INTERNATIONAL COTTON ADVISORY COMMITTEE

Technical Change in Seed Cotton Production

Plastina, A. and M.R. Chaudry, ICAC
Presented at the Beltwide Cotton Conference 2008

Abstract

This study uses data from the Survey of the Cost of Production of Raw Cotton implemented by the International Cotton Advisory Committee to calculate superlative indexes of technical change for a set of regions over the 2001-2007 period. Changes in production practices are analyzed through the evolution of cost shares over time. Preliminary results suggest that technical change and production practices evolved differently across regions, and even between different periods in a same region.

Justification

World seed cotton production almost doubled over the last twenty six years, going from 41 million tons in 1980/81 to 77 million tons in 2006/07, driven mainly by yield increases (yields increased by about two-thirds over the same period).[i] Yields increases have been the result of several technical and managerial advances, such as the improvement of the genetic material in conventional seeds, the introduction of genetically engineered seeds, and/or the adoption of better water, soil and pest management techniques. Although it is indisputable that technical progress has occurred in seed cotton production at the aggregate level, we are unaware of any attempt to measure the speed at which technical change occurred in different countries or how it affected the distribution of income generated among factors of production (labor, capital, land and materials). An analysis of such measures will contribute to the global understanding of how patterns of production changed in the latest years, and their impact on the livelihood of cotton producers and input providers around the world.

Objective

The objective of this study is twofold: (1) to measure technical change in seed cotton production, and (2) to analyze changes in local production practices for a set of countries between 2001 and 2007.

Materials and Methods

Yields, measured in kilograms per hectare, are usually reported by the International Cotton Advisory Committee (ICAC) as indicators of aggregate productivity. However, changes in yields between two points in time can be the result of several factors, such as different intensities of use of the inputs of production (due to changes in relative input prices or input qualities), economies of scale, technical change or climatic factors. Technical change is usually defined as the change in the amount of output produced from the same set of inputs; or, conversely, the change in the amount of inputs used in the production of the same output. In the present study, an index number approach is used in the calculation of technical change. This approach relies on the assumption that seed cotton producers behave as profit maximizing firms and, as a result, measuring technical change does not require the assumption of constant returns to scale in seed cotton production. The production function provides a reasonable way to aggregate inputs. Consider the following translog production function as a flexible, second order approximation to the true seed cotton production function (see Chambers 1988):

$$(1)\ \ln y_t = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln x_{it} + \frac{1}{2}\sum_i \sum_j \alpha_{ij} \ln x_{it} \ln x_{jt} + \beta_0 t + \beta_{00} t^2 + t\sum_{i=1}^{n} \beta_{ij} \ln x_{it}$$

Where ln denotes natural logarithm, y is output, the x_i's are the inputs of production (i=1,…,n) and t is an index of time. As data is available for seasons 2000/2001, 2003/2004 and 2006/2007, the index number approach (which measures technical change over discrete time intervals) is preferred to other approaches based on the assumption that data is observable in continuous time. Using a result developed by Diewert (1976), the following relation between a production function in time t and time v holds:

$$(2)\ \ln y_t - \ln y_v = \frac{1}{2}\sum_i \left(\frac{\partial \ln y_t}{\partial \ln x_{it}} + \frac{\partial \ln y_v}{\partial \ln x_{iv}} \right)(\ln x_{it} - \ln x_{iv}) + \frac{1}{2}\left(\frac{\partial \ln y_t}{\partial t} + \frac{\partial \ln y_v}{\partial v} \right)(t - v)$$

Under profit maximization, the output elasticities equal input shares in total revenue:

$$(3)\ \frac{\partial \ln y_t}{\partial \ln x_{it}} = \frac{w_{it} x_{it}}{p_t y_t} = V_{it}$$

Where w_i is the unit cost of input i and p is the revenue per unit of output. Letting $\frac{\partial \ln y_t}{\partial t} = T_t$ and choosing units arbitrarily so that t=1 and v=0,

$$(4)\ \frac{1}{2}(T_1 + T_0) = (\ln y_1 - \ln y_0) - \frac{1}{2}\sum_i (V_{i1} + V_{i0})(\ln x_{i1} - \ln x_{i0})$$

