Intangibles, markups, and the measurement of productivity growth

Nicolas Crouzet and Janice Eberly

Northwestern University
Since late 90’s, measured TFP growth has declined.
The decline in TFP growth

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>GDP growth (p.p.)</td>
<td>3.62</td>
<td>2.68</td>
<td>-0.93</td>
</tr>
<tr>
<td>TFP growth $\frac{dZ}{Z}$ (p.p.)</td>
<td>1.36</td>
<td>0.86</td>
<td>-0.50</td>
</tr>
</tbody>
</table>

Fernald (2014)
Question

Since late 90’s, measured TFP growth has declined

This decline coincided with two other trends
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This decline coincided with two other trends:

- Rise in measured profits (Barkai, 2017; Gutierrez and Philippon, 2017, 2018)
- Growing importance of intangible capital (Crouzet and Eberly, 2018, 2019)

Did these trends contribute to the decline in TFP growth by affecting its measurement?
Rising profits

\[ \frac{\Pi}{K_1} \]


- BEA
- Compustat
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   (Barkai, 2017; Gutierrez and Philippon, 2017, 2018)

2. Growing importance of intangible capital
   (Crouzet and Eberly, 2018, 2019)
The growing importance of intangible capital

\[
\frac{Q_2 K_2}{Q_1 K_1}
\]

BEA; \( K_2 = \text{R&D} \)

Compustat, \( K_2 = \text{R&D} \)

Compustat; \( K_2 = \text{R&D} + \text{organization capital} + \text{balance sheet intangibles} \)
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Did these trends contribute to the decline TFP growth?

... by affecting its measurement?

≠ declining pace of innovation
  (Gordon, 2017)
This paper

What we do:
- theory: derive conditions under which intangibles + rents lead to \( \frac{\hat{dZ}}{Z} < \frac{dZ}{Z} \) in a general framework.
- data: test conditions and estimate \( \frac{dZ}{Z} - \frac{\hat{dZ}}{Z} \)

What we find:
- theory: for \( \frac{\hat{dZ}}{Z} < \frac{dZ}{Z} \), need both high intangible share \( \eta \) and high intangible price growth \( gQ^2 + \mu > 1 \) (bias in growth, off balanced growth).
- data: intermediate services as omitted intangible (organization capital) 97-18: \( \frac{\hat{dZ}}{Z} - \frac{dZ}{Z} = -30 \text{bps} = 0.6 \times \Delta(\frac{\hat{dZ}}{Z}) \) 47-96: \( \frac{\hat{dZ}}{Z} - \frac{dZ}{Z} = -5 \text{bps} \).
This paper

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- **theory**: derive conditions under which intangibles + rents lead to $\frac{\hat{d}Z}{Z} < \frac{dZ}{Z}$
This paper

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This paper

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  \[
  \begin{align*}
  97-18: \quad & \hat{dZ}/Z - dZ/Z = -30 \text{bps} = 0.6 \times \Delta \left( \hat{dZ}/Z \right) \\
  47-96: \quad & \hat{dZ}/Z - dZ/Z = -5 \text{bps}
  \end{align*}
  \]
1. Measurement of productivity growth:
   - Solow (1957), Jorgenson and Griliches (1968), Basu and Fernald (2001), Corrado et al. (2009), Cette et al. (2016), Byrne et al. (2017), Fernald et al. (2017)
   
   **This paper**: bias in input shares and capital growth; organization capital

2. Investment-specific technical change:
   - Greenwood et al. (1997), Greenwood et al. (1998), Basu et al. (2013), Gourio and Rognlie (2020)
   
   **This paper**: markups+intan → overestimate contrib. of $g_Q$ to growth

3. Macroeconomic implications of rising rents and rising intangibles:
   - Gutiérrez and Philippon (2017, 2018); Farhi and Gourio (2018); Barkai (2020); De Loecker et al. (2020); Crouzet and Eberly (2020); Edmond, Midrigan and Xu (2020)
   
   **This paper**: aggregate technical change, not allocative efficiency
1. Theory
The simple Solow residual approach

\[
\frac{\hat{d}Z}{Z} = \frac{\hat{d}Y}{Y} - (1 - \hat{s}_L) \frac{\hat{d}K}{K} - \hat{s}_L \frac{\hat{d}L}{L}
\]

A1: Constant returns to scale in production

\[
\frac{dZ}{Z} = \frac{dY}{Y} - (1 - \epsilon_L) \frac{dK}{K} - \epsilon_L \frac{dL}{L}
\]

