Technical Efficiency & Productivity Growth in the Northwest Sawmill Industry

May 3, 2006

Outline

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- Methods of Analysis
  - Data Envelopment Analysis (DEA)
  - Stochastic Frontier Analysis (SFA)
- Data
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  - Inputs & Output
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- Results

Objectives

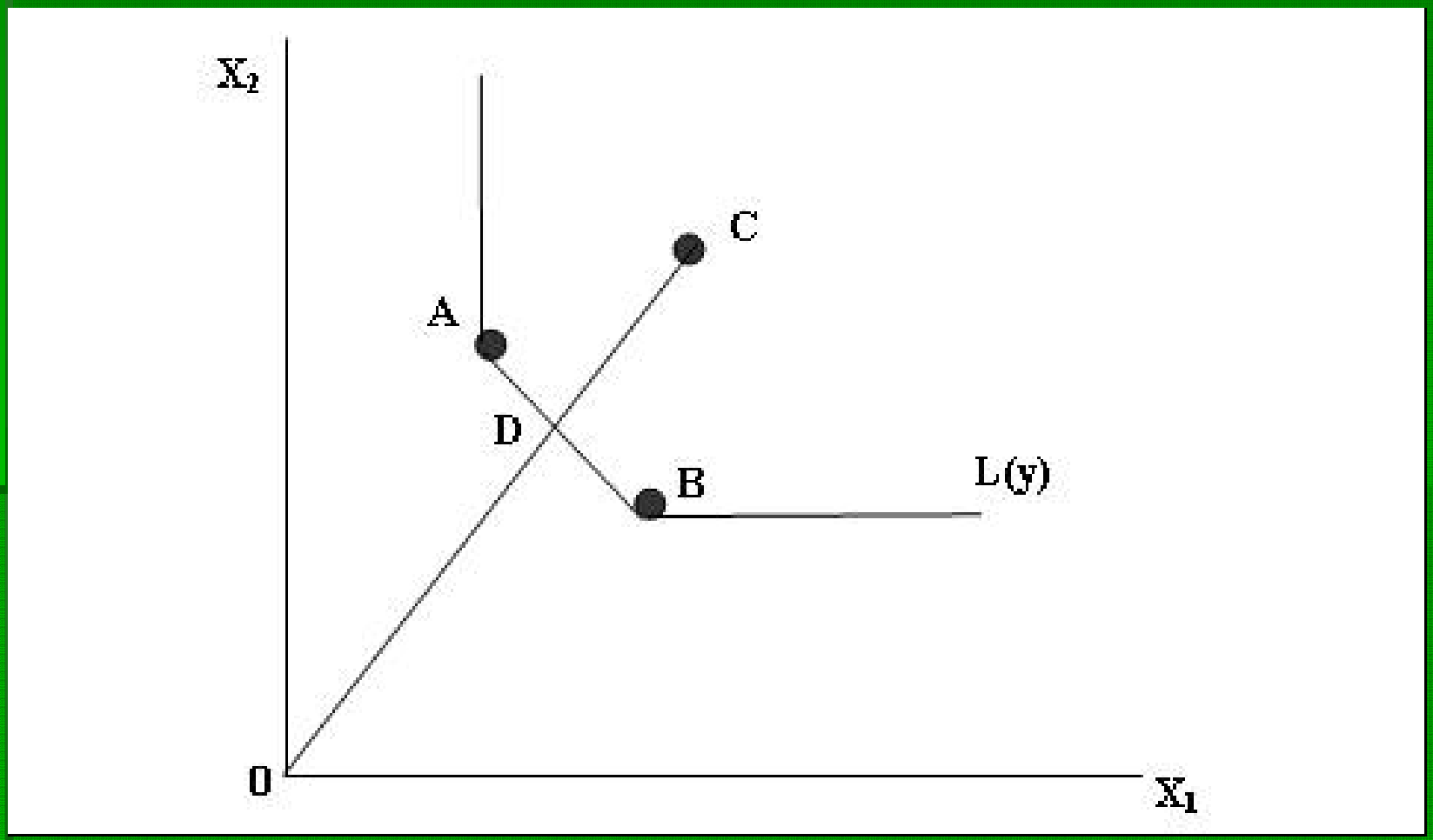
- To Estimate…
  - Efficiency of sawmill industry (Relative)
  - Technical change, efficiency change, and productivity growth over study period (1968-2002)
  - RTS of the industry
  - Output elasticities
  - Elasticities of substitution between inputs
- Compare results obtained from DEA & SFA

