U.S. Agricultural Productivity and Returns to Research

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Food & Fuel: The Implications for Agricultural Research Policy
June 4-6, 2007, University of Saskatchewan, Saskatoon
Overview

Agricultural Productivity

Agricultural R&D

Model Specification & Assumptions

Returns to Research
U.S. Public R&D Funding, 1890-2004

- **SAES**
- **USDA IM**

Millions of 2000 US$
U.S. Public R&D Funding, 1890-2004

- SAES
- Extension
- USDA IM

Millions of 2000 US$
U.S. Agricultural Productivity

- **Productivity Data**
  - Based on input and output quantities
  - Started with data from Aquaye, Alston, and Pardey, 2002
    - Quantities adjusted for quality
    - State-specific prices used in index construction
  - Revised by Alston, Andersen, and Pardey
    - Added more outputs and inputs
    - Improved accounting of capital components

- **Multi-Factor Productivity (MFP)**
  - Output per quantity of Input
U.S. Agricultural Productivity, 1949-2002

Index (1949 = 100)

Output Index
U.S. Agricultural Productivity, 1949-2002

The graph illustrates the trend of U.S. agricultural productivity from 1949 to 2002. The index values are normalized to 1949 = 100.

Output Index shows a steady increase over the years, with fluctuations around 1970 and 1980. Input Index, on the other hand, remains relatively stable throughout the period, indicating a lower sensitivity to changes in productivity.
U.S. Agricultural Productivity, 1949-2002

Multi-Factor Productivity

Output Index

Input Index
Output Indexes in U.S. Agriculture

Output Quantity Index

Quantity Index (1949 = 100)

- Field Crops
- Nursery & Greenhouse
- Livestock

Year:
- 1949
- 1959
- 1969
- 1979
- 1989
- 1999

Graph shows the trend of output indexes from 1949 to 1999 for different categories.
State-Specific Growth in Inputs and Outputs, 1950-2002

Each diamond represents one state.
Values are averages of year-to-year state-specific rates of growth in outputs and inputs.

U.S.
State-Specific Growth in Inputs and Outputs, 1950-2002

45-degree line through the origin indicates combination with no growth in productivity.
State-Specific Growth in Inputs and Outputs, 1950-2002

45-degree line through U.S. indicates growth in productivity equal to U.S. average
Spatial Patterns of Input and Output Growth
Northeastern States

Output Growth

Input Growth

-2.5%  -1.5%  -0.5%  0.5%  1.5%

-1%  0%  1%  2%  3%

-2.5%  -1.5%  -0.5%  0.5%  1.5%

VT  ME  NY

NJ  RI  NH

MA

-1%  0%  1%  2%  3%

Spatial Patterns of Input and Output Growth
Northeastern States
Spatial Patterns of Input and Output Growth
Pacific States

- Output Growth
  - CA
  - WA
  - OR

- Input Growth
  - -2.5%
  - -1.5%
  - -0.5%
  - 0.5%
  - 1.5%
Spatial Patterns of Input and Output Growth
Southern States

Output Growth

Input Growth

AL

FL

GA

KY

AR

LA

MS

0%
1%
2%
3%
-1%
-0.5%
-1.5%
-2.5%
0.5%
1.5%
Spatial Patterns of Input and Output Growth
Big Wheat-Producing States

Output Growth

Input Growth
Spatial Patterns of Input and Output Growth
Big Beef-Producing States

Output Growth

Input Growth

- SD
- IA
- NE
- KS
- CO
- CA
- TX
- OK
Temporal Patterns of Input and Output Growth, Pre- and Post-1990

Output Growth

Input Growth

Pre-1990
Temporal Patterns of Input and Output Growth, Pre- and Post-1990

Output Growth

Pre-1990 in teal
Post-1990 in orange

Input Growth

-2.5% -1.5% -0.5% 0.5% 1.5%
Share of Public R&D Directed to Enhancing Farm Productivity

[Graph showing the percentage of public R&D directed to enhancing farm productivity from 1975 to 2000, with a general trend of decrease over time.]
Linking R&D Investments to Productivity

- **Goals:**
  - To obtain econometric estimates of the effect of R&D on productivity
  - To use those estimates to calculate the returns to research

\[
MFP_{it} = f (R&D \text{ Spending, other factors})
\]

- **Specification Issues:**
  - Functional form
  - Imposing structure on spending data
Managing the Spending Data

- R&D spending by any particular state in any particular year will (most likely):
  - have little effect for several years
  - then have increasingly pronounced effects for some years
  - after which, effects taper off

- Have similar effects in other states
  - Especially those that are agriculturally similar

- A complete econometric specification would include variables for
  - Each of two types of spending for 48 states
  - Federal IM spending
  - For last 50 years (give or take)
Managing the Spending Data (cont.)