An exact index of technical change for a flexible technology, i.e. a superlative index, is obtained by taking the exponential form of equation (4):

$$(5)\ \exp\left[\frac{1}{2}(T_1 + T_0)\right] = \frac{y_1}{y_0} \prod_{i=1}^{n} \left(\frac{x_{i0}}{x_{i1}} \right)^{1/2[V_{i1} + V_{i0}]}$$

The right hand side of equation (5) can be loosely interpreted as the ratio of the average product of an aggregate input calculated at two different time periods. If the right hand side of equation (5) is less than 1, then (½)[T_1+T_0]<0, implying that technical regression exists in either period 0 or period 1 and, moreover, that if technical progress exists at all, it is dominated by technical regression. Therefore, equation (5) measures the average rate of technical change for the two time periods.[ii]

The second objective of this study is addressed by analyzing the changes through time of the shares of each input in total cost of production. In this sense, technical change is said to be unbiased (share neutral) if the cost shares are independent of the state of technology, i.e. technical change leaves relative cost shares undisturbed. If technical change is biased, then share-using (saving) technical change is that characterized by an increase (decrease) in the proportion of costs represented by an input of production.

The Technical Information Section of the ICAC maintains a rich database with survey data on the cost of production of seed cotton for several countries that dates back to the early 1980s. The survey was implemented at irregular intervals until 1992, when it started to be implemented every three years, and the collected data includes information on the unit price and the quantity of variable and fixed inputs of production used in the production of one hectare of seed cotton, as well as on the unit price and quantity of seed cotton produced per hectare. However, since participation in the survey is voluntary, not all countries responded every time the survey was implemented. The following countries, selected only on grounds of data availability and completeness, are included in the analysis and together represented about one third of world cotton production in 2006/07: Argentina (Santiago del Estero), Brazil (Northeast), Colombia (Sinú Region), Cote d'Ivoire (Savanna), India (North, Central and South), Iran, Mali, Nigeria, and Pakistan (Punjab). Between seasons 2000/2001 and 2006/2007 world seed cotton yields increased by 25%, at an average annual rate of 4%. However, yields in each country/region evolved differently (Table 1), influenced by local production practices, climate factors, the exchange rate, local inflation, the quality of the inputs, etc. The average increase in seed cotton yields in the selected regions between 2000/2001 and 2006/2007 amounted to 35%, or an annual average equivalent of 5%, with the Southern region of India (rain-fed) experiencing the greatest increase and the Northeastern region of Brazil experiencing the smallest increase in yields over the whole period (125% and 11%, respectively). In all countries/regions in the sample the representative farmer rents the land, except for the Santiago del Estero region in Argentina, where the representative farmer owns the land. Mali and Cote d'Ivoire do not report land rent.

Table 1. Seed Cotton Yields (kg/ha)

Irrigated	**2000/2001**	**2003/2004**	**2006/2007**
Argentina-Stgo. Del Estero	2,000	2,000	2,500
India-North	1,500	1,700	1,800
India-Central	1,500	1,450	2,000
Iran	1,930	2,500	2,350
Pakistan-Punjab	2,200	2,000	na
Average	1,826	1,930	2,163
Rain-fed			
Brazil-Northeast	1,078	1,500	1,200
Colombia-Sinú	na	2,500	2,491
Cote d'Ivoire	na	1,232	1,200
India-Central	800	963	1,000
India-South	800	1,293	1,800
Mali	952	1,135	na
Nigeria	na	500	900
Average	908	1,303	1,432

na: not available

Results

Measures of technical change between 2000/2001 and 2003/2004 (from now on referred to as 2001 and 2004, respectively) are reported in the first column of Table 2. Among the irrigated areas, Argentina, Iran and the Northern region of India experienced technical progress, while the Central region of India and the Punjab region of Pakistan experienced technical regression. The greatest average rate of technical progress was experienced by Iran (7%), while the highest average rate of technical regression was experienced by the Central region of India (-11%). On the other hand, all rain-fed regions experienced technical progress between 2001 and 2004. The Northern region of Brazil experienced the greatest average rate of technical progress (33%), followed by the Southern and the Central regions of India (24% and 21%, respectively), and Mali (10%).

