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EVALUATING THE PRODUCTIVITY OF U.S. COTTON PRODUCTION

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Abstract

Total Factor Productivity indexes were calculated for 1996-2001. The U.S. is represented by the six largest producing states with available input data. States show similar trends in annual technology measurements. Input inefficiencies are a major cause of differing TFP trends among states. Productivity for the U.S. increased by an average annual rate of 1.1 percent. This is a result of technology improvements that began in 1999. Technology enhancements have compensated for input inefficiencies in states with adverse environmental conditions.

Introduction

Productivity measures output relative to inputs used for production. Increased productivity accounts for output growth that is not due to growth in inputs. A simple method of analyzing productivity is to construct separate ratios for output to each of the inputs. As the ratio increases, this measure of partial factor productivity increases. In comparison, total factor productivity measures the relative change in output due to a combination of all inputs considered simultaneously. Productivity growth indicates resources are applied in an increasingly efficient manner that allows for increased profit and reallocation of resources to other production endeavors. This study attempts to calculate productivity for U.S. upland cotton production.

Research devoted to agricultural productivity has focused on national agricultural economies with multiple outputs. Ahearn et al. calculate the productivity of U.S agriculture increasing by an annual average of 1.94 percent between 1948 and 1994. Later years have higher rates, with a TFP of 3.36 for 1980-1990, and a TFP of 2.77 for 1990-1994. Productivity measures for U.S. agriculture consist of state TFP components. While U.S. aggregate TFP may indicate a relatively stable increase, state measures may have differing rates of increase and greater variability between years (Ball et al.).

Cooke and Sundquist conducted a measure of cotton productivity for 1974-1982. National TFP for cotton increased by an average annual rate of 0.2 percent, with state TFP ranging from –4.0 percent to 6 percent per year. This compares to a TFP increase of 5.2 percent per year between 1939 and 1978 reported by Thirtle. Mitchell, Traxler, and Novak show that TFP increases for 1900-1990 in Alabama are the result of increasing and decreasing cycles of productivity change.

Trends in U.S Cotton Production

Data for this research are from the National Agricultural Statistics Service (NASS) and the Economic Research Service (ERS) of the United States Department of Agriculture. National and selected state data for fertilizer and pesticide usage are published annually by NASS. Rates are published on a per planted acre basis for the largest producing states. States for this study include those with data published annually from 1996 to 2001. Other data published by NASS are for production, acreage, and yield. ERS publishes costs and returns data for production regions. State data are derived for capital and labor costs of cotton production.

Evaluating U.S. upland cotton yields since 1996 shows a steady decline until 1999, with yields rebounding in 2000 and 2001. Averaging the annual changes results in a yield decline of one percent per year. Rate of fertilizer application varied up and down each year for an overall increase, until a sharp decrease in 2001 led to an average decrease of 3.6 percent per year. Pesticide application rates show a pattern similar to fertilizer. However, a large increase in 1999 causes the annual rate to increase by less than one percent. Planted acreage has increased by a rate of 1.5 percent and harvested acreage by 1.4 percent. Even though the average abandonment, planted acreage not harvested, is 12.4 percent during the 1996-2001 period, there has only been an increase of 0.1 percent. Production has increased by 1.3 percent, but this is the result of great volatility between years. These data indicate that there has not been a significant increase in production during 1996-2001, but only a slight upward trend resulting from a 1.5 percent acreage increase per year.

Fertilizer rates and pesticide rates per acre for six selected states are presented in Figure 1 and Figure 2, respectively. Data for 2001 are not published for California. Georgia has the highest fertilizer rate, while Texas has the lowest. Only Louisiana and Mississippi do not have declining trends. For pesticides, Arkansas, Georgia, and Texas have comparatively low rates of application. In later years, all states have similar rate changes for pesticides, unlike 1996 and 1997, which show some states with increasing pesticide rates and others with decreasing rates. Texas and Louisiana have increased pesticide rates of 8.9 percent and 7.7 percent per year, respectively. Georgia and Mississippi have the greatest decreases in pesticide rates. Adoption of biotechnology crops and participation in the boll weevil eradication program may impact pesticide rates. Texas plants approximately 50 percent of cotton acreage in varieties with biotechnology, while Georgia and Mississippi plant approximately 90 percent in varieties with biotechnology (NASS, Crop Production-Acreage). California and Georgia have completed eradication of the boll weevil, while the other states are active in achieving eradication through the boll weevil eradication program.

