Overview

- The growth of agricultural productivity has long been chronicled as the single most important source of economic growth in the U.S. farm sector.

- Though their methods differ in important ways, the major sectoral productivity studies (Kendrick and Grossman, 1980; Jorgenson, Gollop, and Fraumeni, 1987; Jorgenson and Gollop, 1992; Jorgenson, Ho, and Stiroh, 2005) share this conclusion.
However, the capacity of the sector to sustain historical rates of productivity growth has come into question

- Alston et al. (2009a,b; 2010) find evidence of a slowdown in the rate of productivity growth

- If productivity growth falters, growing global demand will likely lead to sharply higher food prices and to increased environmental stress

In the following, we provide a review of the methods/data underlying the USDA’s estimates of productivity growth

- We identify the sources of economic growth in the farm sector

- And we investigate the hypothesis that sectoral productivity growth is slowing
The USDA’s Productivity Estimates

- The U.S. Department of Agriculture (USDA) has been monitoring the industry’s productivity performance for decades.
- In fact, in 1960, the USDA was the first agency to introduce multifactor productivity measurement into the Federal statistical program.
- Today the USDA’s Economic Research Service routinely publishes total factor productivity (TFP) measures from production accounts, distinguishing multiple outputs and inputs and adjusting for quality change in each input category.
- Indexes of productivity growth are constructed for each state and the aggregate farm sector (Ball, 1985; Ball et al., 1997; 1999).
- The state series provide estimates of the growth and relative levels of productivity (Ball, Hallahan and Nehring, 2004; Ball, San Juan and Ulloa, 2012).
- There is also an ongoing effort to develop international comparisons of agricultural productivity (Ball et al., 1997; 2001; 2008; 2010).
Methodology

- The USDA model is based on the translog transformation frontier

- It relates the growth rates of multiple outputs to the cost-share weighted growth rates of labor, capital, and intermediate inputs

The Production Accounts

- The USDA constructs both state and aggregate farm sector accounts

- The state and aggregate farm sector accounts are consistent with a gross output model of production

- Output is defined as gross production leaving the farm, as opposed to real value added

- Inputs are not limited to capital and labor, but include intermediate inputs as well
The state and aggregate models view agriculture within their respective geographic boundaries as a single farm.

Output includes deliveries to final demand and to intermediate demand in the non-farm sector.

State output accounts include these deliveries plus interstate shipments to intermediate farm demand.

Translog indexes of output are formed by aggregating over agricultural goods and services using revenue-share weights based on shadow prices.
Intermediate Input

- Intermediate input consists of all goods and services used in production during the calendar year, whether withdrawn from beginning inventories or purchased from outside the farm sector.

- In the case of the state accounts, intermediate inputs also includes purchases of intermediate goods from farms in other states.

- Price and quantity data corresponding to purchases of feed, seed, and livestock are available and enter the calculation of intermediate input.

- Translog indexes of energy input are constructed by weighting the growth rates of petroleum fuels, natural gas, and electricity by their shares in the overall value of energy inputs.
Pesticides and fertilizers are important intermediate inputs, but price/consumption data require adjustment since these inputs have undergone significant changes in input quality.

Price indexes for pesticides and fertilizers are constructed using hedonic methods where the price of individual pesticides or fertilizer materials is a function of chemical attributes and time/state dummy variables.

The corresponding quantity indexes are formed implicitly by taking the ratio of the value of each aggregate to corresponding hedonic price index.

Finally, price and implicit quantity indexes of purchased services (e.g., custom machine services; contract feeding of livestock; contract labor services) are constructed.

A translog index of total intermediate input is constructed for each state and the aggregate farm sector by weighting the growth rates of each category of intermediate input by their value shares in the overall value of intermediate input.
Labor

- The labor accounts incorporate demographic cross-classifications of the agricultural labor force developed by Jorgenson, Gollop, and Fraumeni (1987)

- Hours worked and compensation per hour are cross-classified by sex, age, education, and employment class (employee versus self-employed and unpaid family workers)

- Indexes of labor input are constructed for each state and the aggregate farm sector using demographically cross-classified hours and compensation data

- Labor hours having higher marginal productivities (i.e., wages) are given higher weights in the index than hours having lower marginal productivities