Table 2. Measures of Technical Change (equation 5)

	2004-2001	2007-2004	2007-2001
Irrigated			
Argentina-Stgo. Del Estero (land owner)	1.05	1.24	1.30
India-North	1.06	1.07	1.13
India-Central	0.90	1.34	1.21
Iran	1.07	0.98	1.05
Pakistan-Punjab	0.93	na	na
Rain-fed			
Brazil-Northeast (excluding capital)	1.39	0.87	1.21
Colombia-Sinú	na	0.99	na
Cote d'Ivoire	na	0.93	na
India-Central	1.24	1.03	1.28
India-South	1.27	1.33	1.69
Mali	1.11	na	na
Nigeria	na	1.66	na

na: not available

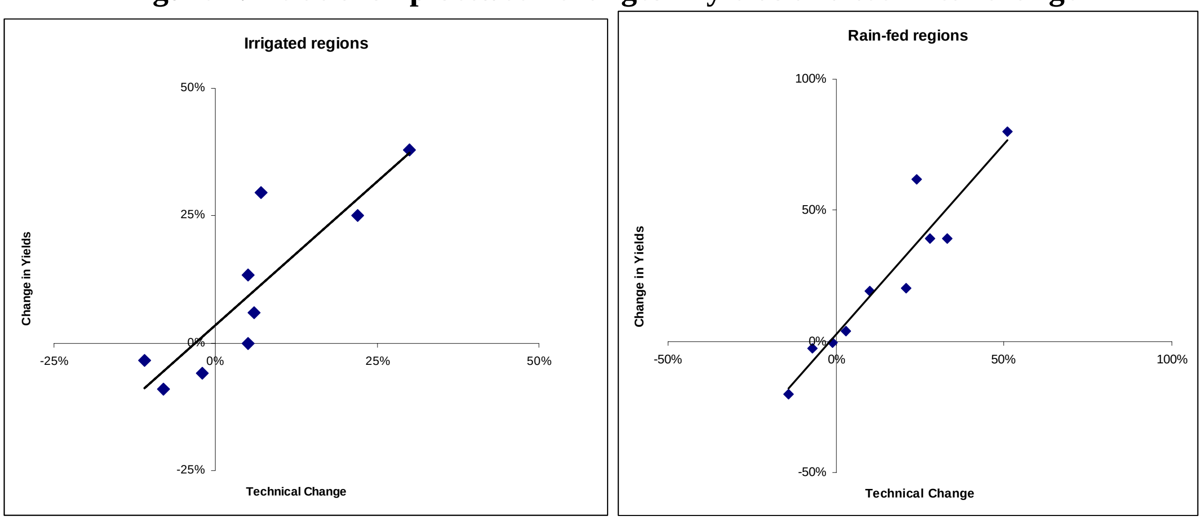
Measures of technical change between 2004 and 2007 are reported in the second column of Table 2. Among the irrigated areas, only Iran experienced slight technical regression over that period (-2%). The Central region of India experienced the fastest rate of technical progress (30%), followed by Argentina (22%) and the Northern region of India (6%). Among the rain-fed regions, Nigeria experienced the fastest average rate of technical progress (51%), followed by the Southern and the Central regions of India (28% and 3%, respectively). However, such technical progress in Nigeria is difficult to reconcile with observed national averages, which indicate that Nigerian seed cotton production decreased by about 10% between 2004 and 2007. On the other hand, the Northeastern region of Brazil experienced substantial technological regression (-14%), followed by Cote d'Ivoire (-7%) and the Sinú region in Colombia (-1%).

Among the irrigated regions, only Argentina and the Northern region of India experienced technical progress over the entire 2001-2007 period, while the Central region of India first experienced technical regression and then technical progression, opposite to the Iranian case. Among the rain-fed regions, the Central and Southern regions of India experienced technical progress over the entire 2001-2007 period, while the Northeastern region of Brazil experienced technical progress first followed by technical regression in the second sub-period.

A relevant finding is that all regions for which data is available experienced technical progress between 2001 and 2007, as indicated in the third column of table 2.

Finally, figure 1 supports our initial statement about the relationship between change in yields and technical change (as measured by equation 4) between two points in time: the (positive) intercepts of the regression lines for the pooled series (regions and sub-periods) suggest that, as expected, yield changes can be the result of factors other than technical change; the (positive) slopes suggest that technical progress tends to generate increases in yields, and technical regression tends to generate decreases in yields.

