The Texas Journal of Agriculture and Natural Resources 32:1-11 (2019) 1

Economics of Comparative Advantage: Evidence from Upland Cotton Production in Texas in 1997-2016

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ABSTRACT

By using three different comparative advantage indices, which include Efficiency Advantage Index (*EAI*), Scale Advantage Index (*SAI*), and Aggregate Advantage Index (*AAI*), the study explores the changes in comparative advantages in upland cotton production in Texas; compares the changes in comparative advantage between upland cotton production with four other major crops planted in Texas; and compares the changes in comparative advantage in upland cotton production between Texas and four other major cotton-producing states from 1997 to 2016. The study reveals that the Texas has a notable comparative advantage in upland cotton production.

KEYWORDS: Aggregate Advantage Index (*AAI*); comparative advantage; Efficiency Advantage Index (*EAI*); Scale Advantage Index (*SAI*); upland cotton

INTRODUCTION

Cotton is one of the most important textile fibers in the world, accounting for 35% of total world fiber use. China, India, and U.S. are three major cotton producers and produce two-thirds of the cotton in the world (Rosson et al. 2011). Currently, the U.S. is the world's third largest cotton producer which produces more than one-third of the world's exported cotton and the largest exporter, which regularly ships 40 to 60% of its produced cotton abroad (Johnson et al. 2018). The cotton industry generates more than 191,000 jobs among the various sectors from farm to textile mill and accounts for more than $50 billion in products and services annually in the U.S. (Richardson and Outlaw 2013).

Currently, there are 17 states that grow cotton in U.S (National Agricultural Statistics Service (NASS) 2017). The primary variety of cotton grown is American upland (*Gossypium hirsutum*), which makes up about 97% of the total production. It is grown throughout the U.S. Cotton Belt, including areas of the Texas High and Rolling Plains, Mississippi, Arkansas, and Louisiana Delta, California's San Joaquin Valley, Central Arizona, and Southern Georgia (National Cotton Council 2011).

Texas is the largest cotton producer in the nation (Census of Agriculture 2015). On average, Texas plants 5.9 million acres and produces 27.5 billion bales of cotton annually from 1995 to 2017, which represents about 48% of acreage and 47% of total

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cotton production in the U.S. (NASS 2017). Cotton production generated $2.2 billion in 2017 for Texas farmers and is the state's top cash crop. The crop has a statewide impact of $24 billion, including money generated by supporting industries associated with harvesting, transporting, processing, and marketing cotton (Southern Farm Press 2017). On average, cotton makes up 10.2% of all the state's agricultural cash receipts and ranks third in the state behind the beef and poultry industries from 2010 to 2017 (Texas Agricultural Statistics 2017).

From 1991 to 2017, U.S. upland cotton yield has improved 38% (National Cotton Council 2017). Modern technology has played an important role in the crop production. In recent years, productivity in cotton production has increased dramatically, because of increased use of fertilizers, improved pest management, improved cultivars, and enhanced irrigation practices (Meyer et al. 2007).

The objectives of this study are: (1) to evaluate the changes in comparative advantage of upland cotton production in Texas from 1997 to 2016; (2) to compare the comparative advantage among different major crops produced in Texas from 1997 to 2016; and (3) to evaluate the comparative advantage in major cotton producing states from 1997 to 2016.

The paper is organized as follows: the introduction, materials and method, results, and concludes with the key messages of this study.

MATERIALS AND METHODS

There are several previous studies related to comparative advantage in agriculture. Pearson and Meyer (1974) evaluated comparative advantages of the four main coffee growing countries in Africa. The focus of the study was to calculate the Domestic Resource Cost (DRC) per unit of foreign exchange earned or saved. The study found that Uganda, Ethiopia, and Tanzania all had strong comparative advantages in coffee production with very little deviation among each country's respective indices, while Ivory Coast was found to be reasonably weaker in competition compared to the other three countries. Zhong et al. (2000) studied the comparative advantage in grain production across different regions of China. Net Social Profitability (NSP) and Domestic Resource Cost (DRC) were used to measure price advantages, while Efficiency Advantage Index (*EAI*), Scale Advantage Index (*SAI*), and Aggregate Advantage Index (*AAI*) were used to measure production advantages. The study found that advantages varied in major grain crops among different regions in China, and there was a potential to improve grain production efficiency in China through the reallocation of natural resources and restructuring of the grain sector. Li (2005) estimated the *EAI*, *SAI*, and *AAI* of non-timber forest products (NTFPs) in Zhejiang Province, and found that there existed tremendous variations among these regions, suggesting that NTFPs should be chosen according to the regional conditions.