California is the leader in average yield and the rate of yield increase during 1996-2001, as indicated in Figure 3. Besides an increase of less than one percent in Arkansas, all other states have decreased yields. Overall yield rates are affected by significant increases for 2001 in Arkansas, Georgia, Mississippi, and Texas. These final year increases belie the poor yields that occurred in earlier years. Louisiana has the largest annual yield decline at 3.6 percent.

Method of Analysis

A non-parametric method of calculating the Malmquist TFP indexes is applied for this research. Coelli, Rao, and Battese provide a full theoretical development of using efficiency measurement methods, as well as a brief history of applications. Malmquist indexes are defined by using distance functions. An output distance function evaluates a production technology by calculating the maximum potential expansion of output for a constant level of inputs.

A production technology is defined as the vector of outputs, y, which can be produced with a vector of inputs, x,

1) $P(x) = \{y: x \text{ can produce } y\}$.

The output distance function is defined using equation (1) as

2) $$d_0(x,y) = \min \left\{ \delta : \left(\frac{y}{\delta} \right) \in P(x) \right\}.$$

A Malmquist TFP index measures the change between two output data points by calculating the ratio of the distances each data point is from a common technology. For two time periods, s and t, a Malmquist TFP index is:

3) $$M_0(y_s, x_s, y_t, x_t) = \left[\frac{d_0^s(y_t, x_t)}{d_0^s(y_s, x_s)} \times \frac{d_0^t(y_t, x_t)}{d_0^t(y_s, x_s)} \right]^{\frac{1}{2}},$$

Where s is the base time period, and $d_0^s(y_t, x_t)$ is the distance that the observed output in period t is from the point of what could have been produced with x_t applied to period s technology. The terms in brackets of equation (3) are two TFP indexes, one calculated at period s technology and the other at period t technology. Referring to equation (2), values of δ, for each distance function, are less than or equal to one if y is on or inside of the feasible production set, and greater than one when y is outside the feasible production set. Thus, the Malmquist TFP is the geometric mean of two TFP indexes in (3). For time series data over *N* years, the Malmquist TFP is the geometric mean of *N*-1 TFP indexes.

Equation (3) can be rewritten to express components for technical change and efficiency change. Technical change measures the shift in technology between two periods and is:

4) $$\text{Technical change} = \left[\frac{d_0^s(y_t, x_t)}{d_0^t(y_t, x_t)} \times \frac{d_0^s(y_s, x_s)}{d_0^t(y_s, x_s)} \right]^{\frac{1}{2}}.$$

Efficiency change measures the mix of inputs that produce a given output between two periods as:

5) $$\text{Efficiency change} = \frac{d_0^s(y_t, x_t)}{d_0^s(y_s, x_s)}.$$

TFP is the product of technical change and efficiency change.

Calculation of TFP in (3) requires solving four linear programs, one for each distance function. Coelli, Rao, and Battese (p. 227) describe the LP models for solution under the assumption of constant returns to scale. The authors also present potential problems associated with solving inter-period LP's under the assumption of variable returns to scale. Malmquist TFP indexes for this study are calculated using *DEAP* (Coelli).

Total Factor Productivity

Table 1 presents the 1996-2001 indexes for output, planted acres, yield, fertilizer and pesticide rates, as well as estimates for capital and hired labor allocated to cotton production. Fertilizer and pesticide rates are multiplied by planted acreage for application in TFP calculations. Data for 2001 are not published for California, but fertilizer and pesticide rates are estimated to have decreased in 2001, based on historical proportions of the U.S rate. A fertilizer rate is estimated as 141.4 lbs. per acre and pesticides are estimated as 5.25 lbs per acre. Capital and labor are estimated for each state by applying cost of production data from the Economic Research Service. Regional data on a per acre basis are multiplied by acres for a state in order to derive total capital and labor expenditures. A limitation of this data is that production technologies are based on a single survey year, and costs for subsequent years are derived from only price changes. This method of estimation assumes a capital and labor market for each state that is fundamentally unchanged during 1996-2001.