Figure 1. Relationship between changes in yields and technical change



In pursuit of the second objective of this study, the evolution of the cost structure in each irrigated region is presented in table 3. Inputs are grouped into labor, seed, agro-chemicals (fertilizers, herbicides, insecticides and defoliants), land and other inputs (mechanical harvesting, opportunity cost of invested capital, managerial costs, cost of irrigation, etc.). In Argentina, the representative cotton farm switched from machine picking in 2001 to manual picking in 2004, before returning to machine picking in 2007. As a result, the share of labor is significantly higher in 2004 than in the other two years. However, the share of labor in 2001 was somewhat higher than the share of labor in 2007, indicating that technological progress has been labor-decreasing. Concurrently, the share of agro-chemicals has increased through time, indicating that technological progress has been chemical-increasing. The share of seeds was higher in 2007 than in previous years. The Argentine peso depreciated over the two sub-periods.

In the Northern region of India, the share of land tripled between 2001 and 2004, only to decline slightly in 2007. The share of labor has declined substantially between 2001 and 2004, but the increase in the cost of a man-hour between 2004 and 2007 more than compensated the reduction in man-hours used in production, generating the share of labor to more than double over that period. The share of seeds and agro-chemicals increased between 2001 and 2004, but the share of seeds increased while the share of agro-chemicals decreased between 2004 and 2007. The rupee remained stable between 2001 and 2004, but appreciated about 15% between 2004 and 2007.

In the Central region of India, the share of labor declined significantly between 2001 and 2004, but a significant increase in the number of man-hours applied to dibbling and weeding between 2004 and 2007 generated the share of labor to increase over the latter period. Unlike in the Northern region, in the Central region of India the unit cost of labor remained relatively stable between 2004 and 2007. The shares of seeds and agro-chemicals increased between 2001 and 2004, but the share of seeds more than doubled and the share of agro-chemicals decreased by 45% between 2004 and 2007. Finally, the share of land increased over the whole period.

In Iran, high management and opportunity costs, as well as irrigation costs contributed to high shares of "other inputs". The share of seeds increased and the share of agro-chemicals decreased over the whole period. The share of land decreased significantly between 2001 and 2004, and increased slightly in 2007. The share of labor increased significantly between 2001 and 2004, and remained stable between 2004 and 2007.

In the Punjab region of Pakistan, the shares of agro-chemicals and labor increased substantially, while the shares of land and seeds declined between 2001 and 2004.

Table 3. Evolution of cost shares through time for each irrigated region.

	2000/2001	**2003/2004**	**2006/2007**
Argentina-Stgo. Del Estero			
Labor	23.8	55.0	19.9
Seed	5.2	5.2	7.2
Agro-chemicals	14.8	19.2	37.6
Land	0.6	0.7	0.7
Other Inputs	55.6	19.9	34.5
Total Cost	100.0	100.0	100.0
Total Cost per ha	459.6	479.3	446.2
India-North			
Labor	43.9	15.6	34.5
Seed	1.6	1.9	2.8
Agro-chemicals	22.1	23.5	20.0
Land	11.7	29.2	24.8
Other Inputs	20.7	29.8	17.9
Total Cost	100.0	100.0	100.0
Total Cost per ha	650.0	651.7	636.1
India-Central-Irrigated			
Labor	39.4	22.3	36.2
Seed	3.4	5.1	10.9
Agro-chemicals	27.4	31.4	17.2
Land	10.6	16.8	17.0
Total Cost	100.0	100.0	100.0
Total Cost per ha	513.4	535.3	563.2
Iran			

Labor	23.5	33.8	33.0
Seed	1.8	2.4	2.7
Agro-chemicals	7.7	5.7	5.0
Land	25.1	13.6	16.6
Other Inputs	41.9	44.6	42.6
Total Cost	100.0	100.0	100.0
Total Cost per ha	806.3	1,285.1	1,419.0
Pakistan-Punjab			
Labor	16.2	20.0	
Seed	3.7	2.3	
Agro-chemicals	28.6	36.4	
Land	19.8	17.8	
Other Inputs	31.6	23.5	
Total Cost	100.0	100.0	
Total Cost per ha	833.6	985.2	

Note: Total cost per ha in current US$

The evolution of cost shares in rain-fed regions is depicted in Table 4. In Brazil, the cost share of "other inputs" increased throughout the whole period, but it is not possible to identify what is driving the increase from the survey data. The cost of land, as above mentioned, was not reported for this region in any survey. The combined share of seeds and agro-chemicals increased slightly between 2001 and 2004, but declined significantly between 2004 and 2007. The latter result might have been affected by the depreciation of the reais over the first sub-period, and its appreciation over the second sub-period.