Data Envelopment Analysis (DEA)

- Method for estimating the production frontier of a set of “decision making units” (DMUs)
- Based on ideas described by Farrell (1957)
- Adapted into linear programming framework by Charnes, Cooper, & Rhodes (1978)
- Traditionally considered to be “deterministic”
- Through 2004, more than 1,800 articles in referred journals that employ DEA

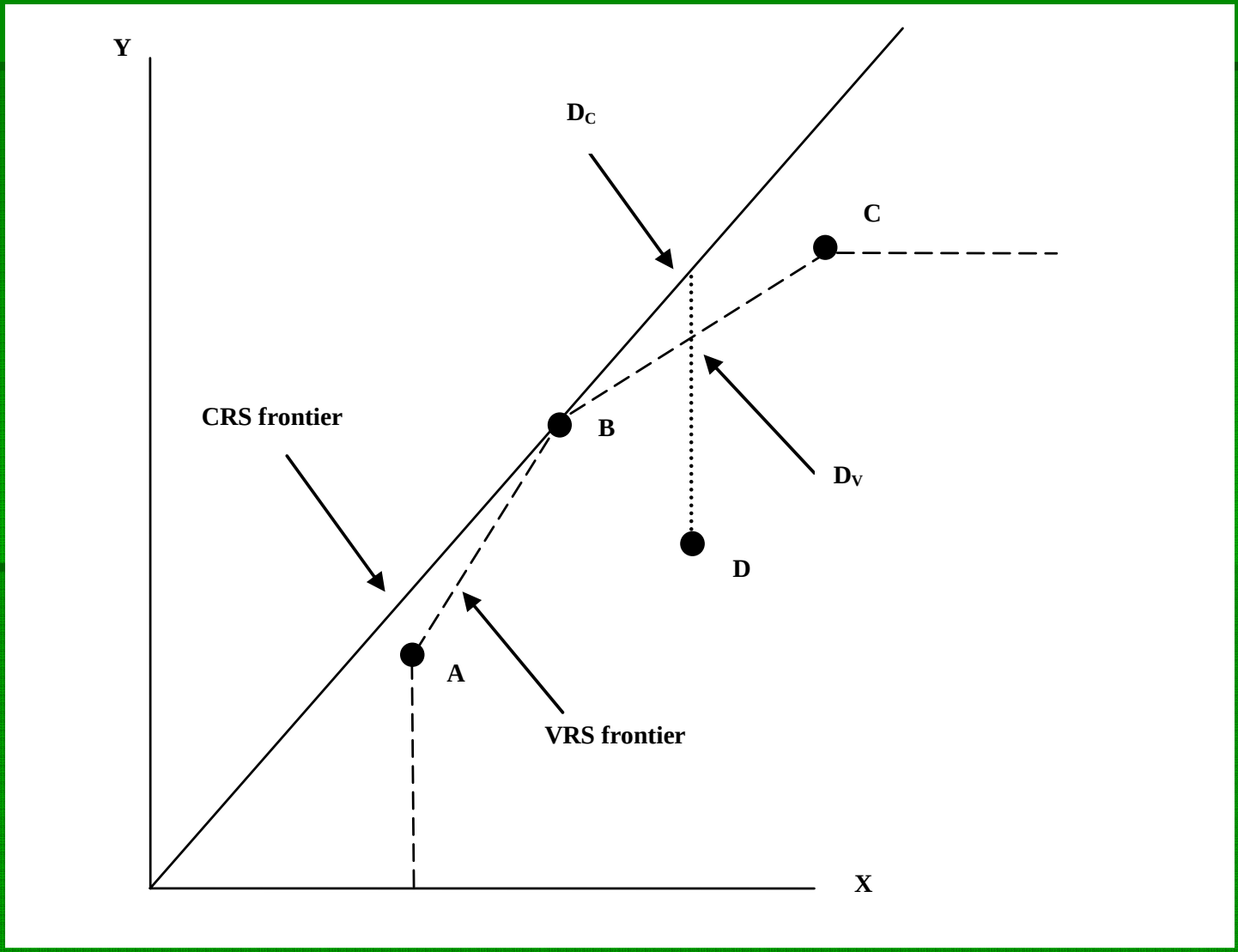
DEA (cont.)