Figure 4 shows each state represented by an index of 1.0 in 1996, and subsequent years are the cumulative affect of TFP change. Table 2 presents the annual changes in TFP from the previous year and total change that is the geometric mean over all years. Geometric means are calculated by multiplying changes for all years and taking the root as determined by the number of years. See equation (3) for an example of a geometric mean over two years.

Figure 4 indicates similar TFP trends among states in many years. Productivity for the U.S. increased at an average annual rate of 1.1 percent in Table 2. In 1997, Georgia and Louisiana have sharp declines, but all states have declines in 1998. There is then a leveling in TFP, followed by a general increase in later years. Louisiana and Mississippi have cumulative declines. Arkansas, Georgia and Texas have total increases that are attributed to tremendous TFP increases in 2001. Only California has stable increases throughout 1996-2001. The measured productivity of California may be attributed to a large decrease in planted acreage and inputs, with increased yields.

TFP measures include a measure for technical change in equation (4) that shows a change in production technology. Figure 5 presents the cumulative technical change that is a component of TFP. Table 3 shows the annual changes in technology and the average for each year, as well as each selected state. In cases where technical change is greater than TFP, this must be due to a low input efficiency change measure in equation (5). Thus, while technology may increase, other factors may negatively impact TFP. Climactic conditions are a primary consideration for declining input efficiency during periods of technology increase. These technology trends should be compared to the trends for fertilizers, pesticides, and yield. The only year of U.S. technical decrease occurs in 1998 when there was a large decrease in yield. Technical change measurements should be regarded as representing utilization of technology rather than a technology stock. While Figures 1-3 show significant annual differences among states, technical change results in Figure 5 show that farmers in all states have similar capabilities to adopt technology in order to maintain productivity. All states have an increasing average technology change, with much less volatility than TFP measures. Texas and California are the leaders in technical change. California has TFP equal to technical change in each year, meaning no measured input inefficiencies. Other states have years with TFP greatly different than technical change, indicating input inefficiency impacts. Increasing trends in all state technical change measures begin in 1999.

Summary

Between 1996 and 2001, U.S. cotton productivity increased by an annual rate of 1.1 percent. Increased productivity is due to substantial technology improvements during 1999-2001. National productivity is a composite of state productivity measures, which show a 19.1 percent difference between the highest state and the lowest state. Differences in productivity are mostly due to input efficiency decreases in some states. General results of technical change trends indicate that U.S farmers respond similarly to production circumstances and market conditions. However, inefficiencies that are attributed to environmental factors negatively affect long-term TFP measures in states with highly volatile production circumstances. Long-term TFP may be greatly enhanced by production methods that minimize negative changes in difficult years.

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Table 1. Geometric Mean of Indexes for Production, Harvested Acres, Yield, and Inputs, 1996-2001, by State.

	AR	CA	GA	LA	MS	TX
Production	1.0230	0.9417	1.0132	0.9573	1.0501	0.9961
Acres Planted	1.0155	0.9117	1.0214	0.9955	1.0766	1.0103
Yield	1.0082	1.0335	0.9927	0.9639	0.9743	0.9889
Fertilizer Rate	0.9732	NA	0.9513	1.0029	1.0048	0.9420
Pesticide Rate	0.9967	NA	0.9542	1.0768	0.9432	1.0885
Capital	1.0134	0.9064	1.0165	0.9934	1.0744	1.0101
Labor	1.0230	0.9100	1.0316	1.0028	1.0846	1.0172

Table 2. Geometric Mean of Malmquist TFP, 1997-2001, by State.