A2: Variable cost minimization

\[
\epsilon_L = \frac{WL}{MCY}
\]

A3: Price = Marginal cost

\[
\hat{s}_L = \frac{WL}{PY} = \frac{WL}{MCY} = \epsilon_L
\]

A4: \( \frac{\hat{d}X}{X} = dX/X \)

\[
\frac{\hat{d}Z}{Z} = \frac{dZ}{Z}
\]
**Measurement bias from markups**

\[
A3: \quad P = \mu MC, \quad \mu > 1
\]

**Result 1:**

\[
\frac{\hat{d}Z}{Z} - \frac{dZ}{Z} = \hat{s}_L (1 - \mu) \left( \frac{dK}{K} - \frac{dL}{L} \right) < 0
\]

\( \hat{s}_L \) **under-estimates** \( \epsilon_L \):

\[
\hat{s}_L = \mu^{-1} \epsilon_L < \epsilon_L
\]

Basu and Fernald (2002), Fernald and Neiman (2011)
Measurement bias from markups

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<thead>
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<tbody>
<tr>
<td>$\hat{s}_L$</td>
<td>0.68</td>
<td>0.62</td>
<td>-0.04</td>
</tr>
<tr>
<td>$\hat{dZ}/Z - dZ/Z$ ($\epsilon_L = 1.00$)</td>
<td>-0.73</td>
<td>-0.84</td>
<td>-0.11</td>
</tr>
<tr>
<td>$\hat{dZ}/Z - dZ/Z$ ($\epsilon_L = 0.68$)</td>
<td>0.00</td>
<td>-0.09</td>
<td>-0.09</td>
</tr>
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</table>

9bps, vs. 50bps observed decline in $\hat{dZ}/Z$. 
Measurement bias from intangibles

\[ A4 : \hat{K} \neq K \]

\[ \hat{PY} = PY - B \]

Some capital is omitted from the measured stock \( \hat{K} \)

The corresponding investment \( B \) is treated as intermediate purchases in GDP
Measurement bias from intangibles

$A4 \implies \text{Capital growth might be mismeasured:}$

$$\frac{\hat{dK}}{K} \geq \frac{dK}{K}$$
Measurement bias from intangibles

\[ \frac{\hat{d}Y}{Y} = \frac{dY}{Y} + \left( \frac{1}{b} - 1 \right) \left( \frac{dY}{Y} - \frac{d\tilde{B}}{\tilde{B}} \right) \]

\[ b = \frac{\hat{P}Y}{PY} \leq 1 \]

\[ \tilde{B} \equiv \left( \frac{B}{\hat{P}} \right) \left( \frac{P}{\tilde{P}} \right)^{\frac{b}{1-b}} \]
Measurement bias from intangibles

\[ A4 \implies \hat{s}_L \text{ over-estimates } \epsilon_L: \]

\[ \hat{s}_L = \frac{WL}{\hat{P}\hat{Y}} = \frac{WL}{PY} \frac{PY}{\hat{P}\hat{Y}} = \frac{\epsilon_L}{b} > \epsilon_L \]
Measurement bias from intangibles

Result 2:

\[
\frac{\hat{d}Z}{Z} - \frac{dZ}{Z} \equiv \Delta = \Delta^{(1)} + \Delta^{(2)} + \Delta^{(3)}
\]

\[
\Delta^{(1)} = \left( \frac{1}{b} - 1 \right) \left( \frac{dY}{Y} - \frac{d\hat{B}}{\hat{B}} \right) \quad \text{(GDP growth bias)} \geq 0
\]

\[
\Delta^{(2)} = \hat{s}_L (1 - b) \left( \frac{\hat{d}K}{K} - \frac{dL}{L} \right) \quad \text{(labor share bias)} > 0
\]

\[
\Delta^{(3)} = (1 - \epsilon_L) \left( \frac{dK}{K} - \frac{\hat{d}K}{K} \right) \quad \text{(capital growth bias)} \geq 0
\]

But:

\[
\hat{s}_L = \frac{\epsilon_L}{b} \quad \text{should be high/growing}
\]
Measurement bias from intangibles+markups