This study will use a set of indicators, which include Efficiency Advantage Index (*EAI*), Scale Advantage Index (*SAI*), and Aggregate Advantage Index (*AAI*) to measure the relative yield, scale, and aggregate advantage of upland cotton production in Texas (Yu et al. 2006; Yin and Huang 2014; Chen and Cao 2013).

EAI is an indication of how efficiently a crop grows in one specific region. It is calculated by using the relative yield of one crop in one region divided by the average yield of all crops in the same region, over the average yield of the same crop in the nation relative to the average yield of all crops in the nation. It can be expressed as follows:

$$EAI_{ij} = \frac{Y_{ij}/Y_i}{Y_{nj}/Y_n} \quad (1)$$

where, EAI_{ij} represents the Efficiency Advantage Index of the *j*th crop in the *i*th region; Y_{ij} is the yield of the *j*th crop in the *i*th region; Y_i represents the average yield of all crops in the *i*th region; Y_{nj} is the national average yield of the *j*th crop; and Y_n is the national average yield of all crops.

If $EAI_{ij} > 1$, the yield of the *j*th crop in the *i*th region, relative to all other crops' yield growing in the same region is higher than that of the national average. It can be interpreted as in the *i*th region, there is a yield or an efficiency advantage in growing the *j*th crop; and vice versa, if $EAI_{ij} < 1$. By assuming no government intervention or policy support and a fully competitive market structure, the EAI_{ij} can be taken as an indicator of relative physical efficiency due to natural resources and other local economic, social and cultural factors in the study region.

The *SAI* indicates the extent of concentration of a certain crop growing in a region, relative to that ratio of the same crop growing in the nation. It can be expressed as follows:

$$SAI_{ij} = \frac{S_{ij}/S_i}{S_{nj}/S_n} \quad (2)$$

where, SAI_{ij} is the Scale Advantage Index of the *j*th crop in the *i*th region; S_{ij} represents the planted area of the *j*th crop in the *i*th region; S_i is the total planted area of all crops in the *i*th region; S_{nj} is the total planted area of the *j*th crop in the nation; and S_n represents the total planted area of all crops in the nation. If $SAI_{ij} > 1$, it implies the degree of concentration of the *j*th crop growing in the *i*th region is higher than the average concentration ratio in the nation. It also indicates that producers in the *i*th region prefer to grow more of *j*th crop, compared to other producers in the nation and vice versa, if $SAI_{ij} < 1$.

Assuming a fully competitive market structure and that producers can quickly adjust the crop mix by responding to the market price and cost changes, the concentration level is determined by the profit level of certain crop growth in the region. A low value of *SAI* implies producers are not willing to increase the share of that crop production in the region. This is may be because it is less profitable than other crops or may be that it is restricted by natural or other conditions, while a high value of *SAI* implies that producers want to increase the share of that crop production in that particular region.

The *AAI* is an aggregate indication of the overall comparative advantage of a certain crop in one region relative to the national average. It can be calculated as the geometric average of the *EAI* and *SAI* as follows:

$$AAI_{ij} = \sqrt{EAI_{ij} \times SAI_{ij}} \quad (3)$$

If $AAI_{ij} > 1$, the *j*th crop in the *i*th region is considered to have an overall comparative advantage over the national average, while $AAI_{ij} < 1$ indicates *j*th crop in the *i*th region does not have an overall comparative advantage over the national average (Cui and Zhou 2013).

Upland cotton is thecrop that will be studied in this research.. Cotton and other major crops' yields and production data are used in calculating the three indices. The primary source of data for this study is the NASS of the United States Department of

Agriculture (USDA), which include individual state-level data in the U.S. Table 1 provides a summary of variables from the study period for Texas and the U.S., e.g., cotton yield, cotton planted acreage, corn yield, corn planted acreage, hay yield, hay acreage, sorghum yield, sorghum planted acreage, wheat yield, and wheat acreage (NASS 2017).