	AR	CA	GA	LA	MS	TX	Average
2001	1.131	1.111	1.581	0.916	1.111	1.568	1.212
2000	1.009	1.233	1.027	0.877	0.913	0.762	0.959
1999	1.092	1.248	0.913	1.261	0.937	1.173	1.095
1998	0.779	0.872	0.903	0.770	0.807	0.862	0.831
1997	1.067	1.141	0.762	0.910	1.091	1.068	0.997
Total	1.007	1.112	1.004	0.934	0.965	1.052	1.011

Table 3. Geometric Mean of Technical Change, 1997-2001, by State.

	AR	CA	GA	LA	MS	TX	Average
2001	0.977	1.111	1.114	0.977	0.977	1.108	1.042
2000	1.093	1.233	1.093	1.093	1.093	1.393	1.162
1999	1.292	1.248	1.330	1.255	1.131	1.090	1.221
1998	0.779	0.872	0.791	0.794	0.807	0.995	0.836
1997	1.067	1.141	1.003	1.052	1.091	1.068	1.069
Total	1.028	1.112	1.051	1.023	1.012	1.123	1.057

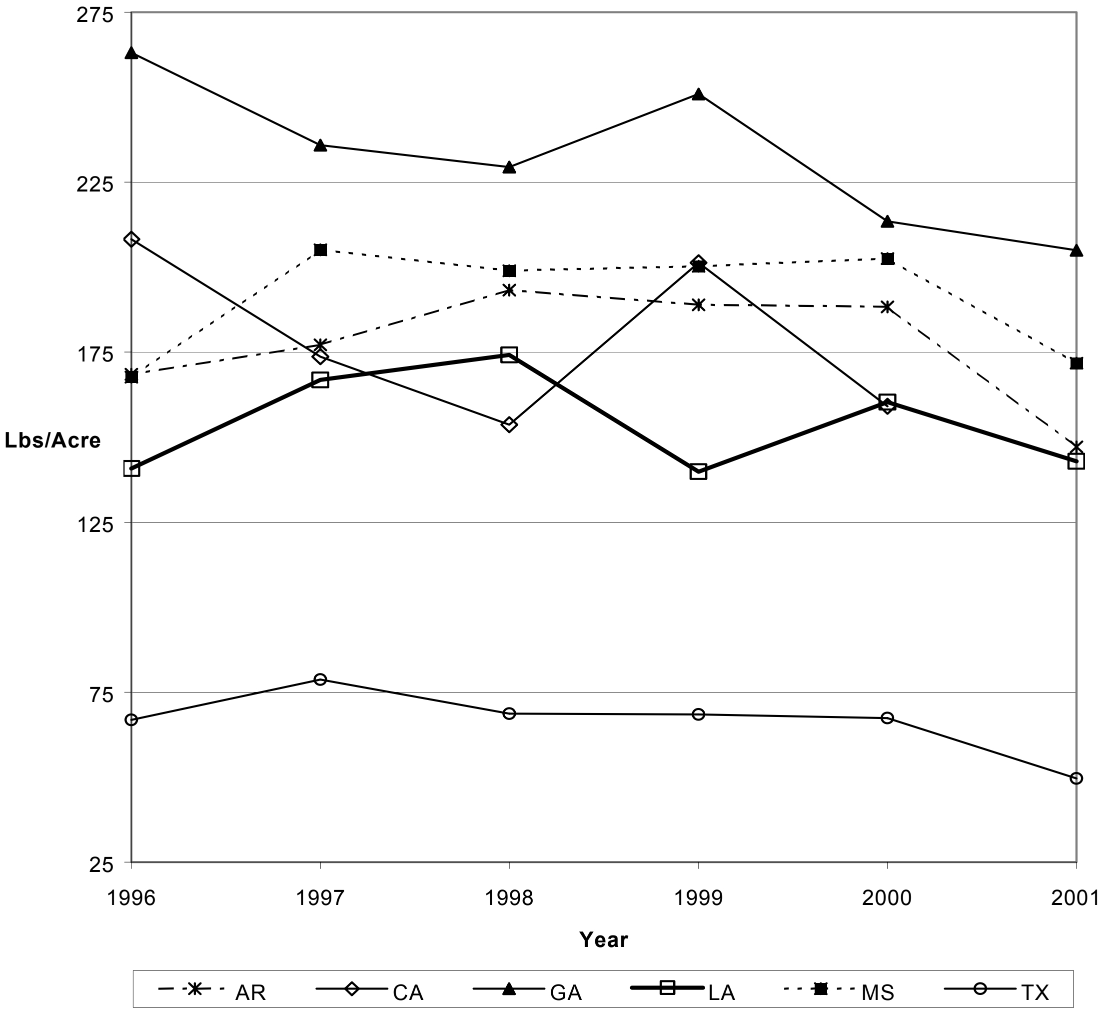

Figure 1. Fertilizer Rate per Acre, 1996-2001, by Selected States.

