U.S. Agricultural Productivity and Returns to Research

Julian M. Alston
University of California, Davis

Philip G. Pardey
University of Minnesota

Matt Andersen

Jennifer S. James

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

Agricultural Productivity

Returns to Research

Agricultural R&D

Model Specification & Assumptions
U.S. Public R&D Funding, 1890-2004

millions of 2000 US$

USDA IM
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

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

Output Quantity Index

Quantity Index (1949 = 100)

- Field Crops
- Nursery & Greenhouse
- Livestock

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

Graph showing the trend of output indexes for different categories over time from 1949 to 1999.
Input Indexes in U.S. Agriculture

Index (1949 = 100)

- Materials
- Capital
- Land
- Labor
- All Inputs

Bar chart showing the index values for different inputs over the years from 1949 to 1999.
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.
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%

VT ME NY

NJ RI NH MA
Spatial Patterns of Input and Output Growth
Corn Belt & Lake States

Output Growth

Input Growth

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

-1%  0%  1%  2%  3%

States:
- MN
- IA
- WI
- IL
- IN
- OH
- MO
- MI

Growth Percentages:
- Output Growth:
  - MN: 3%
  - IA: 2%
  - MI: 1%
  - IL: 0%
  - IN: -1%

- Input Growth:
  - OH: -2.5%
  - MO: -1.5%
  - WI: -0.5%
  - IN: 0.5%
  - MI: 1.5%
Spatial Patterns of Input and Output Growth
Pacific States

Output Growth

Input Growth

CA
WA
OR
Spatial Patterns of Input and Output Growth
Southern States

Output Growth

Input Growth

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

AL
FL
GA
KY
AR
LA
MS
Spatial Patterns of Input and Output Growth
Big Wheat-Producing States

Output Growth

Input Growth

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

Output Growth

3%
2%
1%
0%
-1%
-2.5%
-1.5%
-0.5%
0.5%
1.5%

Input Growth

3%
2%
1%
0%
-1%
-2.5%
-1.5%
-0.5%
0.5%
1.5%

SD
IA
OK
CO
KS
NE
CA
IA
TX
OK
NE
CO
CA
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%
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

- 70%
- 65%
- 60%
- 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

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

- SAES
- Extension
- USDA-IM
- Growing
- Condition
- Index

**Specification Issues:**
- Functional form
- Imposing structure on 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

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

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

Growing Condition Index

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

![Graph showing lag structure with weights and lags.](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  
  \[ MFP_{it} = a_i + 0.000000057 \times \text{Own-State Stock} + 0.000000072 \times \text{Spillin Stock} \]
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

Number of States

Range of Benefit/Cost Ratios

0 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 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
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 spillover 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