Industry & State Level Value Added and Productivity Decompositions

Shipei Zeng\textsuperscript{1}, Stephanie Parsons\textsuperscript{1,3}, W. Erwin Diewert\textsuperscript{1,2}, and Kevin J. Fox\textsuperscript{1}

\textsuperscript{1}School of Economics, UNSW Sydney
\textsuperscript{2}Vancouver School of Economics, University of British Columbia
\textsuperscript{3}Reserve Bank of Australia

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Value added decomposition

- Parametric and non-parametric estimation of production frontiers

- A recent decomposition proposed by Diewert and Fox (2017)
  - Free Disposal Hull (FDH) and index number theory
  - Rule out technical regress
  - A non-parametric approach involving only observable data
Value added decomposition for Australian market sector industries
- 12 selected industries and 16 market sector industries
- Decomposition at an aggregate level and an industry level
- Sectoral explanations for Australian TFP change

Simple enough to be implemented by national statistical offices
- Data cubes from Australian Bureau of Statistics
- R package: dfvad
Defining the optimal output value

- **Cost constrained value added function**
  
  \[
  R^t(p, w, x) = \max_{y, z} \{ p \cdot y : (y, z) \in S^t; w \cdot z \leq w \cdot x \}
  \]

- **Unit cost function**
  
  \[
  c^t(w, p) = \min_s \left\{ \frac{w \cdot x^s}{p \cdot y^s} : s = 1, \ldots, t \right\}
  \]
Defining the optimal output value

- Rewrite the cost constrained value added function

\[ R^t(p, w, x) = \max_s \left\{ p \cdot y^s \frac{w \cdot x}{w \cdot x^s} : s = 1, \cdots, t \right\} \]

\[ = \frac{w \cdot x}{c^t(w, p)} \]

- A sequential approach which rules out technical regress
Explanatory factors

- Net output price indexes

\[ \alpha(p^{t-1}, p^t, w, x, s) = \frac{R^s(p^t, w, x)}{R^s(p^{t-1}, w, x)} \]

- Input quantity indexes

\[ \beta(x^{t-1}, x^t, w) = \frac{w \cdot x^t}{w \cdot x^{t-1}} \]
Explanatory factors

- **Input mix indexes**

  \[\gamma(w^{t-1}, w^t, p, x, s) = \frac{R_s(p, w^t, x)}{R_s(p, w^{t-1}, x)}\]

- **Returns to scale**

  \[\delta(x^{t-1}, x^t, p, w, s) = \frac{R_s(p, w, x^t)/R_s(p, w, x^{t-1})}{w \cdot x^t/w \cdot x^{t-1}} = 1\]
Explanatory factors

- Growth in value added efficiency

\[ e^t = \frac{p^t \cdot y^t}{R^t(p^t, w^t, x^t)} \leq 1 \]

\[ \varepsilon^t = \frac{e^t}{e^{t-1}} \]

- Technical progress

\[ \tau(t-1, t, p, w, x) = \frac{R^t(p, w, x)}{R^{t-1}(p, w, x)} \]
Straightforward decomposition

- **Value added growth decomposition**

\[
\frac{p^t \cdot y^t}{p^{t-1} \cdot y^{t-1}} = \alpha^t \cdot \beta^t \cdot \gamma^t \cdot \varepsilon^t \cdot \tau^t
\]

- **TFP growth decomposition**

\[
TFPG^t = \frac{p^t \cdot y^t / p^{t-1} \cdot y^{t-1}}{\alpha^t \cdot \beta^t} = \gamma^t \cdot \varepsilon^t \cdot \tau^t
\]
A weighted average industry approach

- Törnqvist explanatory factors: \( \lambda \in \{\alpha, \beta, \gamma, \varepsilon, \tau\} \)

\[
\ln \lambda^{t\bullet} = \sum_{k=1}^{K} \frac{1}{2} (s^{kt} + s^{k,t-1}) \ln \lambda^{kt}
\]

