Bennet-Bowley Measure for Productivity Analysis of Georgia Agriculture

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Output of agricultural products impacts the Georgia economy through linkages in other economic sectors that supply production inputs and process Georgia commodities for consumer purchase. In 2006, the Georgia farm gate value of agricultural products was $10.4 billion (Boatright and McKissick 2007). Total output impact of agricultural production and directly related processing was $55.2 billion, representing 8.1% of state total output value. A method for calculating aggregate agricultural production and productivity is valuable in evaluating impacts of public resources and policies to support agriculture.

Productivity analysis assesses the relationship between output and inputs utilized in the production process. A basic determination of productivity is comparing a single output to a single input. Single-factor productivity measures one output (y) and one input (x). If the single input is labor, its productivity is expressed as productivity = y/x. Labor productivity increases as the ratio increases either by increasing y, decreasing x, or a combination. Total factor productivity (TFP) includes all products and services of the Georgia agricultural economy and accounts for all resources applied to produce output. Calculating TFP requires a method of aggregating outputs and inputs for comparing relative trends. Tornqvist indexes are one measure to aggregate diverse agricultural commodities into an output index and aggregate numerous inputs into a composite input requirement index. Tornqvist output and input quantities are useful for comparing physical quantities, but provide no information about agricultural profitability. Public resources devoted to agriculture should enhance farm profitability while increasing productivity. The Bennet-Bowley indicator is a measure of productivity that can be decomposed to determine the relationship between farm productivity and profitability. The objective of this

research is to develop a method for evaluating productivity in the Georgia agricultural economy which allows evaluating profitability that derives from increased productivity.

Related Research

Fundamentals of productivity analysis are presented by Coelli et al (2005). Indexes included for prices and quantities are the Laspeyres, Paasche, Fisher, and Tornqvist indexes. Fried, Lovell, and Schmidt (2008) compare computation of Tornqvist and Fisher productivity indexes, as well as the Bennet-Bowley indicator. Bennet-Bowley is referred to as an indicator rather than an index because it is defined in terms of differences in outputs and inputs rather than ratios of outputs to inputs. White (1998) calculated Tornqvist indexes and productivity for 1951-1994. Indexes for outputs, inputs, and TFP are calculated for each US state and as a national aggregate by USDA, ERS (2007a). State level productivity is calculated for 1960-1999.

Data

Data for productivity analysis is from farm income data that includes revenue and expenses for Georgia during 1960-2006 (USDA, ERS 2007b). Georgia commodity prices (USDA, NASS 2007) are applied to determine output by an indirect approach in which Quantity = Value/ Price. Tornqvist output quantities are determined for aggregated crops, meats, and a category for other which includes services and forestry products sold by farms. The Tornqvist output index for each of three categories is a weighted average of output quantity expressed as:

$$(1) \qquad Q_{01} = \prod_{i=1}^{N} \left[\frac{q_{i1}}{q_{i0}} \right]^{\frac{w_{i0}+w_{i1}}{2}} ,$$

where *1* is the current year, *0* represents the base year, *i* represents each commodity in the index, and *w* is a weight determined by the percentage of total revenue derived from commodity *i* in each time period (Coelli et al 2005). Output indexes are calculated for each pair of years between

1960 and 2006 (Fried, Lovell, and Schmidt 2008). Equation (1) can be rearranged into logarithmic form as:

$$(2) \qquad \ln Q_{01} = \sum_{i=1}^{N} \left(\frac{w_{i0} + w_{i1}}{2} \right) (\ln q_{i1} - \ln q_{i0}) .$$

Chart 1 shows Tornqvist output indexes for crops, meats, and other output between 1960 and 2006. Quantities for output categories are normalized to a value of 1960 = 1.0 so that annual output indexes represent change from the base year. Crops increased by an average annual rate of 3.7% for an ending index of 2.7. Meats increased by an average annual rate of 4.6% and ended the period with an index of 3.1. The crop index represents volatility consistent with annual yield variations while the meat index has a steady trend. The category for other increased at a 2.6% rate for a final index of 2.2.

Farm income data includes expenses, and prices for inputs are from USDA, NASS (2007). Input prices for electricity are from the US Dept. of Commerce, BEA (2007). Input expenses from farm income data are feed, livestock, seed, fertilizer, chemicals, fuel, electricity, machinery, labor, and other expenses. Input quantities are derived in an indirect manner with ten input quantities calculated as Quantity = Value/Price. Farm acreage as an input and the average Georgia rental rate as price are from USDA, NASS (2007). Input prices are indexes with a beginning value of 1.0, and resulting input quantities are set to 1.0 for 1960. Application of Equation (1) or Equation (2) to inputs results in a single aggregate input index that includes eleven inputs.