Result 3:

\[ \frac{\hat{d}Z}{Z} - \frac{dZ}{Z} \equiv \Delta = \Delta^{(1)} + \Delta^{(2)} + \Delta^{(3)} \]

\[ \Delta^{(1)} = \left( \frac{1}{b} - 1 \right) \left( \frac{dY}{Y} - \frac{d\hat{B}}{\hat{B}} \right) \quad \text{(GDP growth bias)} \geq 0 \]

\[ \Delta^{(2)} = \hat{s}_L \left( 1 - \mu_b \right) \left( \frac{\hat{d}K}{K} - \frac{dL}{L} \right) \quad \text{(labor share bias)} \geq 0 \]

\[ \Delta^{(3)} = (1 - \epsilon_L) \left( \frac{dK}{K} - \frac{\hat{d}K}{K} \right) \quad \text{(capital growth bias)} \geq 0 \]

And:

\[ \hat{s}_L = \frac{\epsilon_L}{b\mu} \quad \text{could be low/falling} \]
A model to help with the measurement

\[ U = \int_0^{+\infty} e^{-\rho t} \frac{C_t^{1-\sigma}}{1-\sigma} dt \]

\[ Y_t = Z_t K_t^\alpha L_t^{1-\alpha}, \quad \frac{dL_t}{L_t} = g_L dt, \quad \frac{dZ_t}{Z_t} = g_Z dt \]
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\[ K_t = K_{1,t}^{1-\eta} K_{2,t}^{\eta}, \quad \frac{dQ_{n,t}}{Q_{n,t}} = g_{Q_n} dt \quad n = 1, 2 \]
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\[ Y_{t} = Q_{1,t}I_{1,t} + Q_{2,t}I_{2,t} + C_{t}, \quad \hat{Y}_{t} = Y_{t} - Q_{2,t}I_{2,t}, \quad \hat{K}_{t} = K_{1,t} \]
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\[ W_{t} = \frac{1-\alpha Y_{t}}{\mu} \frac{Y_{t}}{L_{t}} \]
A model to help with the measurement

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\[ W_t = \frac{1 - \alpha Y_t}{\mu L_t} \]

A1, A2, A4, A3
Insights from the model

1. $\Delta (1) = GDP\ growth\ bias = 0$
   $Y_t, Q_2, t, I_2, t, \hat{Y}_t = Y_t - Q_2, t, I_2, t, all\ grow\ at\ same\ rate\ on\ the\ BGP$

2. $\Delta (2) = capital\ growth\ bias = -\alpha \eta (g_{Q_2} - g_{Q_1})$
   negative\ when\ $g_{Q_2} > g_{Q_1}$ and $b < 1$

3. $\Delta (3) = labor\ share\ bias\ still\ has\ an\ ambiguous\ sign ...\ but\ (generally)\ negative\ when\ g_{Q_2} > g_{Q_1}, b < 1, \ and \ \mu > 1$

Derivations
Insights from the model

1. \( \Delta^{(1)} = \) GDP growth bias = 0

\[ Y_t, \quad Q_{2,t}I_{2,t}, \quad \hat{Y}_t = Y_t - Q_{2,t}I_{2,t} \quad \text{all grow at same rate on the BGP} \]
Insights from the model

1. $\Delta^{(1)} = \text{GDP growth bias} = 0$

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   negative when $g_{Q_2} > g_{Q_1}$ and $b < 1$

3. $\Delta^{(3)} = \text{labor share bias}$ still has an ambiguous sign ...

   ... but (generally) negative when $g_{Q_2} > g_{Q_1}, \ b < 1,$ and $\mu > 1$
2. Data
Methodology

Given estimates of $\hat{b}$ and $\hat{g}_{Q2}$, and $\{\hat{g}, \hat{g}_K, \hat{g}_L, \hat{s}_L\}$, construct:

$$\eta = \frac{1 - \hat{b}}{\hat{b}\hat{s}_L} \frac{1 - \alpha \hat{r} + \delta_2 - \hat{g}_{Q2}}{\alpha \hat{g} + \delta_2 - \hat{g}_{Q2}}$$

$$g_Z = \hat{g} - (1 - \alpha)\hat{g}_L - \alpha \hat{g}_K + \alpha \eta (\hat{g}_{Q2} - (\hat{g} - \hat{g}_K)) \quad \text{[adjusted Solow residual]}$$

$$\mu = \frac{1 - \alpha}{\hat{b}\hat{s}_L}$$
Data on $b$

Commodity Use tables, 1997-2018: 61 different commodities and services.
Data

Data on $\hat{b}$

Commodity Use tables, 1997-2018: 61 different commodities and services.