- Approximation of value relatives

\[
\ln \left( \frac{v^{t}}{v^{t-1}} \right) \approx \sum_{k=1}^{K} \frac{1}{2} (s^{kt} + s^{k,t-1}) \ln \left( \frac{v^{kt}}{v^{k,t-1}} \right)
\]

\[
= \sum_{k=1}^{K} \frac{1}{2} (s^{kt} + s^{k,t-1}) \ln \left( \alpha^{kt} \beta^{kt} \gamma^{kt} \varepsilon^{kt} \tau^{kt} \right)
\]

\[
= \ln \alpha^{t\bullet} + \ln \beta^{t\bullet} + \ln \gamma^{t\bullet} + \ln \varepsilon^{t\bullet} + \ln \tau^{t\bullet}
\]
Establishing a benchmark

- $t = 1$
  
  $$A^1 = 1, \quad B^1 = 1, \quad C^1 = 1, \quad E^1 = 1, \quad T^1 = 1$$

- $t > 1$
  
  $$A^t = \alpha^t A^{t-1}, \quad B^t = \beta^t B^{t-1}, \quad C^t = \gamma^t C^{t-1}$$
  $$E^t = \varepsilon^t E^{t-1}, \quad T^t = \tau^t T^{t-1}$$

- Level value of productivity
  
  $$\text{TFP}^t = \frac{p^t \cdot y^t}{p^1 \cdot y^1 \cdot A^t \cdot B^t}$$
  
  $$= C^t E^t T^t$$
Australian market sector

- 16 industries with productivity data available 1994/95-2016/17 (July-June years)
- 12 industries with productivity data available 1989/90-2016/17 (July-June years)
- Concerns about measurement problems and research periods
# Australian market sector

**Table 1:** Industry classification of the market sector in Australia

<table>
<thead>
<tr>
<th>Division</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Agriculture, Forestry and Fishing</td>
</tr>
<tr>
<td>B</td>
<td>Mining</td>
</tr>
<tr>
<td>C</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>D</td>
<td>Electricity, Gas, Water and Waste Services</td>
</tr>
<tr>
<td>E</td>
<td>Construction</td>
</tr>
<tr>
<td>F</td>
<td>Wholesale Trade</td>
</tr>
<tr>
<td>G</td>
<td>Retail Trade</td>
</tr>
<tr>
<td>H</td>
<td>Accommodation and Food Services</td>
</tr>
<tr>
<td>I</td>
<td>Transport, Postal and Warehousing</td>
</tr>
<tr>
<td>J</td>
<td>Information, Media and Telecommunications</td>
</tr>
<tr>
<td>K</td>
<td>Financial and Insurance Services</td>
</tr>
<tr>
<td>L</td>
<td>Rental, Hiring and Real-Estate Services</td>
</tr>
<tr>
<td>M</td>
<td>Professional, Scientific and Technical Services</td>
</tr>
<tr>
<td>N</td>
<td>Administrative and Support Services</td>
</tr>
<tr>
<td>R</td>
<td>Arts and Recreation Services</td>
</tr>
<tr>
<td>S</td>
<td>Other Services</td>
</tr>
</tbody>
</table>
Productivity of 12 selected industries

![Graph showing productivity trends from 1990 to 2016 for different methods: ABS (12), DF Method with ABS Aggregates, and Weighted Industry Aggregation Method. The graph displays a log index on the y-axis and years from 1990 to 2016 on the x-axis.]
DF Method with ABS aggregates
Industry-level decomposition

Weighted industry aggregation method

![Graph showing industry-level decomposition and weighted aggregation method over time with labeled axes and data points.](image)
Industry-level decomposition

Divisions A–D

Agriculture

Mining

Manufacturing

Utilities

\[ \text{lnTFP} = \text{lnT} + \text{lnE} + \text{lnC} \]

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Divisions E–H

Industry-level decomposition

Construction

Wholesale

Retail

Accommodation

$\ln TFP \quad \ln T \quad \ln E \quad \ln C$

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Divisions I–K, R

Transport

Information

Financial

Arts

InIndex

Year

lnTFP lnT lnE lnC

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Thoughts on the industry results

- Only 4 industries showed considerable technical progress beyond 2004
  - Agriculture, forestry and fishing
  - Retail trade
  - Wholesale trade
  - Financial and insurance services

- Some industries showed little technical progress even earlier than the 2004 peak
  - Mining (1996)
  - Electricity, gas, water and waste services (1998)
  - Information, media and telecommunications (1999)
  - Arts and recreation services (1991)
Thoughts on the industry results

- The amount of inefficiency for some industries was huge
  - Manufacturing
  - Mining
  - Electricity, gas, water and waste services
  - Accommodation and food services
  - Arts and recreation services