In the Sinú region of Colombia, where the representative farm is characterized by a manual production system, a significant decrease in the share of agro-chemicals and a slight increase in the share of seeds were observed between 2004 and 2007, as well as a substantial increase in the share of "other inputs", driven mainly by the increase in management and administrative costs. At the same time, the Colombian peso appreciated by one fifth over the observed period.

In Cote d'Ivoire, the share of agro-chemicals decreased significantly, due mainly to a decrease in the quantity of herbicides, while the share of labor increased proportionally between 2004 and 2007. Note that seed was distributed free by the government and the exchange rate appreciated over that period.

In the Southern and Central rain-fed regions of India, the share of seeds decreased slightly and the share of agro-chemicals increased significantly between 2001 and 2004, but the share of seeds increased substantially and the share of agro-chemicals decreased substantially reverted between 2004 and 2007. The share of land increased in both regions during the first sub-period, but increased in Central India and decreased slightly in Southern India over the second sub-period. The share of labor first decreased and then increased in both regions.

In Mali, seeds were distributed free of charge in 2004. The share of agro-chemicals increased, the share of labor decreased slightly, and the African Franc appreciated by about one third between 2001 and 2004. Finally, in Nigeria, the significant increase in the share of labor between 2001 and 2004 was accommodated by decreases in the shares of seeds, agro-chemicals and land.

Table 4. Evolution of cost shares through time for each irrigated region

	2001	2004	2007
Brazil-Northeast			
Labor	65.3	53.3	51.8
Seed	5.9	1.8	5.2
Agro-chemicals	14.0	20.1	10.6
Land	na	na	na
Other Inputs	14.9	24.9	32.4
Total Cost	100.0	100.0	100.0
Total Cost per ha	250.5	368.2	688.5
Colombia-Sinú			
Labor		20.8	15.6
Seed		10.0	11.6
Agro-chemicals		45.8	29.5
Land		8.0	10.8
Other Inputs		15.3	32.6
Total Cost		100.0	100.0
Total Cost per ha		1,039.0	1,474.4
Cote d'Ivoire			
Labor		36.7	59.1
Seed		0.0	0.0
Agro-chemicals		52.3	33.8
Land		na	na
Other Inputs		11.0	7.1
Total Cost		100.0	100.0
Total Cost per ha		401.0	581.7
India-Central-Rain-fed			
Labor	34.5	19.1	26.3
Seed	7.2	6.5	14.7
Agro-chemicals	24.9	32.8	17.3
Land	7.2	14.2	23.0
Other Inputs	26.2	27.4	18.7
Total Cost	100.0	100.0	100.0
Total Cost per ha	302.2	401.7	416.7
India-South			
Labor	41.7	26.5	31.8
Seed	6.9	5.9	12.3
Agro-chemicals	23.2	28.8	17.6
Land	6.9	16.3	16.0
Other Inputs	21.3	22.5	22.3
Total Cost	100.0	100.0	100.0
Total Cost per ha	314.2	555.9	589.3
Mali			
Labor	55.0	49.8	
Seed	0.2	0.0	

Agro-chemicals	33.0	37.4	
Land	na	na	
Other Inputs	11.8	12.8	
Total Cost	100.0	100.0	
Total Cost per ha	222.4	450.3	
Nigeria			
Labor		27.5	38.4
Seed		9.3	6.9
Agro-chemicals		44.0	37.0
Land		11.5	9.6
Other Inputs		7.6	8.0
Total Cost		100.0	100.0
Total Cost per ha		503.1	720.8