Table 1. Summary of Descriptive Statistics in 1997-2016.

Parameters	Units	Average	Maximum	Minimum	Standard Deviation
Texas					
Cotton Yield	lbs/ac	611.5	843.0	432.0	106.25
Cotton Acreage	mil ac	5.83	7.57	4.82	0.63
Corn Yield	bu/ac	125.7	148.0	91.0	14.56
Corn Acreage	mil ac	2.11	2.90	1.60	0.83
Hay Yield	tons/ac	2.07	2.76	1.19	0.37
Hay Acreage	mil ac	4.91	5.64	3.70	0.51
Sorghum Yield	bu/ac	57.0	70.0	46.0	6.80
Sorghum Acreage	mil ac	2.70	3.55	1.55	0.60
Wheat Yield	bu/ac	30.6	37.0	24.0	3.46
Wheat Acreage	mil ac	5.95	6.60	5.00	0.41
U.S.					
Cotton Yield	lbs/ac	769.6	892.0	607.0	87.56
Cotton Acreage	mil ac	12.58	15.77	8.58	2.25
Corn Yield	bu/ac	148.1	174.6	123.1	14.66
Corn Acreage	mil ac	85.11	97.29	75.70	6.67
Hay Yield	tons/ac	2.43	2.55	2.14	0.10
Hay Acreage	mil ac	59.64	63.94	53.19	3.13
Sorghum Yield	bu/ac	64.4	77.9	49.6	8.27
Sorghum Acreage	mil ac	7.90	10.25	5.37	1.50
Wheat Yield	bu/ac	45.09	55.30	38.20	3.36
Wheat Acreage	mil ac	42.40	47.99	36.15	3.02

RESULTS

Comparative advantage in Texas upland cotton in 1997-2016. Using the Equations (1) to (3) above, Efficiency Advantage Index (*EAI*), Scale Advantage Index (*SAI*), and Aggregate Advantage Index (*AAI*) were calculated for Texas upland cotton for 1997-2016 and are presented in Figure 1.

From 2007 to 2016, the average *EAI* for Texas upland cotton is 1.02, which indicates that Texas cotton production has a relatively small Efficiency Advantage. *EAI* values ranged from 0.78 to 0.96 (below 1.00) in each year from 1997 to 2006, which means Texas did not have efficiency advantage in this time period. However, *EAI* improved to a range of 1.03 to 1.20 in each year during the period of 2007-2016, which indicated that Texas improved its efficiency in cotton production in this time period.

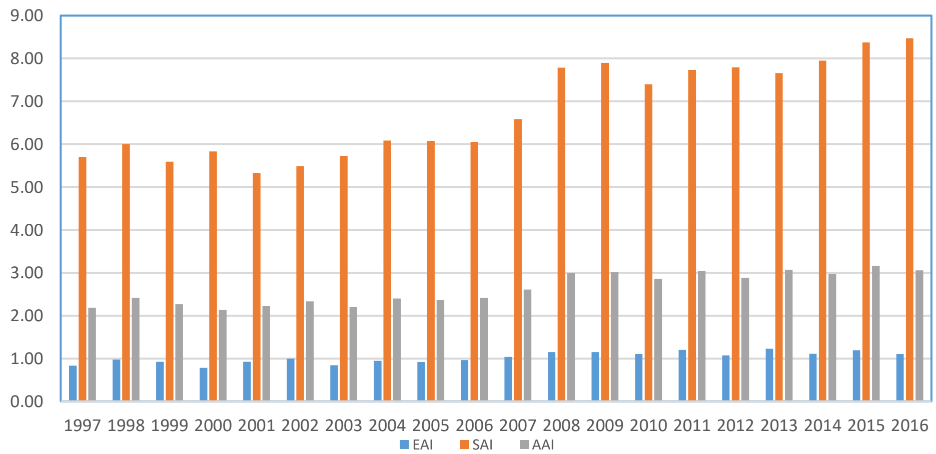

Figure 1. Texas Upland Cotton Comparative Advantage Trends from 1997 to 2016.

The average *SAI* in 1997-2016 was 6.78, which means that Texas had a relatively large scale advantage in cotton planted acres. From 1997 to 2006, the *EAI* ranges from 5.33 to 6.08, while it ranged from 6.58 to 8.47 from 2007 to 2016, which indicated a notable improvement in the scale advantage in the last 10 years of the study period.