- Some of this inefficiency is probably real and some of it probably indicates mismeasurement of inputs and outputs
Industry contribution: aggregation

- The weighted average industry approach

\[ \ln \lambda^{t*} = \sum_k \frac{1}{2} (s^{kt} + s^{k,t-1}) \ln \lambda^{kt} \]

- From growth value to level value

\[ \ln \Lambda^{t*} = \sum_t \sum_k \frac{1}{2} (s^{kt} + s^{k,t-1}) \ln \lambda^{kt} \]

\[ = \sum_k \sum_t \frac{1}{2} (s^{kt} + s^{k,t-1}) \ln \lambda^{kt} \]

\[ = \sum_k \ln \Lambda^{kt} \]
Industry-level decomposition

Industry contribution: productivity

Log Index

Contributions from:
- Agriculture
- Mining
- Manufacturing
- Utilities
- Construction
- Wholesale
- Retail
- Accommodation
- Transport
- Information
- Financial
- Arts
Industry contribution: efficiency

Contributions from:
- Agriculture
- Mining
- Manufacturing
- Utilities
- Construction
- Wholesale
- Retail
- Accommodation
- Transport
- Information
- Financial
- Arts

Industry-level decomposition
Industry contribution: technical progress

Contributions from:
- Agriculture
- Mining
- Manufacturing
- Utilities
- Construction
- Wholesale
- Retail
- Accommodation
- Transport
- Information
- Financial
- Arts
Thoughts on the industry results

- Industry performance contributes to the aggregate level according to value added shares

- Efficiency
  - Unweighted: electricity, gas, water and waste services
  - Weighted: mining

- Technical progress
  - Unweighted: agriculture, forestry and fishing
  - Weighted: financial and insurance services
State-level data

- ABS published the first (experimental) estimates of state TFP in January 2018 for 1994/95 to 2016/17
- Data cover 12 selected industries (aggregate only)
- Less-populated states more prone to measurement error and volatility
State-level TFP growth

Average TFP Growth by State, 1994/95-2016/17

Source: ABS (2018)
Non-mining states
State-level decomposition

Mining states

QLD

WA

SA

NT

lnTFP

lnT

lnE

lnC

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State-level decomposition

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Conclusions

- We have used a new decomposition of industry value added growth, applied to official, publicly available data from the ABS.
- The role of inefficiency proved to be very large for many industries and states:
  - We think that this result is more reasonable than simply interpreting negative TFP growth as technological regress.
  - Industries and states with huge amounts of inefficiency should be investigated for possible mismeasurement of the underlying inputs and outputs.
- Our method is easily implementable by national statistical offices and provides policy-relevant information on growth and productivity.
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Value added decomposition

Mining

[Graph showing the decomposition of value added in mining with logarithmic indices for years 1990 to 2017.]
Manufacturing

![Graph showing the decomposition of value added in manufacturing over years from 1990 to 2017. The graph includes lines for TFP (total factor productivity), labor, capital, and energy, and shows the logarithmic index over time.](image-url)
Construction

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Wholesale Trade

![Graph showing the log index of various factors over years from 1990 to 2017.
There are separate lines and bars for lnTFP, lnT, lnE, and lnC.
The graph indicates an upward trend for all factors, with a significant increase from 2002 onwards.

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New South Wales

![Graph showing the decomposition of value added in New South Wales (NSW) from 1995 to 2015. The graph plots the logarithmic index of total factor productivity (lnTFP) and its components: lnT (technology), lnE (energy), and lnC (capital). The years 1995, 2005, and 2015 are marked on the x-axis. The y-axis represents the log index values. The graph illustrates the trends and contributions of each component to the overall productivity change.]
Victoria

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Queensland

![Graph showing the decomposition of value added in Queensland from 1995 to 2015. The graph includes logarithmic indices for total factor productivity (lnTFP), labor (lnT), capital (lnC), and energy (lnE). The data highlights the contributions of each factor to the overall growth in value added.]
South Australia

![Graph showing log index values for South Australia from 1995 to 2015. The graph includes lines and bars representing different components: lnTFP, lnT, lnE, lnC. The values range from -0.1 to 0.2.](image-url)
Tasmania

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Northern Territory

[Graph showing log index values for Northern Territory from 1995 to 2015, with breakdowns for lnTFP, lnT, lnE, and lnC.]