$B_j = \text{total intermediate use of commodity/service } j$
Data

Data on $\hat{b}$

Commodity Use tables, 1997-2018: 61 different commodities and services.

$B_j = \text{total intermediate use of commodity/service } j$

$\hat{b}_j = \frac{\hat{P}Y}{\hat{P}Y + B_j}$
Data

Data on $\hat{b}$

Commodity Use tables, 1997-2018: 61 different commodities and services.

$B_j = \text{total intermediate use of commodity/service } j$

$$\hat{b}_j = \frac{\hat{PY}}{\hat{PY} + B_j}$$

Data on $\hat{g}_{Q_2}$

61 deflators from GDP-by-industry tables, 1997-2018 (minus PCE deflator).
Data

Data on $\hat{b}$

Commodity Use tables, 1997-2018: 61 different commodities and services.

$B_j = \text{total} \ intermediate \ use \ of \ commodity/service \ j$

$$\hat{b}_j = \frac{\hat{PY}}{\hat{PY} + B_j}$$

Data on $\hat{g}_{Q_2}$

61 deflators from GDP-by-industry tables, 1997-2018 (minus PCE deflator).

need commodity/service ↔ industry
### 10 largest GDP adjustments $\hat{b}_j$

<table>
<thead>
<tr>
<th>Service</th>
<th>$\hat{b}_j$</th>
<th>$\hat{g}_{Q2,j}$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Services</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professional, scientific, and technical services</td>
<td>0.940</td>
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<td>0.964</td>
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</tr>
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<td>Insurance carriers and related activities</td>
<td>0.972</td>
<td>-0.31</td>
</tr>
<tr>
<td>Credit intermediation and related activities</td>
<td>0.973</td>
<td>0.96</td>
</tr>
<tr>
<td>Management of companies and enterprises</td>
<td>0.974</td>
<td>1.44</td>
</tr>
<tr>
<td><strong>Commodities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical products</td>
<td>0.962</td>
<td>1.21</td>
</tr>
<tr>
<td>Oil and gas extraction</td>
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<td>3.68</td>
</tr>
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<td>Food and beverage and tobacco products</td>
<td>0.976</td>
<td>1.02</td>
</tr>
</tbody>
</table>

Investment in organization capital, misclassified as intermediates?
## Cumulative GDP adjustments for business service sector

<table>
<thead>
<tr>
<th>Service groups</th>
<th>Average, 1997-2018</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\hat{b}$</td>
</tr>
<tr>
<td>Prof. services</td>
<td>0.94</td>
</tr>
<tr>
<td>Prof. services + Manag.</td>
<td>0.92</td>
</tr>
<tr>
<td>Prof. services + Manag. + Admin.</td>
<td>0.89</td>
</tr>
</tbody>
</table>
Ratio of unadjusted to adjusted GDP

- IO tables, Prof. services
- IO tables, Prof. services + Management
- IO tables, Prof. services + Management + Admin.
## Total adjustment to TFP growth

<table>
<thead>
<tr>
<th>Year</th>
<th>$\hat{b}$</th>
<th>$\hat{g}_{Q_2}$ (%)</th>
<th>$\hat{g}_{Z}$ (%)</th>
<th>$\mu$</th>
<th>$\eta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1947-1996</td>
<td>0</td>
<td>0</td>
<td>1.36</td>
<td>1.00</td>
<td>0</td>
</tr>
<tr>
<td>1997-2018</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No adj., no markups</td>
<td>0</td>
<td>0</td>
<td>0.86</td>
<td>1.00</td>
<td>0</td>
</tr>
<tr>
<td>No adj., markups</td>
<td>0</td>
<td>0</td>
<td>0.95</td>
<td>1.06</td>
<td>0</td>
</tr>
<tr>
<td>Adj. for Prof. services</td>
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<td>0.49</td>
<td>1.04</td>
<td>1.13</td>
<td>0.25</td>
</tr>
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<td>0.55</td>
<td>1.14</td>
<td>1.19</td>
<td>0.50</td>
</tr>
</tbody>
</table>

$\Delta \hat{g}_{Z} = -22$bps (adjusted) vs. $\Delta \hat{g}_{Z} = -50$bps (unadjusted)
## Total adjustment to TFP growth

<table>
<thead>
<tr>
<th></th>
<th>$\hat{b}$</th>
<th>$\hat{g}_{Q2}$ (%)</th>
<th>$g_Z$ (%)</th>
<th>$\mu$</th>
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$\Delta g_Z = -22\text{bps (adjusted)}$ vs. $\Delta g_Z = -50\text{bps (unadjusted)}$
Total adjustment to TFP growth

<table>
<thead>
<tr>
<th></th>
<th>( \hat{b} )</th>
<th>( \hat{g}_{Q_2} ) (%)</th>
<th>( g_Z ) (%)</th>
<th>( \mu )</th>
<th>( \eta )</th>
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\( \Delta g_Z = -22 \text{bps (adjusted)} \) vs. \( \Delta g_Z = -50 \text{bps (unadjusted)} \)
Pre- vs. post-1997

Previous analysis assumes no adjustments needed before 1997. Reasonable?