AAI, the aggregate advantage index, ranged from 2.13 to 3.16, and averaged 2.63 from 1997 to 2016. The results indicated that there is a large aggregate comparative advantage in upland cotton production during the study period.

Most cotton in Texas is planted on non-irrigated land. An increase in irrigated acreage, gene technologies, cotton breeding program, improved technologies, all played important roles in improving cotton yield in Texas (Yu et al. 2000), which led to the improvement of *AAI* over the study period and a large aggregate advantage in cotton production in Texas.

Comparative advantage of major crops produced in Texas in 1997-2016. Texas is the largest cotton-producing state in the nation. Other important agricultural products produced in the state are greenhouse and nursery products, corn for grain, hay, wheat, sorghum grain, peanuts, rice, and cane for sugar (Texas Net State 2016). In order to analyze the comparative advantage of major crops produced in Texas, this study chose the top five cash-receipt crops in Texas based on the average percentage in 1997-2016: upland cotton (26.08%), corn (21.75%), hay (12.54%), sorghum (9.23%), and winter wheat (7.08%) (NASS 2017).

Figure 2 shows that the *SAI* of major crops in Texas varied significantly from 1997 to 2016. Cotton exhibits the largest scale advantage among five crops with an average *SAI* of 6.78 and displays a notable increasing trend. Sorghum ranked the second, with an average *SAI* of 4.79, which means that sorghum also had relatively large-scale advantage in terms of area planted. Both average *SAIs* of wheat (1.98) and hay (1.16) were greater than 1, implying both crops had a scale advantage in terms of area planted. The average *SAI* for corn (0.35) is less than 1, which indicates relatively small planting acres planted and no scale advantage in Texas.

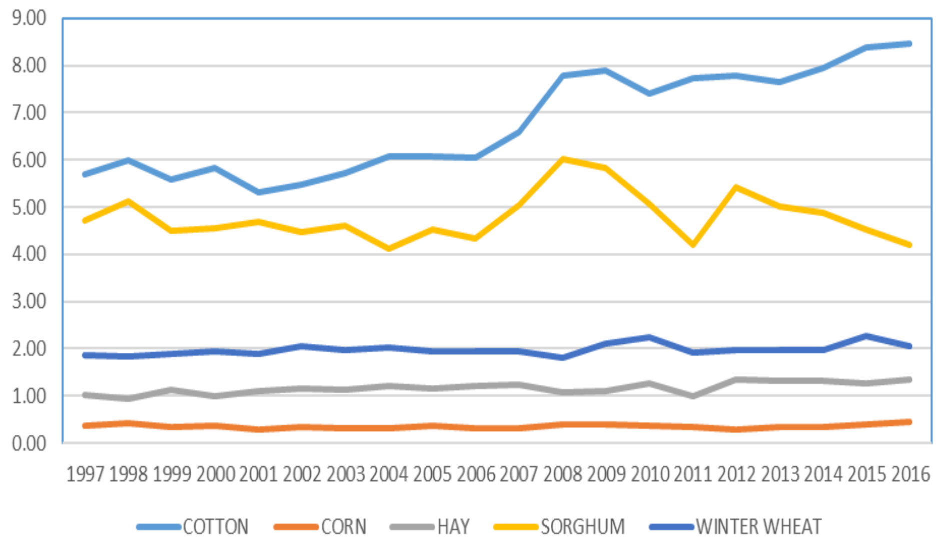

Figure 2. *SAI* of Major Crops in Texas in 1997-2016.

Figure 3 shows the *EAI* of the five major crops in Texas from 1997 to 2016. The average *EAI* can be ranked as sorghum 1.14, corn 1.08, hay 1.08, cotton 1.02, and winter wheat 0.87. *EAI* for sorghum reached the highest value of 1.76 in 2012 and lowest value of 0.79 in 1998. Corn had the highest *EAI* of 1.55 in 2012 and lowest *EAI* value of 0.85 in 1998. Hay displayed the largest efficiency advantage at 1.29 in 2016 and lowest advantage of 0.78 in 1998. *EAI* for cotton reached highest value of 1.23 in 2013 and lowest value of 0.78 in 2000. Winter wheat had the highest *EAI* of 1.04 in 2015 and lowest *EAI* of 0.66 in 2006. Visually, *EAI* displays a lot of variation with *EAI* less than 1 for all five crops in the same year, which can be related to the drought experienced in that year and lack of irrigation system in the state's agriculture.

