after 1999, and the U.S. has a 0.01 percentage point higher growth rate after 1996 during the study period.

Although the public agricultural research and development (R&D) has been stagnant in the last two decades there is no statistical evidence showing a productivity slowdown in the U.S. farm sector. One possible reason may be due to a long lag between the investment in R&D and the technology adoption in the farm. Increasing private R&D investment can also mitigate the negative impacts of slower public R&D investment. In addition, over the last few decades, the U.S. farm sector has undergone structural and organizational changes (see for examples, O'Donoghue et al. (2011), McBride and Key (2013), and MacDonald et al., (2013)). Farmers may apply more efficient practices, increase farm size, or become more specialized, which could enhance technology adoption on the farm and boost overall agricultural productivity growth.

Table 2 Test Results of Productivity Slowdown Hypothesis

Dependent variable: lnTFP									
U.S.					**China**				
Variables	**coefficient**	**t statistics**	**pvalue**	**breakdate**	**Variables**	**coefficient**	**t statistics**	**pvalue**	**breakdate**
Structural break test with unknown breakdate					**Structural break test with unknown breakdate**				
(H_0: no structural break)					**(H_0: no structural break)**				
t	0.014	15.060	0.000	1996	t	0.027	24.260	0.000	1999
constant	3.798	78.770	0.000		constant	3.006	47.690	0.000	
R-square		0.907			R-square		0.934		
Root MSE		0.038			Root MSE		0.062		
Supremum Wald test statistics		30.138	0.000	reject H_0	Supremum Wald test statistics		17.379	0.003	reject H_0
Regressional model results I					**Regressional model results**				
t	0.010	5.950	0.000		t	0.017	6.830	0.000	
D1996*t	0.001	1.940	0.063		D1999*t	0.003	3.790	0.001	
constant	3.929	54.890	0.000		constant	3.405	31.700	0.000	
R-square		0.919			R-square		0.961		
Root MSE		0.036			Root MSE		0.048		
Elliott-Muller qLL test I (H_0: all coeffients are fixed)					**Elliott-Muller qLL test (H_0: all coeffients are fixed)**				
qLL statistics		-9.374	**	reject H_0	qLL statistics		-14.584		cannot reject H_0
Regressional model results II									
t	0.008	6.080	0.000						
d1990	0.075	3.600	0.001						
d1996*t	0.001	2.500	0.019						
constant	3.991	78.260	0.000						
R-square		0.951							
Root MSE		0.028							

Source: Authors' calculation

VI. Summary and Conclusions

The purposes of this paper are to provide relative estimates of total factor productivity for China and the United States farm sectors, identify sources of agricultural output growth in these two countries, and test the hypothesis of agricultural productivity slowdown. The results show that while input growth has accounted for most of China's output growth in early years, TFP growth has played a more important role in recent years. China's TFP level is catching up with the U.S. with a much higher growth rate over the study period. The average annual rate of TFP growth in China is 2.5% during 1985-2013, which is nearly double of the U.S. TFP growth rate over the same period of time. As a result, China's productivity level is catching up with that of the U.S.

The test results of the productivity slowdown hypothesis did not show a productivity slowdown in both countries. In fact, China has grown faster at an average rate of 2 percent per annum since 1999 compared to 1.7 percent per annum in the pre-1999 period. The U.S. has also grown at a higher rate of 1.1 percent per year since 1996 compared to one percent per year in the pre-1996 period on average.

References

Alston, J.M., J.M. Beddow, and P.G. Pardey. 2009. Agricultural Research, Productivity, and Food Prices in the Long Run. Science 325: 1209–1210.

Ball, V. E., S. Cahill, Y. Sheng, R. Nehring and C. S. J. Mesonada (2016). "Comparisons of Capital Input in OECD Agriculture, 1973-2011", Review of Economics and Finance, (3): 25-48.

Ball, Eldon, Sun Ling Wang, Richard Nehring, and Roberto Mosheim, 2016. "Productivity and Economic Growth in U.S. Agriculture: A New Look," Applied Economic Perspectives and Policy, Volume 38, Number 1, pp. 30–49.

Ball, V. E., D. Schimmelpfennig, and S. L. Wang. 2013. Is U.S. Agricultural Productivity Growth Slowing?—A Time Series Analysis. Applied Economic Perspectives and Policy. Forthcoming.

Eichhorn, W. and J. Voeller (1983). "Axiomatic Foundation of Price Indexes and Purchasing Power Parities," in W.E. Diewert and C. Montmarquette (eds), Price Level Measurement, Ottawa: Statistics Canada.

Elliot, G., and U.K. Mu¨ller. 2006. Efficient Tests for General Persistent Time Variation in Regression Coefficients. Review of Economic Studies 73 (4): 907–940.

Fuglie, K.O. 2008. Is a Slowdown in Agricultural Productivity Growth Contributing to the Rise in Commodity Prices? Agricultural Economics 39 (s1): 431–441.

Hansen, B.E. 2001. The New Econometrics of Structural Change: Dating Breaks in U.S. Labor Productivity. Journal of Economic Perspectives 15 (4): 117–128.

James, J.S., J.M. Alston, P.G. Pardey, and M.A. Andersen. 2009. Structural Changes in U.S. Agricultural Production and Productivity Choices 24 (4).

Jorengenson, D.W., Griliches, Z., 1967. The explanation of productivity change. Rev. Econ. Stud. 34, 249–283.

Jorgenson, D.W., Nishimizu, M., 2007. The Industry Origuns of the US-Japan Productivity Gap. Economic Systems Research. Vol. 19, No. 3, 315-341. September 2007.

MacDonald, J., P. Korb, and R. Hoppe. 2013. Farm Size and the Organization of U.S. Crop Farming. Economic Research Report 152. U.S. Department of Agriculture, Economic Research Service. www.ers.usda.gov/publications/err-economic-research-report/err152.aspx

McBride, W., and N. Key. 2013. U.S. Hog Production From 1992 to 2009: Technology, Restructuring, and Productivity Growth. ERR-158. U.S. Department of Agriculture, Economic Research Service.

O'Donoghue, E. J., Robert A. H., D. E. Banker, R. Ebel, K. Fuglie, P. Korb, M. Livingston, C. Nickerson, and C. Sandretto, 2011. *The Changing Organization of U.S Farming*. EIB-88, USDA, Economic Research Service.

Trindade, F. and L.E. Fulginiti. 2015. "Is there a Slowdown in Agricultural Productivity Growth in South America?" Agricultural Economics, vol. 46 (1): 69-81.

Wang, Sun Ling, Francis Tuan, Fred Gale, Agapi Spmwaru, and James Hansen, 2013. "China's Regional Agricultural Productivity Growth in 1985-2007: A Multilateral Comparison," Agricultural Economics, Vol. 44, No. 2: 241-251

Wang, Sun Ling, Paul Heisey, David Schimmelpfennig, and Eldon Ball, 2015. *Agricultural Productivity Growth in the United States: Measurement, Trends, and Drivers*, ERR-189, USDA, Economic Research Service, July 2015.