Best Practices Frontier in Input Space



DEA (cont.)

Production Function showing CRS & VRS Technologies



DEA Analyses in the Forest Products Industry

- **Salehirad & Sowlati (2005)** examined data on 82 BC sawmills for 2002 using a 2-input, 1-output DEA model. (Forest Science)
- **Nyrud & Baardsen (2002)** examined data on a panel of 66 Norwegian sawmills over the period 1974-1991 using a 6-input, 3-output DEA model (Forest Science)
- **Yin (2000)** employs both DEA & SFA to examine technical efficiency of the global producers of bleached softwood kraft pulp. (Forest Science)

Stochastic Frontier Analysis (SFA)

- Econometric method for estimating the production frontier of a set of “decision making units” (DMUs)
- Based on ideas described by Farrell (1957)
- Developed independently by Aigner, Lovell, and Schmidt (1977), and Meeusen and van Den Broeck (1977)
- Error term is “composed” of (symmetric) random disturbance term and one-sided inefficiency term

SFA (cont.)

- Unlike DEA…
  - SFA includes the direct estimation of standard errors & hypothesis testing
  - SFA does not assume all deviation from frontier is due to inefficiency
  - SFA supports panel data estimation
- On the down side…
  - A functional form must be imposed on the SFA model
  - Must meet or impose regularity conditions of the function
  - No a priori theoretical reason to assume one distributional assumption over another for the one-sided error term
  - Only two conventional econometric packages that readily estimate SFA models (Limdep & Frontier)

SFA Analyses in the Forest Products Industry

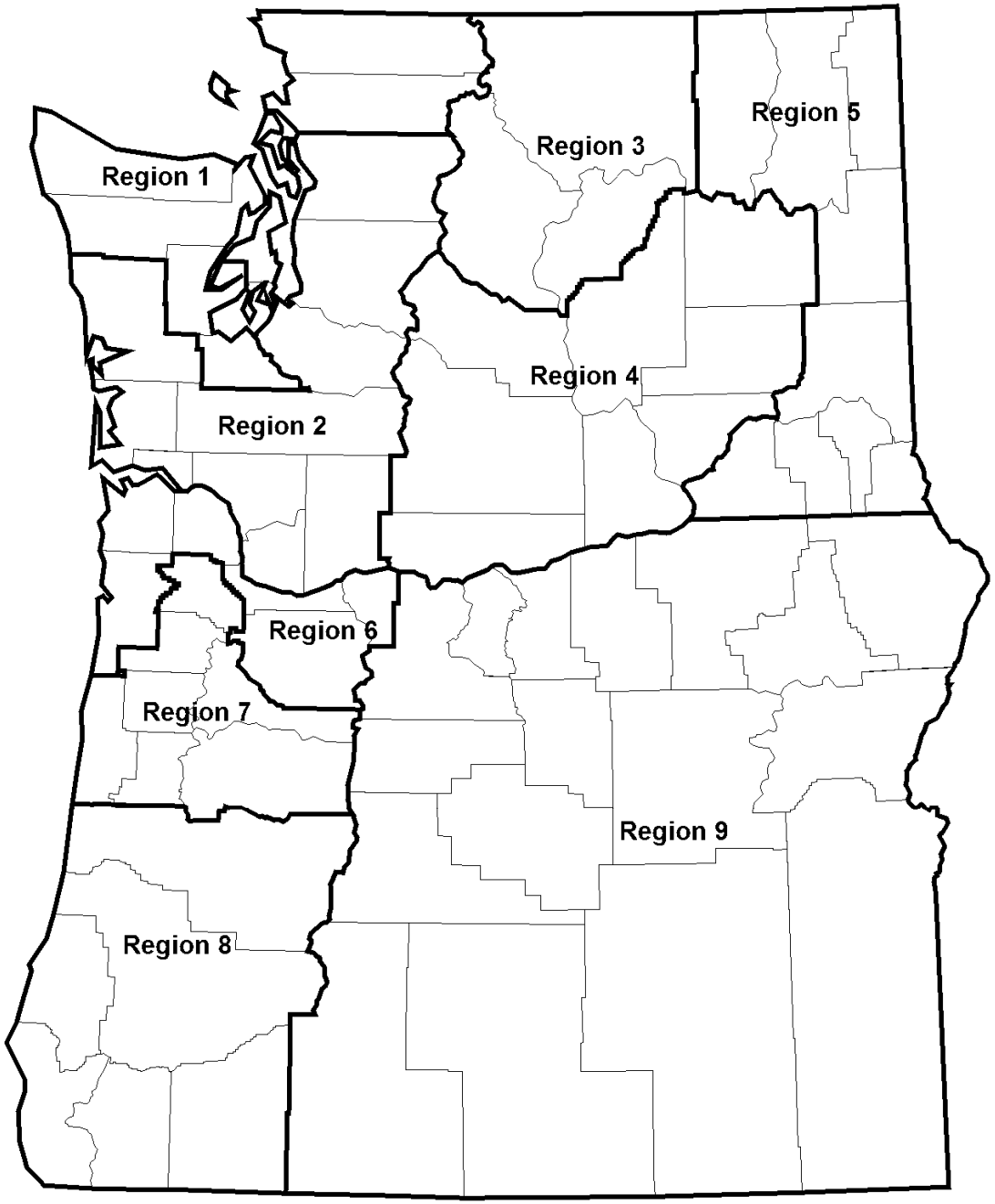
- **Carter & Cubbage (1995)** estimate a stochastic frontier production function using firm-level data from the southern U.S. pulpwood harvesting industry for 1979 and 1987. They found that the industry experienced positive technical change that averaged 1.8% per year. (Forest Science)