- **Problems with complete specification**
  - Too many coefficients to estimate
  - Too much correlation among variables

- **Solution – Create knowledge stocks**
  - Weighted sum of spending data over previous ___ years
  - Weights determined by gamma distribution
    - flexible
    - characterized by only two parameters
  - Alternative structure uses a trapezoid shape for weights

- **Three knowledge stocks**
  - Own-state research
  - Own-state extension
  - Spillins
Spillin Stocks and Spillover Coefficients

- **Technological Spillovers**
  - Technologies developed in one state may be adopted in other states

- **Spillin Stocks**
  - Weighted sum of research (and possibly extension) knowledge stocks in all other states
  - Weights are spillover coefficients

- **Spillover Coefficients**
  - Measure similarity of two states in their output mixes
  - Based on 74 outputs
  - Vary between zero (no similarity) and one (the same)
Estimation Strategy and Issues

\[ \text{MFP}_{it} = g \left( \text{Knowledge Stocks, Other Factors} \right) \]

- Own-State (inc. extension)
- Spillins (including USDA IM)
- Growing Condition Index

- Estimate two parameters of gamma distribution
  - Abbreviated grid search
Some Preliminary Results

- Elasticities implied:
  - Log:
    - wrt own-state stock: 0.29
    - wrt spillin stock: 0.32
  - Linear:
    - wrt own-state stock: 0.12
    - wrt spillin stock: 0.49

- Double-log functional form
  \[ \ln MFP_{it} = a_i + 0.29 \ln (\text{Own-State Stock}) + 0.32 \ln (\text{Spillin Stock}) \]

- Linear functional form
  \[ MFP_{it} = a_i + 0.00000057 \times \text{Own-State Stock} + 0.000000072 \times \text{Spillin Stock} \]
Calculating Returns to Research

- For a hypothetical increase in SAES spending in 1950 in one state
  - Calculate the % increase in productivity in all states in all years
  - Multiply by value of production for each state, year
  - Gives a stream of benefits
  - Discount or compound so valued at same time
  - Calculate the benefit/cost ratio

- Two Benefit/Cost Ratios for Each State
  - Private – only includes benefits accruing to state of hypothetical spending
  - Social – includes benefits accruing to all states (through spillovers)
Private Benefit/Cost Ratios
Double-Log Model

Average = 15
Range 2 to 40

Range of Benefit/Cost Ratios

Number of States
Social Benefit/Cost Ratios
Double-Log Model

Average = 26
Range from 10 to 52
Private Benefit/Cost Ratios
Linear Model (in orange)

Average = 7
Range 0 to 29
Social Benefit/Cost Ratios

Linear Model (in orange)

Average = 25
Range from 9 to 48
Concluding Thoughts

● Evaluate effects of specification choices
  ○ Functional form
  ○ Lag structure (gamma shapes, trapezoid)
  ○ Number of years of spending data included in stocks
  ○ Whether benefits from extension spillover to other states
  ○ How spillin weights are calculated
  ○ Data included in estimation

● Results are quite sensitive to lag specification
Concluding Thoughts (cont.)

- Regardless of Specification Choices
  - Private Benefit/Cost ratios are quite high for most states
    - Implies underinvestment from “private” perspective
  - Social Benefit/Cost ratios are generally much larger than private
    - Broader perspective indicates higher potential returns for increased spending on R&D
    - Degree of underinvestment is greater from national perspective
  - HOWEVER, private and social effects are difficult to separate due to multicollinearity inherent in data

- Relative Benefit/Cost ratios across states suggest less-than-optimal allocation of research funding among states