The Sources of Measured Agricultural Productivity Growth

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Source: Economic Research Service, United States Department of Agriculture
Fact 2: US Agricultural TFP
US aggregate agricultural input has been remarkably stable for almost a century.
Thinking about Facts 1 and Fact 2

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Residual remains.
Fact 3: US Agriculture TFP Change (1949-2008)

Source: Computed from ERS/USDA official statistics
Thinking about Fact 3

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- Is productivity a weather index? Or is productivity a measure of input effectiveness or state of technology?

- We actually want something like the following for a technical-change index

\[
(\frac{f(x_{t+1}, W_{t+1}, t + 1)}{f(x_{t+1}, W_{t+1}, t)} \cdot \frac{f(x_t, W_t, t + 1)}{f(x_t, W_t, t)})^{\frac{1}{2}}
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Thinking about Fact 3

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- Is productivity a weather index? Or is productivity a measure of input effectiveness or state of technology?
- We actually want something like the following for a technical-change index:

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\left( \frac{f(x_{t+1}, W_{t+1}, t+1)}{f(x_{t+1}, W_{t+1}, t)} \right) \frac{f(x_t, W_t, t+1)}{f(x_t, W_t, t)} \right)^{\frac{1}{2}}
\]

- Instead we get:
What Are We Measuring?

\[ f(X, W^G, t^1) \]

\[ f(X, W^B, t^1) \]

\[ f(X, W^B, t^0) \]
Simple Goal

- Incorporate stochastic nature of agriculture into productivity measurement, while allowing for inefficiency.
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A Simple Model

- Random variables (acts) $\Omega \rightarrow \mathbb{R}$, so they can be viewed as elements of $\mathbb{R}^\Omega$

- $T(t)$ is the collection of random variables and the inputs that can produce them

  $$T(t) = \{(\tilde{z}, x) : x \text{ can produce } \tilde{z} \text{ at time } t\}.$$ 

- Approximate it with

  $$T^\Omega(t) = \{(\tilde{z}, x) : z(s) \leq g(x, s, t), s \in \Omega\}$$

  $$g : \Omega \rightarrow \mathbb{R}_+, \tilde{g} = (g(x, s_1, t), g(x, s_2, t), \ldots) \in \mathbb{R}^\Omega_+ \text{ is a random variable.}$$
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Huge number of conceptual problems (Chambers and Quiggin, ad nauseam) but does have advantages: Implementable and easily comparable.
Productivity Index

- Standard Malmquist-type productivity index:

\[
\left( \frac{z^0}{g(x^0, s^1, t^1)} \frac{g(x^1, s^1, t^1)}{z^1} \right)^{\frac{1}{2}} \left( \frac{z^0}{g(x^0, s^0, t^0)} \frac{g(x^1, s^0, t^0)}{z^1} \right)^{\frac{1}{2}},
\]

easily decomposes as

\[
E_{s^0, s^1, t^0, t^1}^s(z^0, x^0; z^1, x^1) \ H_{s^0, s^1, t^0, t^1}^s(z^0, x^0; z^1, x^1),
\]

and \( E_{s^0, s^1, t^0, t^1}^s(z^0, x^0; z^1, x^1) \) is a standard Färe et al. (1994) efficiency change index.
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$$

easily decomposes as

$$E^{s^0, s^1, t^0, t^1} (z^0, x^0; z^1, x^1) H^{s^0, s^1, t^0, t^1} (z^0, x^0; z^1, x^1),$$

and $E^{s^0, s^1, t^0, t^1} (z^0, x^0; z^1, x^1)$ is a standard Färe et al. (1994) efficiency change index.

$H^{s^0, s^1, t^0, t^1} (z^0, x^0; z^1, x^1)$ is a combination of technical change and state of Nature change. Its decomposition is path dependent (standard problem, but see Henderson and Russell (2005))
\[ H^{s_0,s_1,t_0,t_1} = \Omega^{s_0,s_1} (x^0, x^1, t_0, t_1) \times T^{t_0,t_1} (x^0, s^0, x^1, s^1), \]

where \( T^{t_0,t_1} (x^0, s^0, x^1, s^1) \) is technical change of the form

\[
\left( \tilde{T}^{t_0,t_1} (x^0, s^1) \tilde{T}^{t_0,t_1} (x^0, s^0) \tilde{T}^{t_0,t_1} (x^1, s^1) \tilde{T}^{t_0,t_1} (x^1, s^0) \right)
\]

and \( \Omega^{s_0,s_1} (x^0, x^1, t_0, t_1) \) is state-contingent effect of the form

\[
\left( \tilde{\Omega}^{s_0,s^1} (x^0, t_0) \tilde{\Omega}^{s_0,s^1} (x^0, t_1) \tilde{\Omega}^{s_0,s^1} (x^1, t_0) \tilde{\Omega}^{s_0,s^1} (x^1, t_1) \right)^{\frac{1}{2}}
\]
Operationally speaking

- $\Omega \subset \mathbb{R}_+^2$ defined empirically by observations on degree days between $8^\circ$ and $32^\circ$ C and precipitation

Follow Banker and Morey (1986) and (implicitly) O'Donnell and Griffiths (2006) and approximate $\hat{T}_\Omega(t)$ with CRS hull $\hat{T}_\Omega(t) = \begin{cases} \ldots & \text{if } \lambda_k, \nu_k, z_k, x_k, s_k \end{cases}$

where the $z_k$s are taken from V. Eldon Ball's state panel (1960-2004) and the $s_k$s from Schlenker and Roberts (2005)
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$$\hat{T}^\Omega (t) = \left\{ \begin{array}{l}
(z, x, s) : z \leq \sum_{k=1}^{48} \sum_{v=1}^{t} \lambda_{kv} z^{kv}, \\
x \geq \sum_{k=1}^{48} \sum_{v=1}^{t} \lambda_{kv} x^{kv}, \\
s = \sum_{k=1}^{48} \sum_{v=1}^{t} \lambda_{kv} s^{kv}, \\
\lambda_{kv} \geq 0
\end{array} \right\},$$

where the $(x, z)'s$ are taken from V. Eldon Ball’s state panel (1960-2004) and the $s’s$ from Schlenker and Roberts (2005)
California Aggregate Output and Input (1960-2004)

Source: ERS/USDA
Efficiency Change Index for California as calculated with and without Weather
California Productivity and H-Index: The Efficiency Residual Disappears
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Some Final Remarks

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- **Do we learn anything from trying to relax that premise?**
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- Too simple minded?
- For sure, but that’s why I’m trying to raise the issue for the experts.