Apply adjustments to 47-96, and compare to 97-18. Problems:

1. Expenditure data ($\hat{b}_j$):
   - 47-96 service and commodity groups coarser than 97-18.
   - "Administrative and Waste Management Services" $\supset$ "Administrative and Support Services"
   - use higher 47-96 aggregation level $\rightarrow$ mechanically lower $\hat{b}_j$

2. Price data ($\hat{g}_{Q_2,j}$):
   - no deflators in GDP-by-industry tables pre-97; no source for service prices
   - use post-97 values as baseline
Pre vs. post-97: Cumulative GDP adjustment

<table>
<thead>
<tr>
<th></th>
<th>1947-1996</th>
<th>1997-2018</th>
<th>$\Delta \hat{b}$</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prof. services</td>
<td>0.955</td>
<td>0.921</td>
<td>-0.033***</td>
<td>-15.40</td>
</tr>
<tr>
<td>Prof. services + Manag.</td>
<td>0.937</td>
<td>0.899</td>
<td>-0.038***</td>
<td>-18.11</td>
</tr>
<tr>
<td>Prof. services + Manag. + Admin.</td>
<td>0.924</td>
<td>0.866</td>
<td>-0.057***</td>
<td>-16.23</td>
</tr>
</tbody>
</table>

* : $p < 0.05$, ** : $p < 0.01$, *** : $p < 0.001$.

No change in $\hat{b}$ for the average commodity/service group
Pre vs. post-97: results

<table>
<thead>
<tr>
<th></th>
<th>1997-2018 $g_Z$ (%)</th>
<th>1947-1996 $g_Z$ (%)</th>
<th>$\Delta g_Z$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No markups, no intan adjustment</td>
<td>0.86</td>
<td>1.36</td>
<td>-0.50</td>
</tr>
<tr>
<td>Markups, adjustment for Prof. serv.+Manag.+Admin.</td>
<td>1.18</td>
<td>1.43</td>
<td>-0.25</td>
</tr>
</tbody>
</table>
Robustness

Are the magnitudes for $\hat{b}$ reasonable?
- Compustat expenditures on organization capital
- $\hat{b} = 0.91$, vs. 0.89 in Use tables
- Similar adjustment to $\frac{dZ}{Z}$

Are the magnitudes for $\hat{g}_{Q_2}$ reasonable?
- Price data from BLS, 97-18
- $\hat{g}_{Q_2} > \hat{g}_{Q_1}$
- Smaller adjustment (20bps instead of 28bps)

Are the results robust to alternative values of other parameters?
- lower $\delta_2$ slightly magnifies the mismeasurement; $\delta_2 = 0.05 \rightarrow$ 30bps adjustment
- higher $\alpha$ slightly weakens the mismeasurement; $\alpha = 0.36 \rightarrow$ 27bps adjustment
Conclusion
Main take-aways

Since late 90s, \( \frac{dZ}{Z} \) has been declining
Main take-aways

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Since late 90s, $\frac{dZ}{Z}$ has been declining

- 40-60% due to measurement bias, driven by omitted intangibles + markups
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Since late 90s, $\frac{dZ}{Z}$ has been declining

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  - high $\eta$ + high $g_{Q_2}$ + $\mu > 1$
Main take-aways

Since late 90s, $\frac{dZ}{Z}$ has been declining

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  investment in organization capital, misclassified as intermediate purchases
Main take-aways

Since late 90s, $\frac{dZ}{Z}$ has been declining

- 40-60% due to measurement bias, driven by omitted intangibles + markups
  - high $\eta$ + high $g_{Q2} + \mu > 1$
    - investment in organization capital, misclassified as intermediate purchases
- caveat: $g$ is not biased ...