- **Siry and Newman (2001)** study the efficiency of Polish state timber production and management policies for the years 1993-1995 using a time-invariant Cobb-Douglas function. The authors estimate technical efficiency to average 49% over the period, but do not examine productivity change. (Forest Science)

The Data

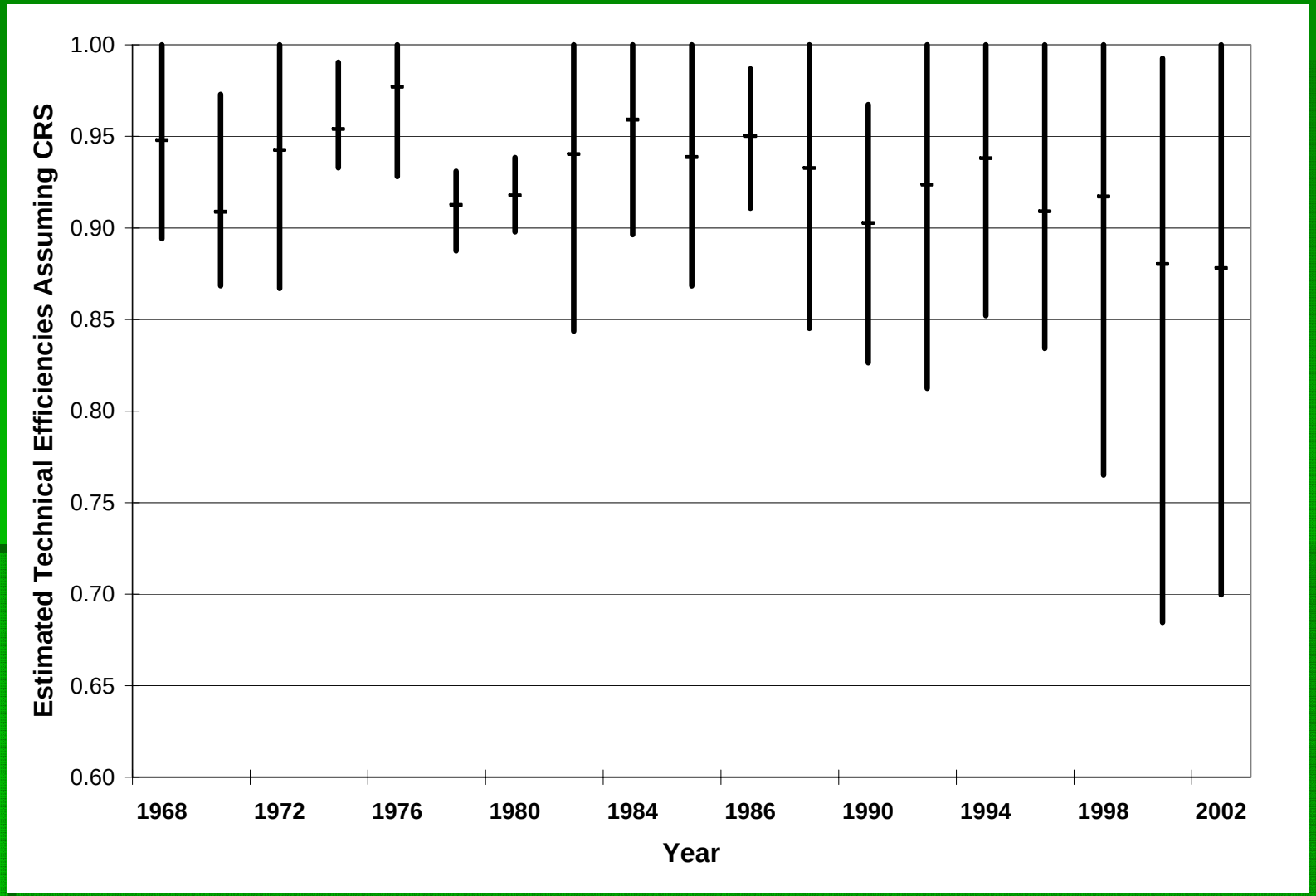
- **Washington:** Mill-level data from the DNR biennial mill survey (1968-2002).
- **Oregon:** County or multi-count aggregate data from the PNW Research Station. Data were collected sporadically (1968, 1972, 1976, 1982, 1985, 1988, 1992, 1994, 1998).
- **Inputs:** Logs, Labor, Capacity, “Other”
- Employment data from respective state employment department
- **Output:** Lumber