- This procedure explicitly adjusts state and aggregate farm sector time series of labor input for “quality” changes in labor hours
Capital Input

- Measurement of capital input begins with estimating the capital stock and rental price for each asset type

- Stocks of depreciable capital are the cumulation of all past investments adjusted for discards of worn-out assets and loss of efficiency of assets over their service life

- Asset discards are calculated based on an assumed mean service life for a homogeneous group of assets (e.g., farm tractors) and a distribution of actual discards around this mean service life

- We assume that the discard distribution is the normal distribution truncated at points two standard deviations above and below the mean
- Loss of efficiency is assumed to be a function of age of the asset

- The function relating efficiency to age of the asset is approximated by a rectangular hyperbola concave to the origin

- Once the frequency of occurrence of a particular service life is determined, the efficiency function for that service life is calculated using the assumed decay parameters

- This process is repeated for all possible service lives

- An aggregate efficiency function is then constructed as a weighted sum of the individual efficiency functions using as weights the frequency of occurrence
To estimate the stock of land, we construct price and implicit quantity indexes of land in farms.

We assume that land in each county is homogeneous, hence aggregation is at the county level.

Spatial differences in land characteristics (i.e., quality) prevent the direct comparison of observed prices across states/countries.

Again, we construct indexes of the relative prices of land using hedonic methods.

The USDA’s World Soil Resources Office has compiled data on characteristics that capture differences in land quality.

These characteristics include soil acidity, salinity, and moisture stress, among others.
The USDA constructs an *ex ante* measure of the user cost of capital.

The *ex ante* rate of return is calculated as the nominal yield on investment grade corporate bonds adjusted for expected rather than actual price inflation.

Translog indexes of capital input in each state and the aggregate farm sector are formed by aggregating over the various capital assets using cost-share weights based on asset-specific rental prices.

As is the case for labor, the resulting measure of capital input is adjusted for changes in asset quality.
Sources of Growth

- Input growth typically has been the dominant source of economic growth for the aggregate economy and for each of its producing sectors.

- Jorgenson, Gollop, and Fraumeni (1987) find that output growth relies most heavily on input growth in forty-two of forty-seven private non-farm business sectors, and in a more aggregate study (Jorgenson and Gollop, 1992) in eight of nine sectors.

- Agriculture turns out to be one of the few exceptions; productivity growth dominates input growth.

In the translog model, the growth in output equals the sum of the contributions of labor, capital and intermediate inputs and TFP growth.

- The contribution of each input equals the product of the input’s growth rate and its respective share in total cost.

- Over the full 1948-2009 period labor input declined at a 2.51% annual rate.

- When weighted by its 20% cost share, the contraction in labor contributes an average -0.52 percentage points to output growth.
Growth of capital input (excluding land) contributed just 0.02 percentage points to output growth.

Land input declined at a -0.51% average annual rate; its contribution to output growth averaged -0.08 percentage points.

Intermediate input’s contribution averaged a substantial positive rate equal to 0.69% per year.

But the net contribution of all inputs was only one-tenth of one percent, leaving responsibility for positive growth in farm sector output to productivity growth.