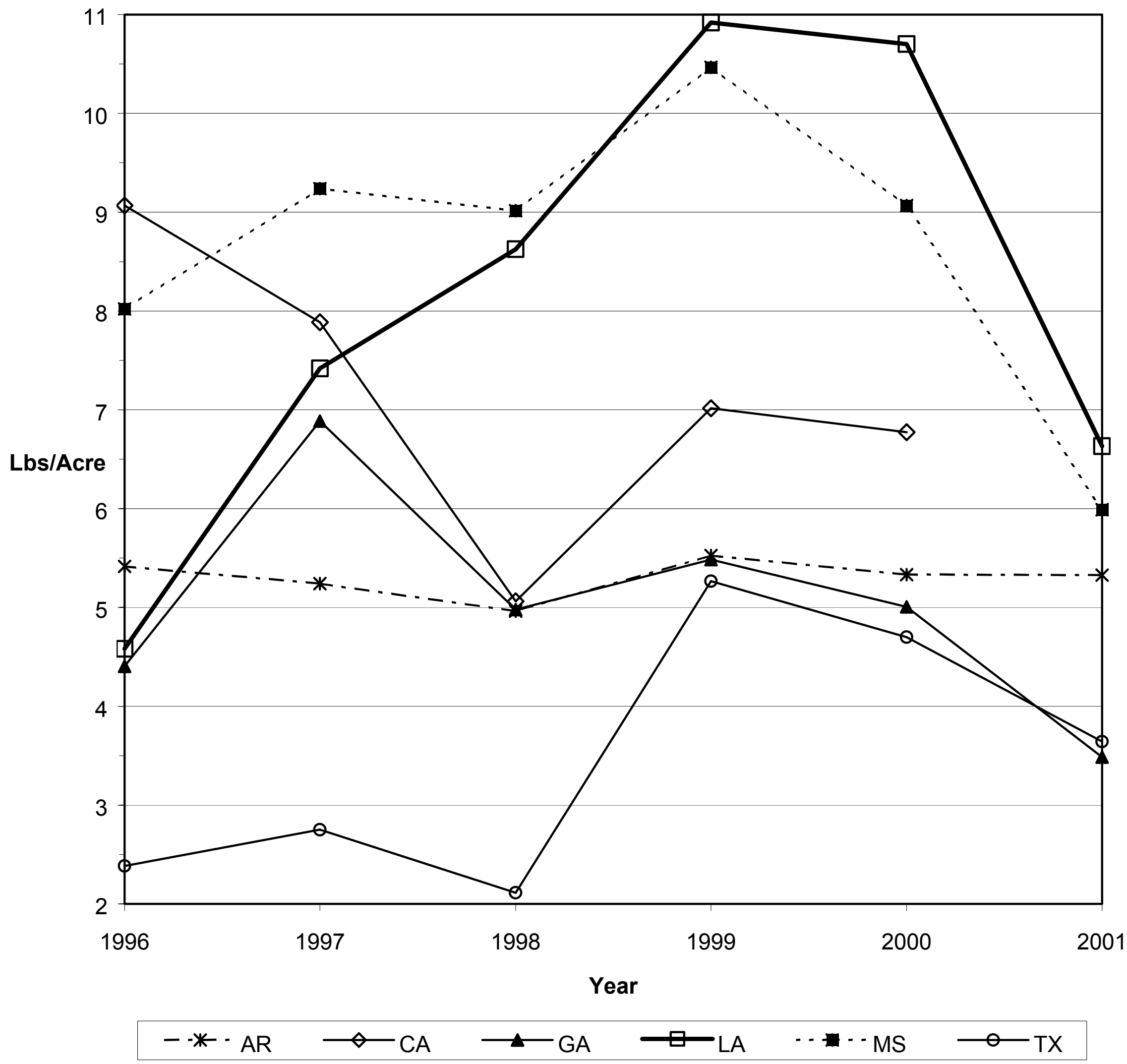

Figure 2. Pesticide Rate per Acre, 1996-2001, by Selected States.