contribution of $g_{Q2}$ overestimated $\leftrightarrow$ contribution of $g_{Z}$ underestimated

open questions
 bias off balanced-growth path
 other proxies for $g_{Q2}$
Main take-aways

Since late 90s, $\frac{dZ}{Z}$ has been declining

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Main take-aways

Since late 90s, \( \frac{dZ}{Z} \) has been declining

- 40-60% due to measurement bias, driven by omitted intangibles + markups
  
  high \( \eta \) + high \( g_{Q_2} + \mu > 1 \)

  investment in organization capital, misclassified as intermediate purchases

- caveat: \( g \) is not biased ...
  
  contribution of \( g_{Q} \) overestimated \( \leftrightarrow \) contribution of \( g_{Z} \) underestimated

- open questions
  
  bias off balanced-growth path

  other proxies for \( g_{Q_2} \)
Reclassifying intermediate expenditures as intangibles

Are the magnitudes for $b$ reasonable?

+ all service purchases treated as investment

− only externally purchased intangibles — no internally generated

Compare to magnitudes obtained using firm accounting data

empirical proxy for investment in org cap (Eisfeldt and Papanikolaou, 2013)

externally purchased + internally generated
Validation with Compustat

Compustat, 1997-2018, mapped to the 61 sectors $s$ in the IO tables.

For each sector $s$,

$$M_s = 0.3 \times (xsga_s - xrd_s)$$

$$Y_s = \text{Adjusted value added} = \hat{Y}_s + M_s$$

$$\hat{Y}_s = \text{Measured value added} = \text{EBITDA}_s + xrd_s + Wages_s$$

Aggregating:

$$b \equiv \frac{\sum_s \hat{Y}_s}{\sum_s \hat{Y}_s + M_s} = \frac{\text{Unadjusted GDP}}{\text{Adjusted GDP}}$$

Note: $Wages_s$ estimated using the IO Use tables
Ratio of unadjusted to adjusted GDP

- IO tables, Prof. services
- IO tables, Prof. services + Management
- IO tables, Prof. services + Management + Admin.
## Compustat comparison

<table>
<thead>
<tr>
<th></th>
<th>$\hat{b}$</th>
<th>$\hat{g}_Q$ (%)</th>
<th>$\hat{g}_Z$ (%)</th>
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<td>1.19</td>
<td>0.50</td>
</tr>
<tr>
<td>Adjusted for Organization capital (Compustat)</td>
<td>0.91</td>
<td>0.68</td>
<td>1.11</td>
<td>1.16</td>
<td>0.38</td>
</tr>
</tbody>
</table>
Nominal investment to GDP, after adjusting for omitted intangible investment
Nominal investment to GDP, after adjusting for omitted intangible investment

- IO tables, unadj.
- IO tables, adj. for Prof. services
- IO tables, adj. for Prof. services + Management
- IO tables, adj. for Prof. services + Management + Admin.
- Compustat, unadj.
- Compustat, adj. for Organization capital
How large can the bias potentially be?

Given \((\eta, g_{Q_2})\), match post-97 moments:

\[
\hat{g} = \frac{\hat{d}Y}{Y}, \quad \hat{g}_L = \frac{\hat{d}L}{L}, \quad \hat{g} - g_{Q_1} = \hat{g}_K = \frac{\hat{d}K}{K}, \quad \hat{s}_L.
\]

Compute and plot implied values of:

\[
g_Z = \hat{g} - (1 - \alpha)\hat{g}_L - \alpha\hat{g}_K + \alpha\eta(g_{Q_2} - g_{Q_1})
\]

\[
\mu = \frac{1 - \alpha}{\hat{s}_L} + \alpha\eta\frac{g + \delta_2 - g_{Q_2}}{r + \delta_2 - g_{Q_2}}
\]

\[
b = \frac{1}{1 + \alpha\eta\frac{\hat{g} + \delta_2 - g_{Q_2}}{1 - \alpha\hat{r} + \delta_2 - g_{Q_2}}}
\]
Implied moments for $\alpha = 0.32$

**TFP growth ($g_z$)**

- Measured TFP growth (pre-97)
- Measured TFP growth (post-97)

**Markup ($\mu$)**

- $g_{Q_2} = 0\%$
- $g_{Q_2} = 1\%$
- $g_{Q_2} = 2\%$

**Measured/Actual GDP ($b$)**

- $b = 1.05$
- $b = 1.00$
- $b = 0.95$
- $b = 0.90$
An alternative source for omitted capital prices