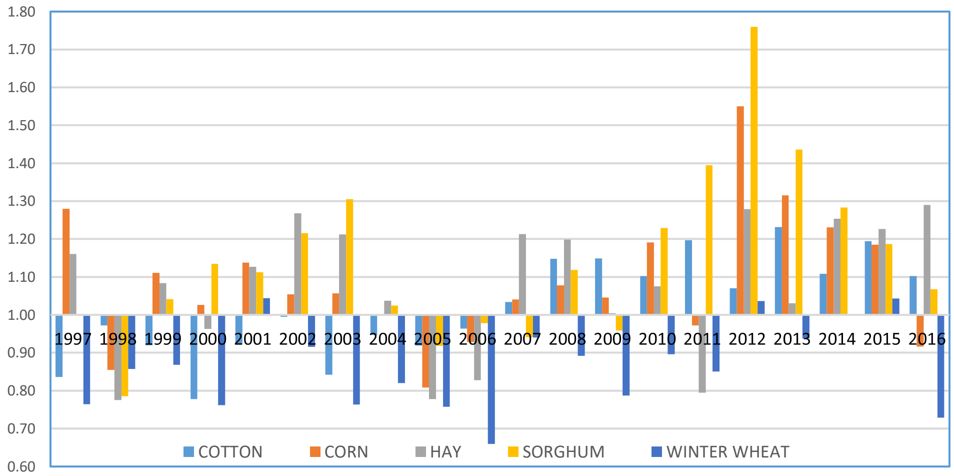

Figure 3. *EAI* of Major Crops in Texas in 1997-2016.

Figure 4 shows the *AAI* of major crops in Texas from 1997 to 2016. Cotton had a large aggregate comparative advantage, and the upward trend in the 20 years is highly notable. Sorghum ranked the second; however, from 2012 to 2016, it displayed a downward trend, and the *AAI* was 2.12 in 2016. The *AAI* for wheat was also greater than 1, while *AAI* for hay was close to 1, implying that both crops had an aggregate advantage. The *AAI* for corn was less than 1 for 20 years, which indicated there was no aggregate advantage in corn production in Texas.

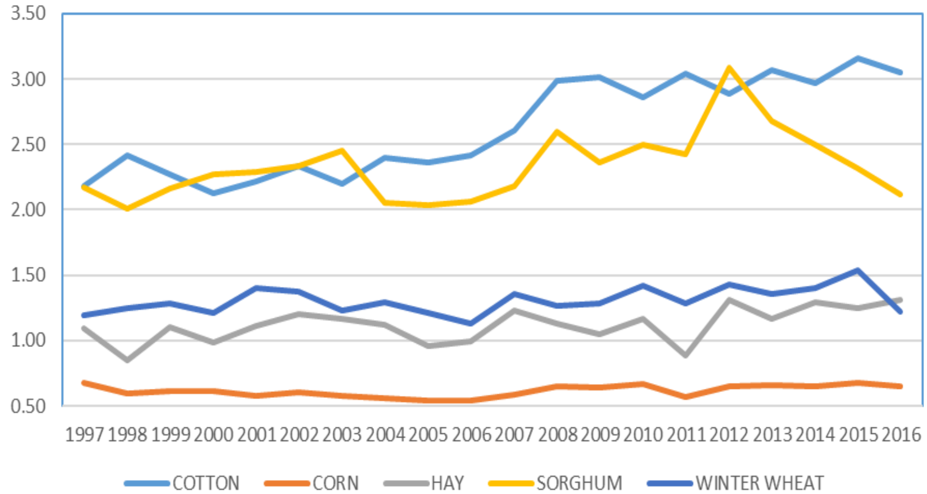

Figure 4. *AAI* of Major Crops Produced in Texas from 1997 to 2016.