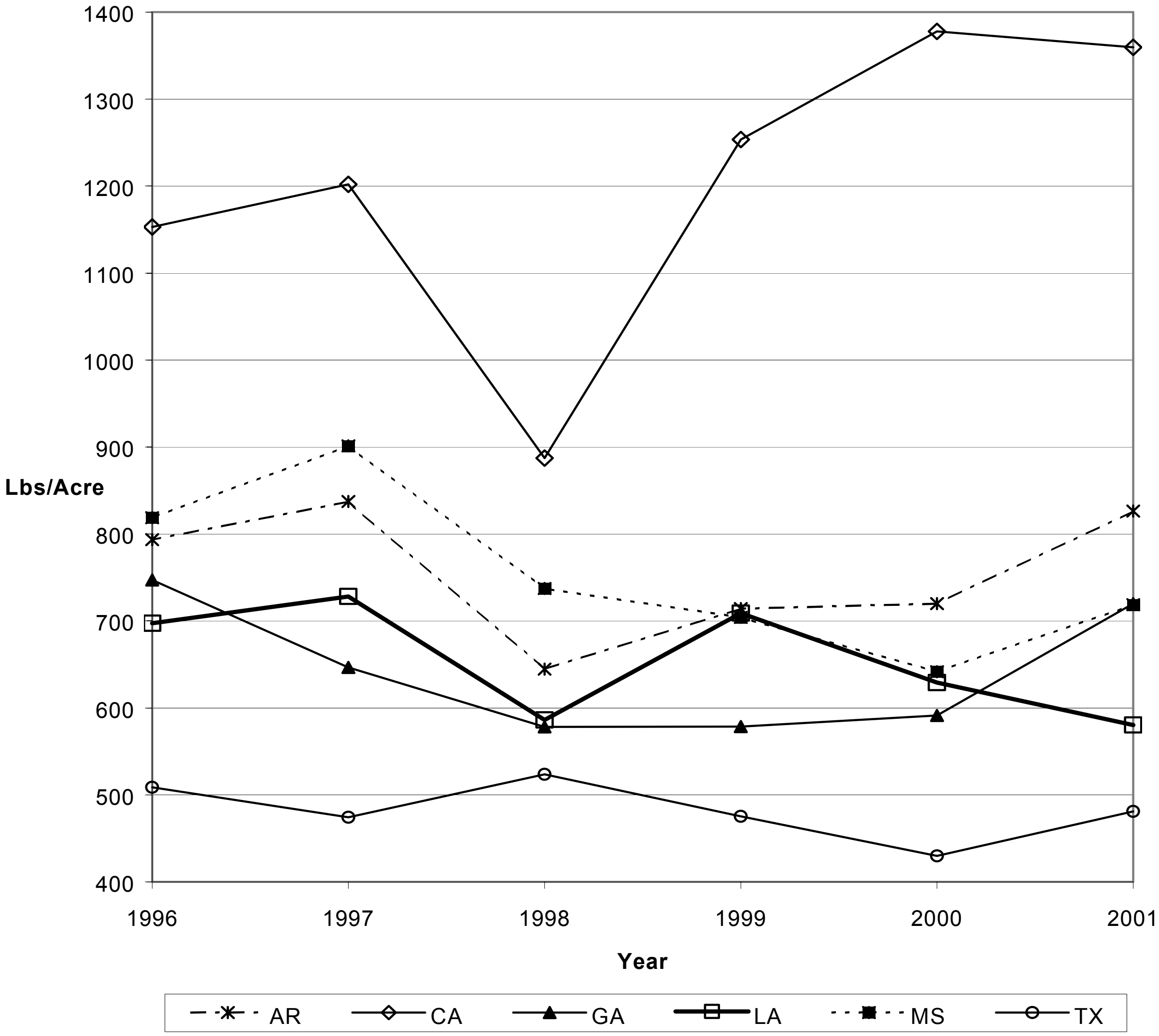

Figure 3. Yield, 1996-2001, by Selected States.