Industry classification does not exactly match IO tables

substantially more detail for certain commodities (e.g. consumer products)

missing commodities/services (e.g. Management of Companies)

Matching commodities/services, corr. w/ IO tables deflators is high but not perfect
## Commodities or services with the largest GDP adjustments, 1997-2018

<table>
<thead>
<tr>
<th></th>
<th>$\hat{b}$</th>
<th>$g_{Q_2}$ (VA)</th>
<th>$g_{Q_2}$ (GO)</th>
<th>$g_{Q_3}$ (BLS)</th>
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<td>0.973</td>
<td>0.010</td>
<td>0.008</td>
<td>-0.016</td>
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<tr>
<td>Management of companies and enterprises</td>
<td>0.974</td>
<td>0.014</td>
<td>0.007</td>
<td>n.a.</td>
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<td><strong>Commodities</strong></td>
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## Implied moments for the different price indices

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</tr>
<tr>
<td>No adjustment, no markups</td>
<td>0.86</td>
<td>1.00</td>
<td>0</td>
<td>0.86</td>
</tr>
<tr>
<td>No adjustment, markups</td>
<td>0.95</td>
<td>1.06</td>
<td>0</td>
<td>0.95</td>
</tr>
<tr>
<td>Adjusted for Prof. services</td>
<td>1.04</td>
<td>1.13</td>
<td>0.25</td>
<td>1.02</td>
</tr>
<tr>
<td>Adjusted for Prof. services + Admin.</td>
<td>1.08</td>
<td>1.17</td>
<td>0.40</td>
<td>1.04</td>
</tr>
<tr>
<td>Adjusted for Org. capital (Compustat)</td>
<td>1.08</td>
<td>1.16</td>
<td>0.38</td>
<td>1.04</td>
</tr>
</tbody>
</table>
## Price deflators in the IO tables vs. BLS PPI deflators

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$g_{Q_2}^{(BLS)}$</td>
<td>0.97***</td>
<td>0.97***</td>
<td>1.04***</td>
<td>1.05***</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(0.18)</td>
<td>(0.17)</td>
<td>(0.18)</td>
</tr>
<tr>
<td>Commodity/service FE</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Year FE</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Clustering of s.e.</td>
<td>commodity + year</td>
<td>commodity + year</td>
<td>commodity + year</td>
<td>commodity + year</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.603</td>
<td>0.633</td>
<td>0.643</td>
<td>0.673</td>
</tr>
<tr>
<td>$N$</td>
<td>829</td>
<td>829</td>
<td>829</td>
<td>829</td>
</tr>
</tbody>
</table>
Implied moments for $\alpha = 0.36$

**TFP growth ($g_z$)**
- Measured TFP growth (pre-97)
- Measured TFP growth (post-97)

**Markup ($\mu$)**
- $g_{Q_z} = 0\%$
- $g_{Q_z} = 1\%$
- $g_{Q_z} = 2\%$

**Measured/Actual GDP ($\theta$)**
Implied TFP growth for alternative values of $\delta_2$

<table>
<thead>
<tr>
<th>$\delta_2$</th>
<th>Implied TFP growth, $g_Z$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>1.15</td>
</tr>
<tr>
<td>0.10</td>
<td>1.14</td>
</tr>
<tr>
<td>0.15</td>
<td>1.13</td>
</tr>
<tr>
<td>0.20</td>
<td>1.12</td>
</tr>
<tr>
<td>0.25</td>
<td>1.11</td>
</tr>
<tr>
<td>0.30</td>
<td>1.10</td>
</tr>
<tr>
<td>0.35</td>
<td>1.09</td>
</tr>
<tr>
<td>0.40</td>
<td>1.08</td>
</tr>
</tbody>
</table>

Implied TFP growth at baseline ($\delta_2=0.20$)
Approach 1: methodology and data

Methodology : for intang investment $B$ misclassified as intermediates:

1. Compute $\hat{b} = \frac{\text{Unadjusted GDP}}{\text{Adjusted GDP}} = \frac{\hat{P}\hat{Y}}{\hat{P}\hat{Y} + B}$

2. From model, obtain $g_{Q2}$ such that:

   $b = \hat{b}$
   $g_{Z} = \text{pre-97 measured TFP growth} = 1.36\%$
   $\hat{g}_{Z} = \text{post-97 measured TFP growth} = 0.86\%$

Data : Commodity Use tables, 1997-2018: 61 different commodities and services.