From the analysis above, the study found that among the five major crops in Texas, the comparative advantage of cotton was the highest, with a clear upward trend. Secondly, sorghum also had a comparative advantage, though in recent years its comparative advantage fluctuated notably. The aggregate comparative advantages for wheat and hay were more stable; however, corn did not have the comparative advantage.

Comparative advantage of major cotton-producing states in 1997-2016. There are 17 states that produce cotton in the U.S. This study calculates the average percentage of cotton planted acreages for 20 years (1997-2016) in each state, and the top five states are selected for further analysis: Texas (48.00%), Georgia (10.76%), Mississippi (6.22%), Arkansas (5.92%), and North Carolina (5.21%) (NASS 2017).

Figure 5 shows the *SAI* of the five largest cotton-producing states. From 1997 to 2016, Georgia had the largest *SAI* with an average of 9.12, followed by Texas 6.78, Mississippi 4.47, North Carolina 3.49, and Arkansas 2.38. From 1997 to 2005, the *SAI* for all five states are relatively stable. From 2006 to 2016, there is a clear distinction among the five states. The *SAI* indices for the top two states (Georgia and Texas) displayed clear increasing trends, while the otherthree states (Mississippi, North Carolina, and Arkansas) demonstrated notable down trends.

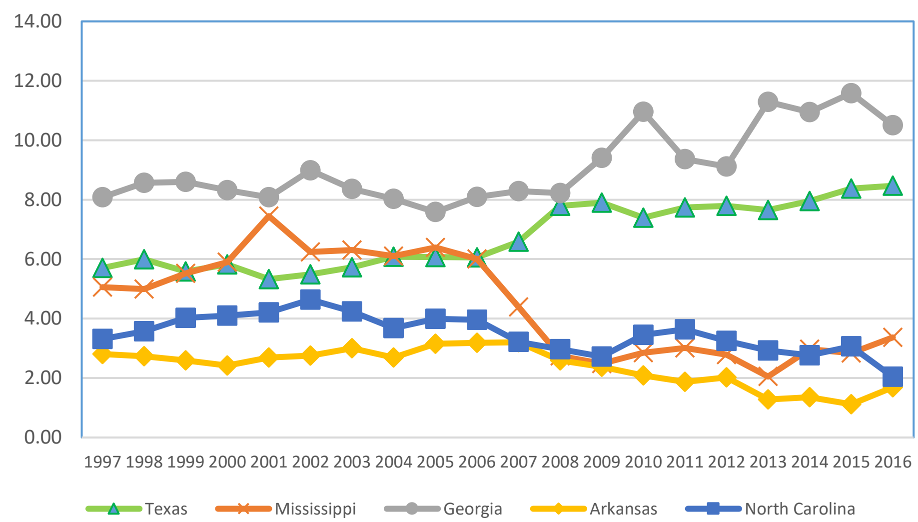

Figure 5. *SAI* of Major Cotton-Producing States in the U.S. from 1997 to 2016.

Figure 6 depicts the *EAI* of major cotton-producing states in the U.S. from 1997 to 2016. On average, Arkansas had the largest *EAI (*1.20), followed by Mississippi (1.14), Texas (1.02), Georgia (0.79), and North Carolina (0.72). *EAI* for Texas and Georgia indicated the consistent increasing trend, while Mississippi, Arkansas, and North Carolina did not indicate notable changes during the study period.