REGIONS


Region 1
Region 2
Region 3
Region 4
Region 5
Region 6
Region 7
Region 8
Region 9

DEA Results

DEA-based Technical Efficiency Estimates Assuming CRS Production Function



DEA Results

- Returns to Scale:
  - Oregon regions found to be operating under CRS throughout study period
  - RTS varied across region and through time for Washington regions
    - Westside WA regions generally operated under CRS
    - North central WA Region found to operate under IRS over entire period

DEA Results: Productivity Growth

Time Period	Point Estimate	Lower Bound 95% CI	Upper Bound 95% CI
Period 1 (1968-1982)	0.50%	0.13%	0.65%
Period 2 (1982-1992)	0.50%	0.40%	0.86%
Period 3 (1992-2002)	0.99%	0.67%	1.49%

DEA Results: Technical Change

Time Period	Point Estimate	Lower Bound 95% CI	Upper Bound 95% CI
Period 1 (1968-1982)	0.61%	0.41%	0.93%
Period 2 (1982-1992)	0.52%	0.33%	0.78%
Period 3 (1992-2002)	1.20%	0.76%	1.59%

DEA Results: Efficiency Change

Time Period	Point Estimate	Lower Bound 95% CI	Upper Bound 95% CI
Period 1 (1968-1982)	-0.12%	-0.69%	0.08%
Period 2 (1982-1992)	-0.01%	-0.26%	0.42%
Period 3 (1992-2002)	-0.21%	-0.74%	0.58%

SFA Results: Output Elasticities & RTS

Input	1970s	1980s	1990s	All Years
Capital	-0.08	0.04	0.16	0.04
Labor	0.13	0.05	-0.04	0.05
Logs	0.58	0.65	0.73	0.65
Other	0.35	0.28	0.22	0.28
RTS	0.98	1.03	1.07	1.03