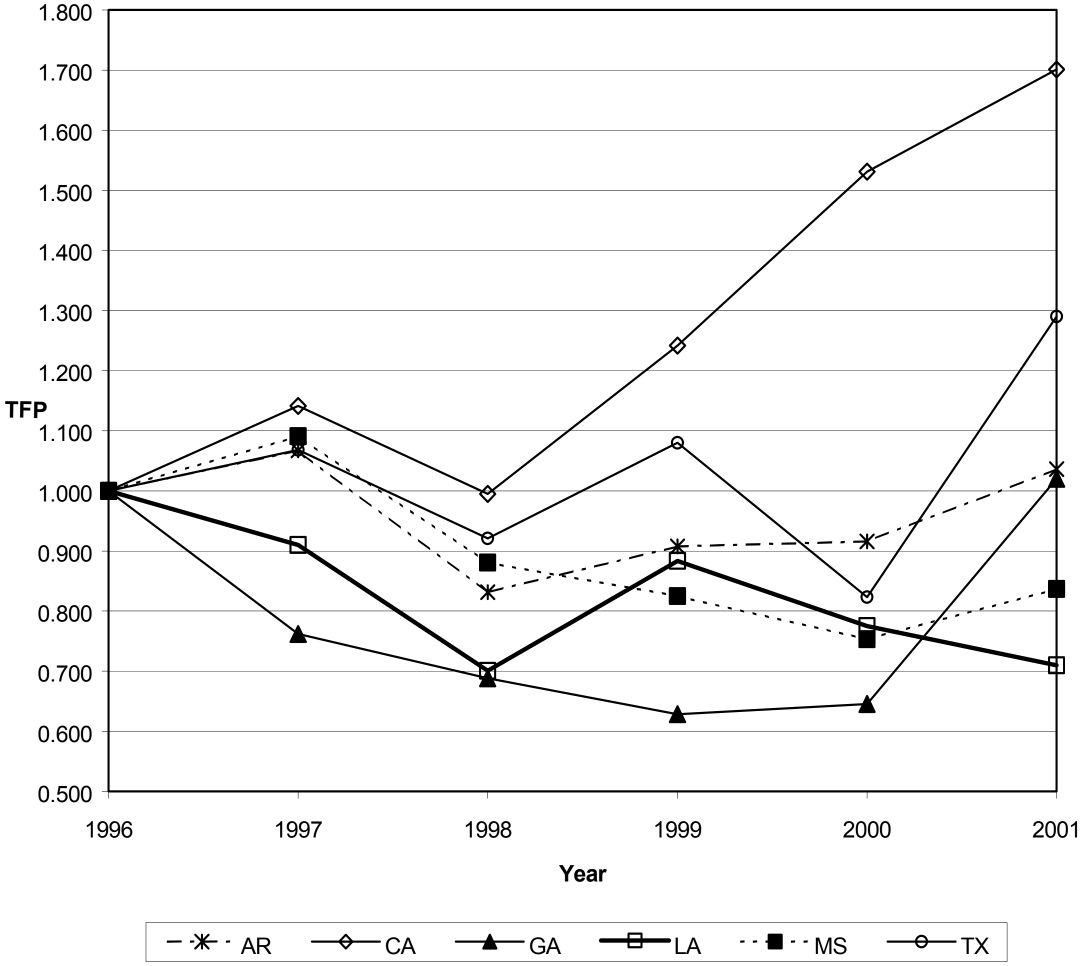

Figure 4. Cumulative TFP, 1996-2001, by Selected States.