Note: Total cost per ha in current US$

Conclusions

The purpose of this study is two-fold: to measure technical change in seed cotton production and to analyze the changes in the share of each input of production in total cost for a set of countries/regions. Using data from the ICAC Survey of the Cost of Production of Raw Cotton, superlative indexes of technical change were calculated. Preliminary results indicate that technical change followed different patterns in different regions, but in all cases has been a major force driving changes in seed cotton yields. Cost shares of the inputs of production evolved differently in each region/country through time, suggesting that production practices changed through time. However, given the small sample size of this analysis (both in the cross-section and time series dimensions), these preliminary results should be interpreted with caution. Two further caveats apply: technical change as measured in this study is highly influenced by climatic factors (see footnote 1); and survey data is subject to reporting errors (cost of production data might closely reflect the costs incurred by the best farmers in one region, and be rough estimates of the cost incurred by the median farmer in another region).

References

Chambers, Robert G. *Applied Production Analysis,* Cambridge University Press 1988.

Diewert, D. E, 1976. "Exact and Superlative Index Numbers," *Journal of Econometrics,* vol. 4, p. 116-145.

ICAC. Survey of the Cost of Production of Raw Cotton, various issues.

---

[i] These figures are based on ICAC statistics on lint production, assuming a ginning outturn ratio of 30%.
[ii] The present methodology is not designed to measure the effects of climatic factors on seed cotton production, so those effects are confounded with technical change. Further analysis should be undertaken to measure the contribution of climatic factors to our measure of technical change.

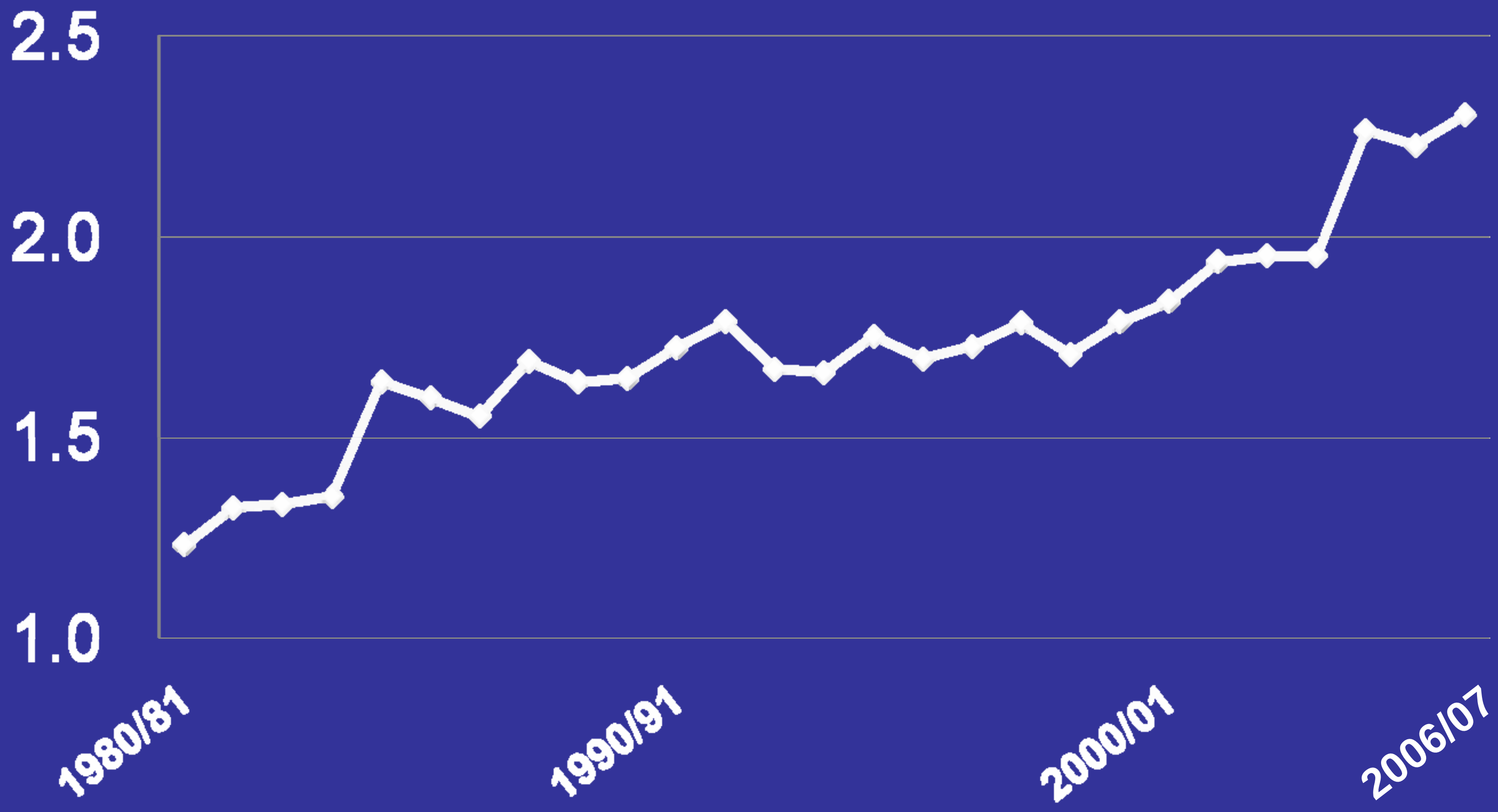
Technical Change in Seed Cotton Production