SFA Results: Tech, Eff, & Prod Change

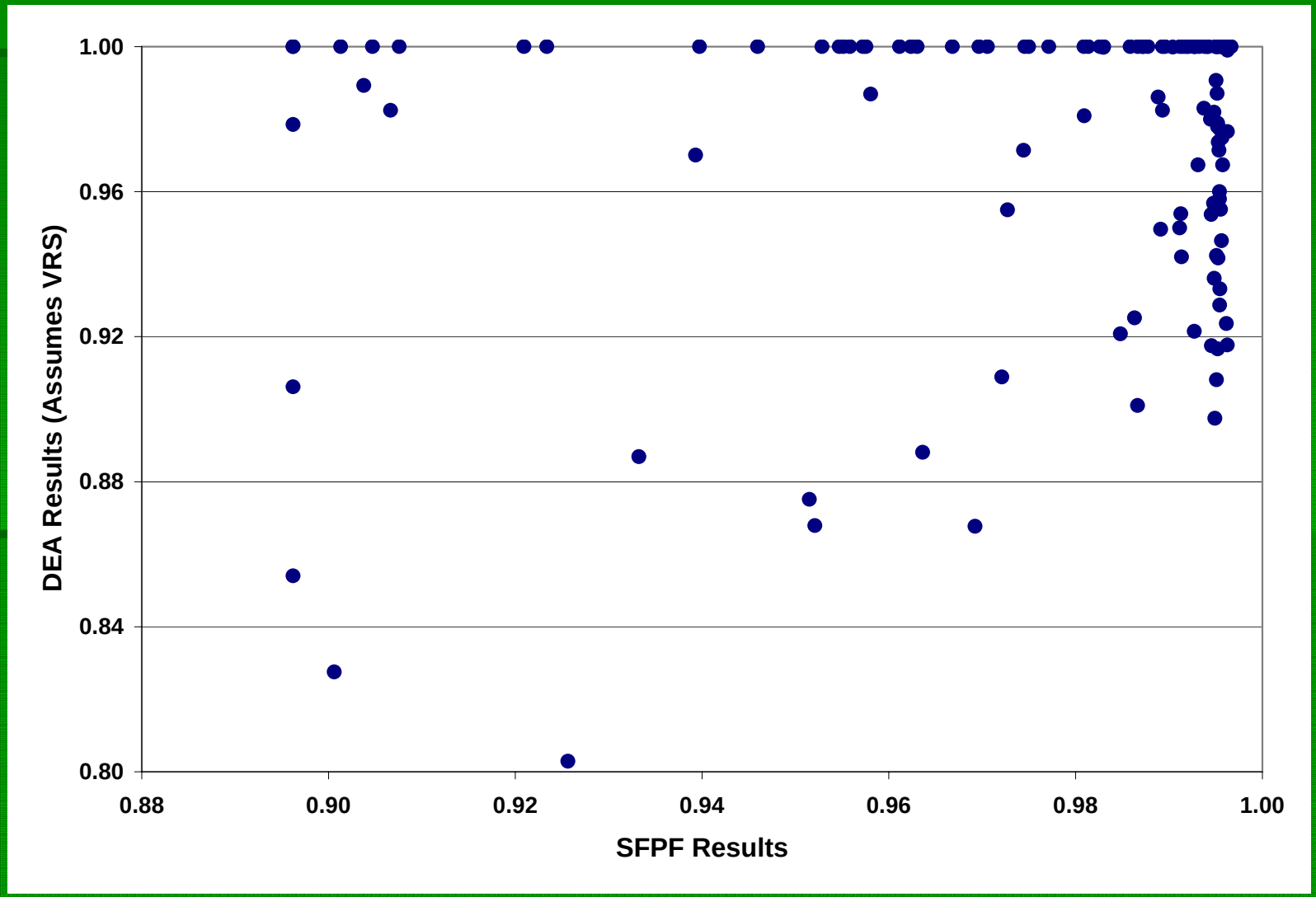
Input	1970s	1980s	1990s	All Years
Technical Change	1.6%	2.1%	2.2%	2.0%
Efficiency Change	-0.02%	-0.3%	-0.3%	-0.2%
Productivity Change	1.6%	1.9%	2.1%	1.8%

SFA Results: Elasticity of Substitution

"Row for Column"	Capital	Labor	Logs
Capital	1	0.91	0.01
Labor	0	1	0
Logs	-0.48	5.4	1

Comparison: SFA vs. DEA

Scatter Plot of SFA and DEA Technical Efficiency Estimates



Comparison: SFA vs. DEA

- Returns to Scale
  - SFA could not reject hypothesis of CRS
  - DEA found most regions operated at point of CRS for most years
- Productivity Growth & Technical & Efficiency Change
  - **Technical change:** SFA results indicate significantly higher annual growth rates than DEA
  - **Efficiency change:** estimates are very similar between SFA & DEA
  - **Productivity Change:** SFA results indicate significantly higher annual growth rates than DEA

Discussion

- These studies are…
  - The first in recent years to focus on the PNW sawmill industry
  - The only studies of the PNW sawmill industry that have utilized DEA and SFA methods
  - Provide two different views on productivity growth (and its decomposition) in the PNW sawmill industry.
  - Productivity growth, technical & efficiency change are…
    - Consistent in *direction* across methods
    - Not consistent in *magnitude*