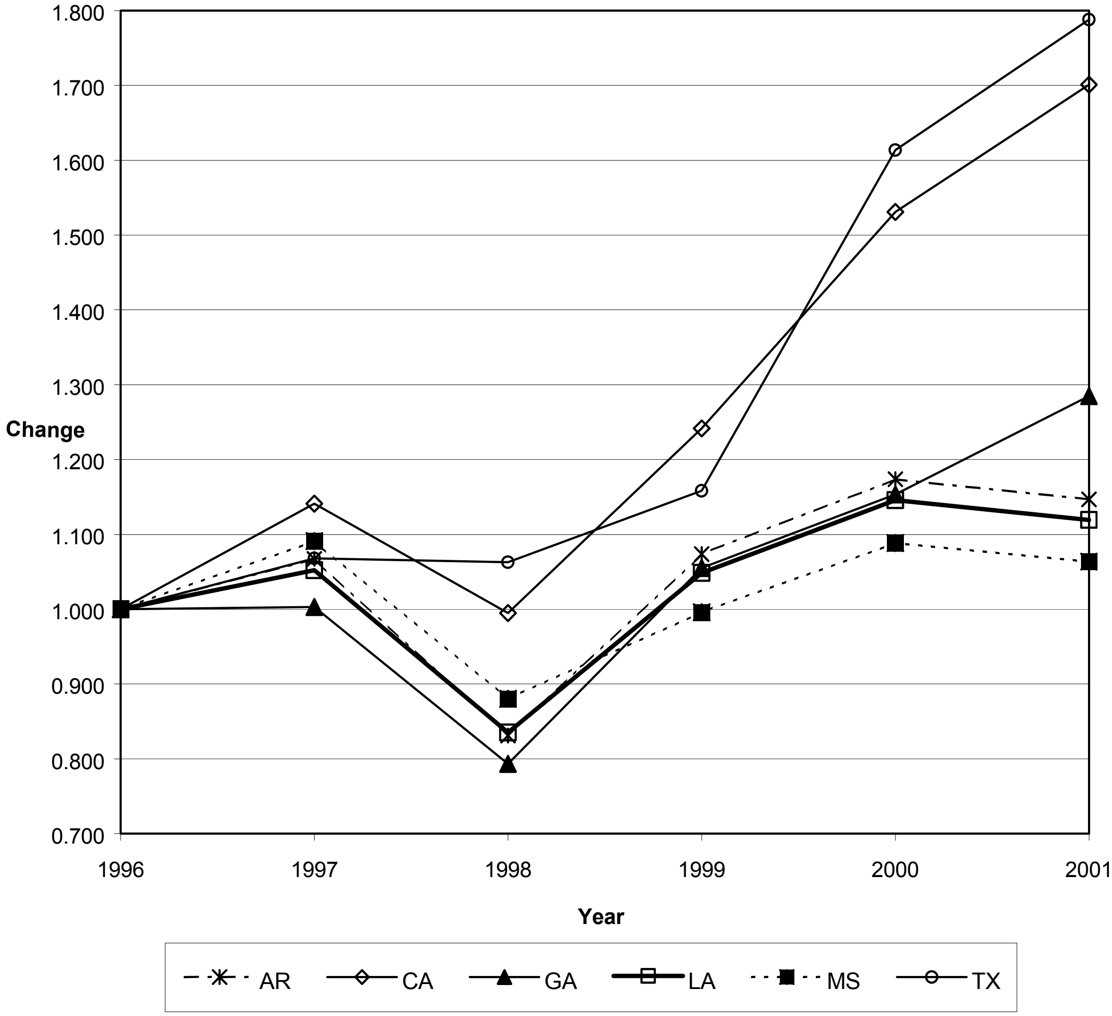

Figure 5. Cumulative Technical Change, 1996-2001, by Selected States.