Output Aggregation and Tornqvist Quantities

Three output categories can be further aggregated into one output index. The Tornqvist price index for each of three output categories is a weighted average of prices expressed by Coelli et al (2005) as:

$$(3) \qquad P_{0t} = \prod_{i=1}^{N} \left[\frac{p_{i1}}{p_{i0}} \right]^{\frac{w_{i0}+w_{i1}}{2}} ,$$

where *1* is the current year, *0* represents the base year, *i* represents each value category, and *w* is a weight determined by the percentage of total revenue derived from category *i* in each time period. Price indexes are calculated for each pair of years between 1960 and 2006 (Fried, Lovell, and Schmidt 2008). A logarithmic form of the Tornqvist price index is:

$$(4) \qquad \ln P_{0t} = \sum_{i=1}^{N} \left(\frac{w_{i0} + w_{i1}}{2} \right) (\ln p_{i1} - \ln p_{i0}) \ .$$

Output for each category is indirectly determined as Quantity = Category Value/Tornqvist Price. A single aggregate output index is calculated by applying Equation (1) or Equation (2) to the three categories of crops, meats, and other output. Tornqvist TFP is calculated as the ratio of Tornqvist output to Tornqvist input. Tornqvist total output and input indexes, as well as TFP are presented in Chart 2.

Output for Georgia agriculture in Chart 2 indicates that production follows a steady upward trend over the previous 47 years. Output increases average 4.3% per year. Table 1 shows commodities with increased or decreased output quantities in 2006 when compared to the base year of 1960. For 2006, there are 16 commodities with greater output and 6 commodities with less output than in 1960. Previous research by White (1998) shows that Georgia agricultural production increased by 33% from 1951-1960. That reported increase and results from this report indicate that Georgia agricultural production continues on an increasing trend and reached a historical high in 2006. Inputs increased with cyclical characteristics during 1960-2006 for an average annual input increase of 0.6%. Comparing annual output indexes to input indexes with a ratio formulation leads to a Tornqvist TFP that averages 3.0% per year.

The input index presented in Chart 2 includes a decreasing trend in farm acreage with total 2006 acreage 49% of 1960 acreage. During this time, the number of farms decreased from 112,000 in 1960 to 49,000 in 2006 (USDA, NASS 2007). Number of farms in 2006 is 44% of the 1960 level. Thus, output increases in Chart 2 have been accompanied by decreasing trends in acreage and farms. Productivity increases explain how the Georgia agricultural economy is expanding during a period when farm acreage and the number of farms are declining.

Bennet-Bowley Productivity Indicator

The Bennet-Bowley productivity indicator uses prices as weights to aggregate inputs and outputs instead of value shares as in Tornqvist indexes. A formulation for this indicator is:

(5) $$2BB_1 = (p_1^* + p_0^*)(y_1 - y_0) - (w_1^* + w_0^*)(x_1 - x_0),$$

where $p_1^* = p_1/(p_1 + w_1)$, $w_1^* = w_1/(p_1 + w_1)$, y is the Tornqvist aggregate output index, x is the Tornqvist aggregate input index, p is the Tornqvist aggregate output price index, and w is the Tornqvist aggregate input price index. Aggregate price indexes are calculated by Equation (3) or Equation (4). Bennet-Bowley indicators are calculated for each pair of years between 1960 and 2006 (Fried, Lovell, and Schmidt 2008). Under assumptions that all producers face the same prices in each period, the aggregate Bennet-Bowley indicator is the average of Bennet-Bowley farm level productivity measures (Chambers and Pope 1996). Bennet-Bowley indicators have a difference form rather than a ratio form. Base year values of the difference form are 0, but values can be normalized to report the base year as 1.0.

A feature of the Bennet-Bowley productivity indicator is that it is a component of normalized profit change. Applying a price change indicator *(PC)* for inputs and outputs, normalized profit change is:

(6) $$\Pi C = BB + PC.$$

The price change indicator is defined as:

$$(7) \qquad 2PC_1 = (p_1^* - p_0^*)(y_1 + y_0) - (w_1^* - w_0^*)(x_1 + x_0),$$

where $p_1^* = p_1/(p_1 + w_1)$, $w_1^* = w_1/(p_1 + w_1)$, and other variables are as previously defined in Equation (5).

Price change will increase profit when output prices increase relative to any change of input prices. Chart 3 shows normalized profit change with the components of productivity and price change. Price changes have not been favorable to profits. The Bennet-Bowley productivity indicator steadily increased from 1960-2006. Thus, increasing profit in Georgia agriculture has occurred due to increases in productivity during a period of unfavorable price changes.