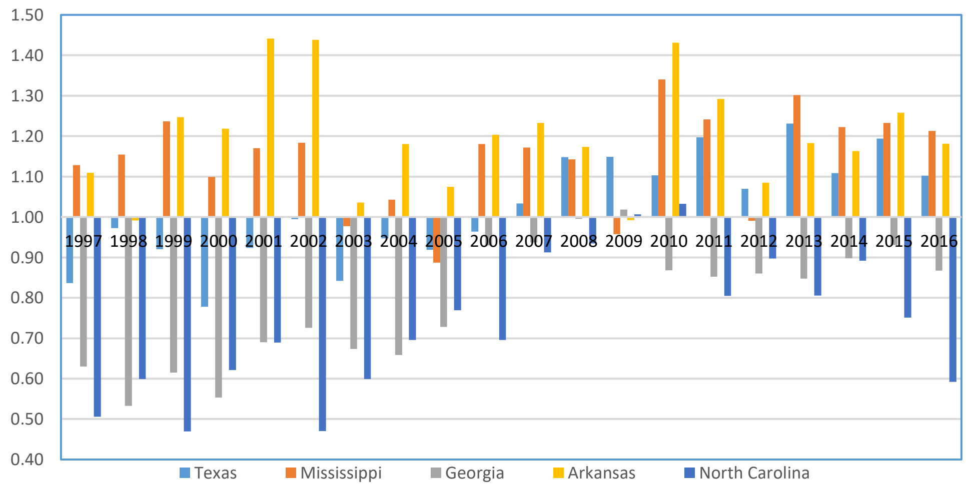

Figure 6. *EAI* of Major Cotton-Producing States in the U.S from 1997 to 2016.

Figure 7 indicates the *AAI* of the five major cotton-producing states, where Georgia led the nation's average *AAI* from 1997 to 2016 with a value of 2.68, followed by Texas 2.64, Mississippi 2.21, Arkansas 1.67, and North Carolina 1.58. All five states have *AAI* values greater than 1 in every year during the study period, which can explain the aggregate comparative advantage in cotton production in these states. Aggregate comparative advantage for Texas and Georgia displayed clear upward trends from 1997 to 2016, while Mississippi, North Carolina, and Arkansas indicated notable down trends, especially from 2006 to 2016. If this trend continues, North Carolina and Arkansas can lose the aggregate comparative advantage in a few years.

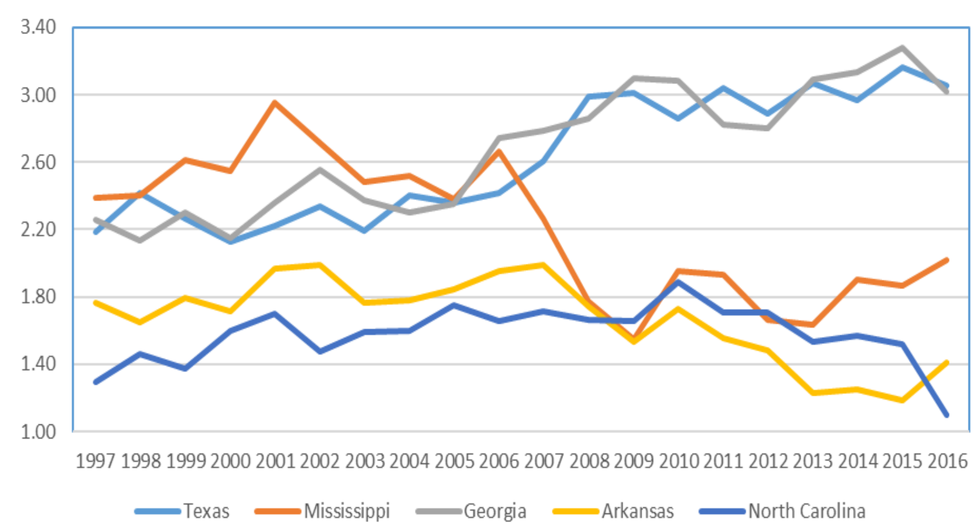

Figure 7. *AAI* of Major Cotton-Producing States in the U.S. from 1997 to 2016.

CONCLUSIONS AND DISCUSSION

The analysis above indicates that Texas upland cotton has had a comparative advantage in the state and country for the past 20 years and this uptrend continues. Compared to four other major corps (corn, hay, sorghum, and winter wheat) grown in Texas, cotton demonstrates a notable overall comparative advantage. Compared to four other major cotton-producing states in the U.S., Texas and Georgia have a notable overall comparative advantage in upland cotton production and the gap between these two states and the other major states (Mississippi, North Carolina, and Arkansas) are widening, especially after 2006.

Numerous factors can contribute to the changes in comparative advantage in agriculture, which include natural (or climatic) factors, economic factors, social factors, and so on (Chen and Cao 2013; Yin and Huang 2014; Pearson and Mayer 1974). These factors can impact the cotton yield, production scale, and production concentration in certain region and will eventually determine the net revenue, cost, and profit. Therefore, further analysis is needed to identify the factor(s) that can affect the comparative advantage in various regions or states. This study is also important for policymakers to pay more attention to the changes in the production structure in different regions as producers are facing more and more of competition from other regions or countries.

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