Alejandro S. Plastina, Ph.D.
M. Rafiq Chaudry, Ph.D.
International Cotton Advisory Committee

Beltwide Cotton Conference 2008

World Average Seed Cotton Yield

Tons/ Hectare



Objective

- To measure technical change in seed cotton production for a set of regions/countries

Data

- Survey of the Cost of Production of Raw Cotton (ICAC):
  - Argentina (Stgo. Estero),
  - Brazil (Northeast),
  - Colombia (Sinú),
  - Cote d'Ivoire,
  - India (North, Central and South),
  - Iran,
  - Mali,
  - Nigeria, and
  - Pakistan (Punjab)

Methodology

- Translog Production Function y=f(x, t)

- Superlative Index of Technical Change:

$$ITC = \frac{y_1}{y_0} \prod_{i=1}^{n} \left(\frac{x_{i0}}{x_{i1}} \right)^{\frac{1}{2}\left[V_{i1}+V_{i0}\right]}$$

- ITC>1: Technical progress
- ITC<1: Technical regression

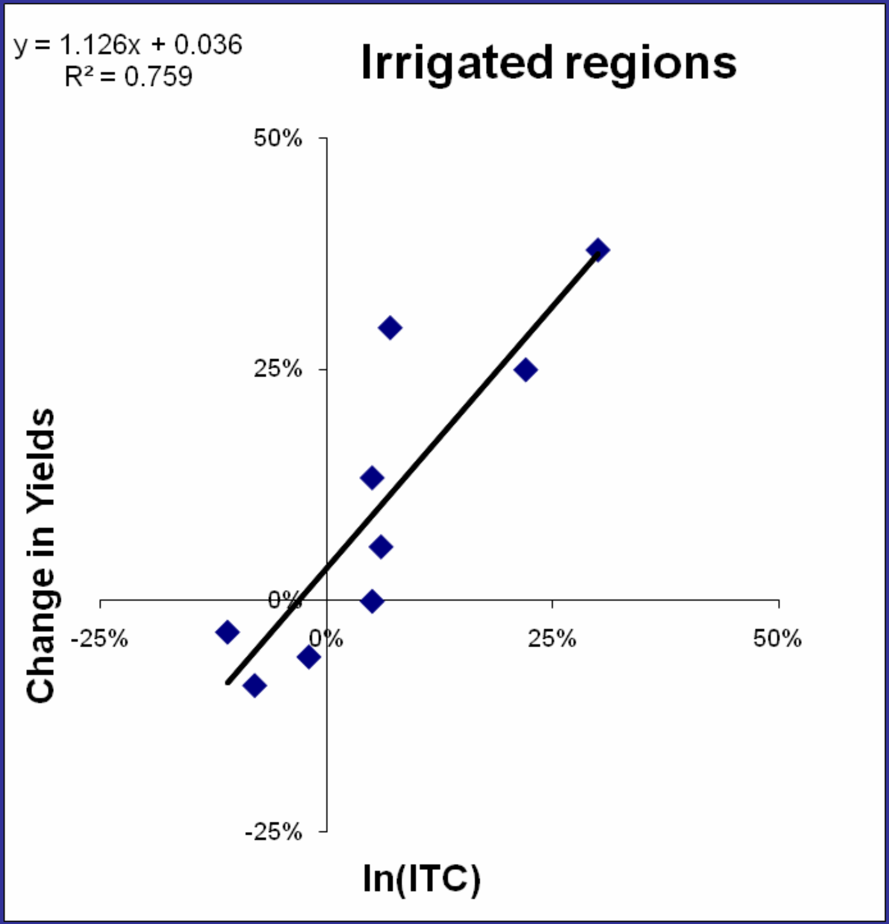