Summary

Georgia agricultural output has followed an increasing trend since 1950, and the 2006 quantity index of aggregate output reached a historical high. Productivity analysis assesses the relationship between output and inputs utilized in the production process. Georgia agricultural production continues on an increasing trend and reached a historical high in 2006. Increases in output have been accompanied by relatively lower levels of input increases. The Tornqvist productivity index indicates an average annual productivity increase of 3.0% during 1960-2006. Productivity increases explain how the Georgia agricultural economy is expanding during a period when farm acreage and the number of farms are declining. An alternative to the Tornqvist productivity index is the Bennet-Bowley productivity indicator. A feature of the Bennet-Bowley indicator is that it is a component of normalized profit change. Profit change can be decomposed into a price change component, as well as a productivity component. Declining output prices relative to input prices during 1960-2006 were not favorable for increased profitability. Results

show that Georgia farm profit increased from 1960-2006 due to increased agricultural productivity.

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Table 1. Commodities with Increases and Decreases in Output Quantity, 2006 Compared to 1960

Increase	Decrease
Grain Sorghum, Hay, Wheat, Rye, Pecans, Blueberries, Grapes, Beef, Soybeans, Peanuts, Broilers, Eggs, Cotton, Milk, Vegetables, Other (Includes Nursery and Greenhouse)	Corn, Oats, Peaches, Apples, Tobacco, Hogs

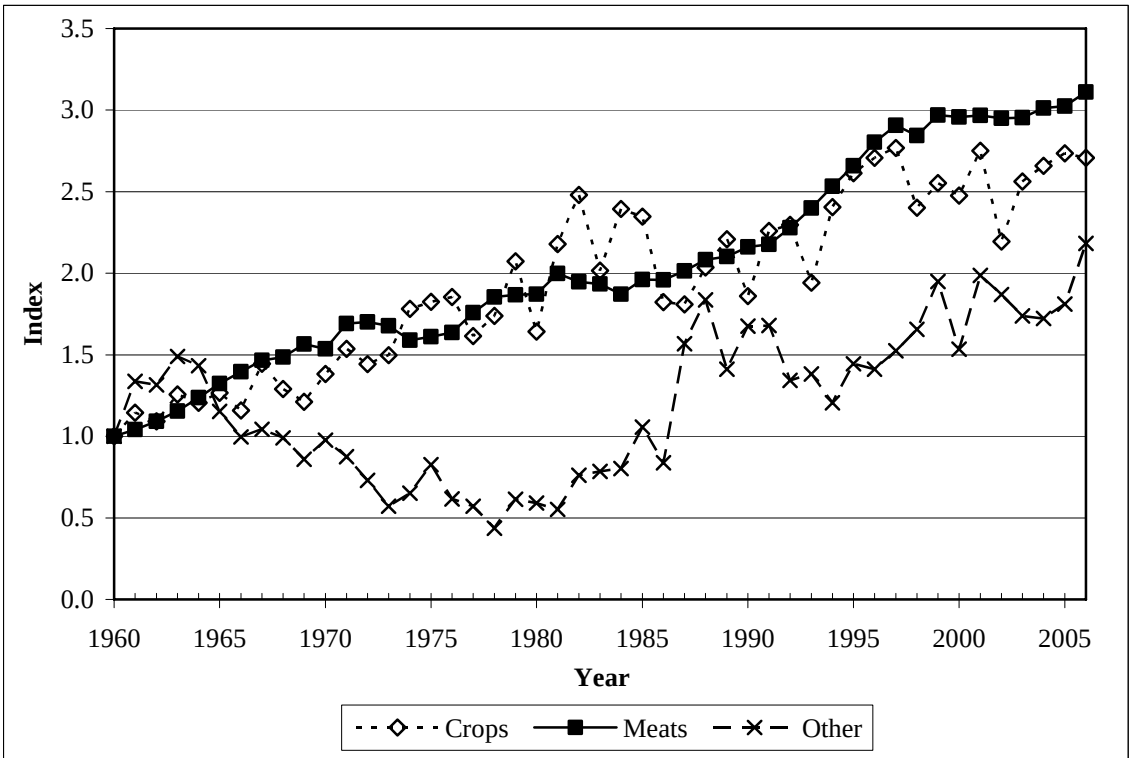

Chart 1. Tornqvist Output Indexes for Crops, Meats, and Other Output, GA, 1960-2006