### Table 2. Sources of Growth in the U.S. Farm Sector, 1948-2009 (average annual growth rates in percent)

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<tbody>
<tr>
<td>Output growth</td>
<td>1.63</td>
<td>1.18</td>
<td>0.96</td>
<td>4.03</td>
<td>1.21</td>
<td>2.24</td>
<td>2.65</td>
<td>2.26</td>
<td>1.54</td>
<td>1.54</td>
<td>0.96</td>
<td>1.84</td>
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<td>Input growth</td>
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<tr>
<td>Labor</td>
<td>-0.52</td>
<td>-0.81</td>
<td>-1.08</td>
<td>-0.83</td>
<td>-0.81</td>
<td>-0.61</td>
<td>-0.38</td>
<td>-0.19</td>
<td>-0.22</td>
<td>-0.43</td>
<td>-0.34</td>
<td>-0.35</td>
<td>-0.64</td>
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<tr>
<td>Capital</td>
<td>0.02</td>
<td>0.54</td>
<td>0.15</td>
<td>0.05</td>
<td>0.06</td>
<td>0.32</td>
<td>0.14</td>
<td>0.32</td>
<td>0.23</td>
<td>-0.61</td>
<td>-0.21</td>
<td>0.05</td>
<td>0.35</td>
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<tr>
<td>Land</td>
<td>-0.08</td>
<td>0.02</td>
<td>-0.17</td>
<td>-0.16</td>
<td>-0.07</td>
<td>-0.22</td>
<td>-0.26</td>
<td>0.00</td>
<td>-0.12</td>
<td>-0.09</td>
<td>0.00</td>
<td>-0.08</td>
<td>-0.12</td>
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<tr>
<td>Materials</td>
<td>0.69</td>
<td>1.50</td>
<td>1.38</td>
<td>1.45</td>
<td>0.85</td>
<td>0.43</td>
<td>0.99</td>
<td>1.50</td>
<td>-1.74</td>
<td>-0.09</td>
<td>0.87</td>
<td>0.52</td>
<td>-1.39</td>
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<tr>
<td>Total factor productivity</td>
<td>1.52</td>
<td>-0.16</td>
<td>0.68</td>
<td>3.53</td>
<td>1.16</td>
<td>2.32</td>
<td>2.19</td>
<td>0.62</td>
<td>3.39</td>
<td>2.19</td>
<td>1.53</td>
<td>0.63</td>
<td>3.68</td>
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</tbody>
</table>

Note: The subperiods are measured from cyclical peak to peak in aggregate economic activity.
The Slowdown Hypothesis

- Over the full 1948-2009 period, the gains in productivity have been impressive

- However, it remains to be determined if slower productivity growth during the 1970s and more recently represent a shift in the long-term path of productivity growth

- Alston et al. (2009a,b; 2010) describe a significant slowdown in productivity growth after 1990, a phenomenon “...that is not a temporary cyclical event but more structural and sustained”

- In arriving at this conclusion, the authors partitioned the time series into arbitrary sub-periods and compared the resulting mean rates of growth
A more formal approach involves estimating the regression parameters for each sub-period and testing the equality of the two sets of parameters.

An important limitation of both approaches is that the structural break must be known a priori.

The researcher must either pick an arbitrary candidate breakdate or pick a breakdate based on some known feature of the data.

As Hansen (2001) notes, the test results can be “uninformative” because they can miss the true breakdate or can be “misleading” because the breakdate is endogenous and the test can indicate a break when none in fact exists.

Ball, Schimmelpfennig, and Wang (2012) test for a slowdown in TFP growth using techniques that allow for unknown structural breaks jointly with a possible unit root.
The empirical evidence suggests that the TFP series is trend stationary with multiple structural breaks.

This result allows estimation of the trend rates of growth using OLS.

We observe a break in trend in 1974.

Prior to 1974 productivity grew at an annual rate of 1.71%, but the trend rate of growth slowed to 1.57% per year after 1974.

A different type of structural change occurred in 1985.

In that year we observe a one-time shift upward in the level of productivity.

The post-1974 rate of growth persisted after the intercept shift in 1985 but growth was from a higher absolute level of productivity.
A more detailed discussion of methods/data and a list of references can be found at our website:

http://www.ers.usda.gov/Data/AgProductivity/
Annex:

Productivity and International Competitiveness

- Ball *et al*. (2010) address the competitiveness of agriculture in the European Union and the United States

- We provide a formal definition of the concept of competitiveness and relate it to the more conventional concept of relative productivity
The most intuitive concept of competitiveness is that of price competitiveness

We assume that markets are competitive and in long-run equilibrium so that the observed price always equals average total cost as measured by the cost dual to the production function

This assumption is used in the calculation of relative competitiveness and productivity gaps between the European Union and the United States

We decompose relative price movements between changes in relative input prices and changes in relative productivity levels
The empirical results suggest that the relative productivity level was the most important factor in determining international competitiveness.

Over time, however, changes in competitiveness were strongly influenced by variations in exchange rates through their impact on input prices.
Productivity Levels Relative to United States (Cont.)

The diagram shows the log of productivity levels relative to the United States for Ireland, Italy, the Netherlands, Sweden, and the United Kingdom from 1973 to 2001. The y-axis represents the log of productivity levels relative to the U.S., ranging from -0.8 to 0.4. The x-axis represents the years from 1973 to 2001. Each country is represented by a different line color and marker style.

The views presented here are those of the authors and do not necessarily reflect official policy of ERS or USDA.