ITC for Irrigated Regions

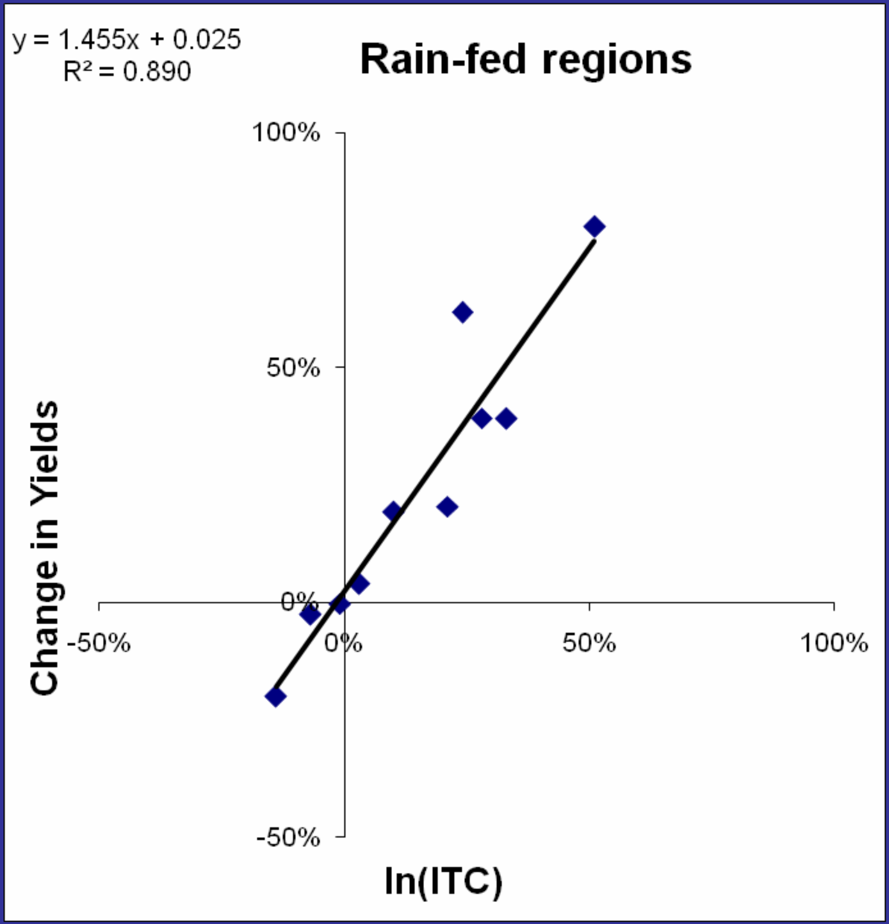
	00/01 to 03/04	03/04 to 06/07	00/01 to 06/07
Argentina-Stgo. Del Estero	1.05	1.24	1.30
India-North	1.06	1.07	1.13
India-Central	0.90	1.34	1.21
Iran	1.07	0.98	1.05
Pakistan-Punjab	0.93	na	na

ITC for Rain-Fed Regions

	00/01 to 03/04	03/04 to 06/07	00/01 to 06/07
Brazil-Northeast	1.39	0.87	1.21
Colombia-Sinú	na	0.99	na
Cote d'Ivoire	na	0.93	na
India-Central	1.24	1.03	1.28
India-South	1.27	1.33	1.69
Mali	1.11	na	na
Nigeria	na	1.66	na

% Change in Yields vs. ln(ITC)





Summary

- Technical progress between 00/01 and 06/07 in all regions
- Technical change followed different patterns in different regions, but in all cases has been a major force driving changes in seed cotton yields

- Caveats: sample size, confounded weather effects, reporting errors

Thank you