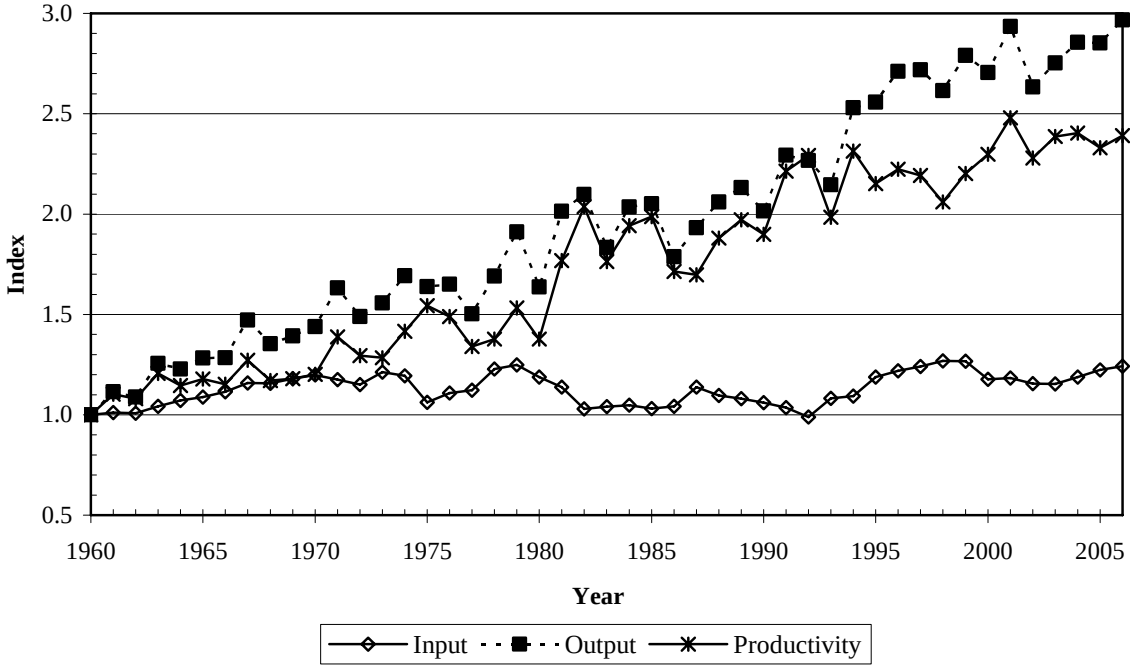

Chart 2. Tornqvist Input, Output and Productivity Indexes, GA Agriculture, 1960-2006

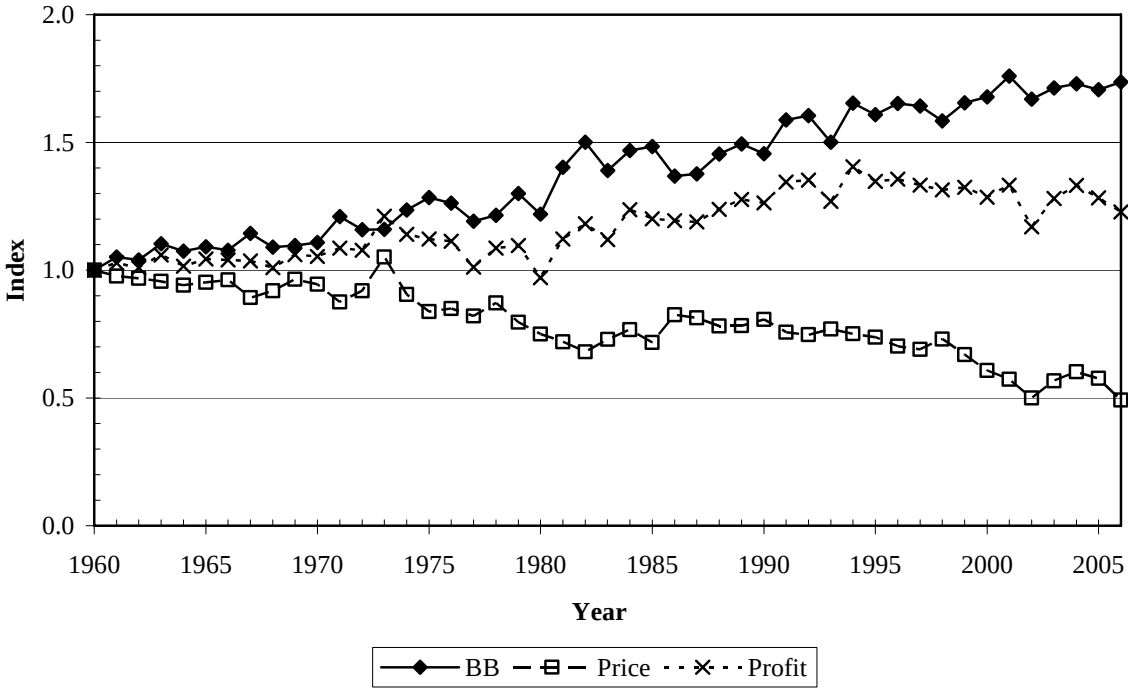

Chart 3. Bennet-Bowley Decomposition, GA Agriculture, 1960-2006