U.S. Agricultural Productivity and Returns to Research

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Overview

Agricultural Productivity

Agricultural R&D

Model Specification & Assumptions

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


Millions of 2000 US$:
- SAES
- USDA IM
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

Index (1949 = 100)

Output Index

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

- **Index (1949 = 100)**
  - Multi-Factor Productivity
  - Output Index
  - Input Index

Years:
- 1949
- 1959
- 1969
- 1979
- 1989
- 1999
Output Indexes in U.S. Agriculture

Output Quantity Index (1949 = 100)

- Field Crops
- Nursery & Greenhouse
- Livestock

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

Quantity Index (1949 = 100)
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.

Input Growth:
- 3%
- 2%
- 1%
- 0%
- -1%
- -2.5%

Output Growth:
- 3%
- 2%
- 1%
- 0%
- -1%
- -2.5%

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
Spatial Patterns of Input and Output Growth
Corn Belt & Lake States

Output Growth

Input Growth

-1% -0.5% 0.5% 1.5%
Spatial Patterns of Input and Output Growth
Southern States

- Output Growth:
  - AL, FL, GA, KY, AR, LA, MS

- Input Growth:
  - -2.5%, -1.5%, -0.5%, 0.5%, 1.5%
Spatial Patterns of Input and Output Growth
Big Wheat-Producing States

Output Growth

Input Growth

- WA
- SD
- ND
- MN
- KS
- TX
- OK
- MT
- ID
Spatial Patterns of Input and Output Growth
Big Beef-Producing States

Output Growth

Input Growth

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

Output Growth

Pre-1990

Input Growth

-2.5%  -1.5%  -0.5%  0.5%  1.5%
-1%  0%  1%  2%  3%
Temporal Patterns of Input and Output Growth, Pre- and Post-1990

Pre-1990 in teal
Post-1990 in orange

Output Growth

Input Growth
Share of Public R&D Directed to Enhancing Farm Productivity

- 1975: 70%
- 1980: 65%
- 1985: 60%
- 1990: 55%
- 1995: 19%
- 2000: 55%
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

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

- **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
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

\[ MFP_{it} = g (\text{Knowledge Stocks, Other Factors}) \]

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

- Estimate two parameters of gamma distribution
  - Abbreviated grid search
Lag Structure Used for Preliminary Results

![Graph showing lag structure with weight variations over lag values from 0 to 50.](image)
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
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

Range of Benefit/Cost Ratios

Number of States

0 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
Social Benefit/Cost Ratios
Linear Model (in orange)

Average = 25
Range from 9 to 48

Number of States

Range of Benefit/Cost Ratios

0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
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
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