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

Returns to Research

Agricultural R&D

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

[Graph showing the trend of U.S. Public R&D Funding from 1890 to 2004, with funding measured in 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

Output Index

Index (1949 = 100)

U.S. Agricultural Productivity, 1949-2002

Index (1949 = 100)

Output Index

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

Multi-Factor Productivity

Output Index

Input Index
Input Indexes in U.S. Agriculture

- Materials
- Capital
- Land
- Labor
- All Inputs

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.

Output Growth
Input Growth

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

- VT
- RI
- NY
- NJ
- NH
- MA
- ME
- CT

Input Growth

Output Growth

-2.5% -1.5% -0.5% 0.5% 1.5%
-1% 0% 1% 2% 3%
Spatial Patterns of Input and Output Growth
Corn Belt & Lake States

Input Growth vs. Output Growth
- States: WI, OH, MO, MN, MI, IA, IN
- Data points indicating input growth ranges from -2.5% to 1.5%, output growth from -1% to 3%
- Linear trend line suggesting a positive correlation between input and output growth
Spatial Patterns of Input and Output Growth

Pacific States

Input Growth

Output Growth

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

WA  OR  CA
Spatial Patterns of Input and Output Growth
Southern States
Spatial Patterns of Input and Output Growth
Big Wheat-Producing States

Input Growth

Output Growth

MN  MT  ID  SD  ND  KS  WA  TX  OK  MT

-1%  0%  1%  2%  3%

-2.5% -1.5% -0.5% 0.5% 1.5%
Spatial Patterns of Input and Output Growth
Big Beef-Producing States
Temporal Patterns of Input and Output Growth, Pre- and Post-1990

Pre-1990

Input Growth

Output Growth

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

Pre-1990 in teal
Post-1990 in orange

Input Growth
Output Growth

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

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

- 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
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

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

Range of Benefit/Cost Ratios

Average = 26
Range from 10 to 52

Number of States

Range of Benefit/Cost Ratios

0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
Private Benefit/Cost Ratios
Linear Model (in orange)

Range of Benefit/Cost Ratios

Number of States

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
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