   $B_{j} = \text{total intermediate use of commodity/service } j \rightarrow \hat{b}_{j}$
## Approach 1: 10 largest GDP adjustments

\( \hat{b}_j \) (average, 1997-2018)

<table>
<thead>
<tr>
<th>Services</th>
<th>( \hat{b}_j )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional, scientific, and technical services</td>
<td>0.940</td>
</tr>
<tr>
<td>Other real estate</td>
<td>0.952</td>
</tr>
<tr>
<td>Administrative and support services</td>
<td>0.964</td>
</tr>
<tr>
<td>Insurance carriers and related activities</td>
<td>0.972</td>
</tr>
<tr>
<td>Credit intermediation and related activities</td>
<td>0.973</td>
</tr>
<tr>
<td>Management of companies and enterprises</td>
<td>0.974</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Commodities</th>
<th>( \hat{b}_j )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical products</td>
<td>0.962</td>
</tr>
<tr>
<td>Oil and gas extraction</td>
<td>0.972</td>
</tr>
<tr>
<td>Petroleum and coal products</td>
<td>0.973</td>
</tr>
<tr>
<td>Food and beverage and tobacco products</td>
<td>0.976</td>
</tr>
</tbody>
</table>
## Approach 1: results

<table>
<thead>
<tr>
<th>Service groups</th>
<th>Average, 1997-2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prof. services</td>
<td>( \hat{b} )</td>
</tr>
<tr>
<td>Prof. services + Manag.</td>
<td>0.94</td>
</tr>
<tr>
<td>Prof. services + Manag. + Admin.</td>
<td>0.89</td>
</tr>
</tbody>
</table>
## Approach 1: results

### Average, 1997-2018

<table>
<thead>
<tr>
<th>Service groups</th>
<th>$\hat{b}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prof. services</td>
<td>0.94</td>
</tr>
<tr>
<td>Prof. services + Manag.</td>
<td>0.92</td>
</tr>
<tr>
<td>Prof. services + Manag. + Admin.</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Are these magnitudes realistic?
## Approach 1: results

<table>
<thead>
<tr>
<th>Service groups</th>
<th>Average, 1997-2018</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\hat{b}$</td>
</tr>
<tr>
<td>Prof. services</td>
<td>0.94</td>
</tr>
<tr>
<td>Prof. services + Manag.</td>
<td>0.92</td>
</tr>
<tr>
<td>Prof. services + Manag. + Admin.</td>
<td>0.89</td>
</tr>
</tbody>
</table>
Approach 1: solution for $g_{Q_2}$

The unique price growth satisfying these conditions is given by:

$$g_{Q_2} = \frac{1}{2} \left( r + \delta_2 + \hat{g} - \hat{g}_K + \hat{\xi} - \sqrt{\left( \hat{\xi} + (\hat{r} - \hat{g} - (\hat{g}_K + \delta_2)) \right)^2 + 4(\hat{r} - \hat{g})(\hat{g}_K + \delta_2)} \right),$$

$$\hat{\xi} = \frac{\hat{s}_L \hat{b}}{(1 - \hat{b})(1 - \alpha)} \left[ g_Z - (\hat{g} - (1 - \alpha)\hat{g}_L - \alpha \hat{g}_K) \right].$$

When $\hat{b} = 0$, $g_{Q_2} = \hat{g} - \hat{g}_K = g_{Q_1}$. 
### Pre vs. post-97: 10 largest GDP adjustments

\[ \hat{b} \text{ (average)} \]

<table>
<thead>
<tr>
<th></th>
<th>1947-1996</th>
<th>1997-2018</th>
<th>( \Delta \hat{b} )</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Services</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prof., scient. &amp; techn. services</td>
<td>0.955</td>
<td>0.921</td>
<td>-0.033***</td>
<td>-15.40</td>
</tr>
<tr>
<td>Finance and Insurance</td>
<td>0.957</td>
<td>0.929</td>
<td>-0.028***</td>
<td>-13.72</td>
</tr>
<tr>
<td>Real estate</td>
<td>0.973</td>
<td>0.952</td>
<td>-0.021***</td>
<td>-13.15</td>
</tr>
<tr>
<td>Admin. and waste services</td>
<td>0.984</td>
<td>0.959</td>
<td>-0.025***</td>
<td>-13.84</td>
</tr>
<tr>
<td>Information</td>
<td>0.979</td>
<td>0.967</td>
<td>-0.013***</td>
<td>-9.89</td>
</tr>
<tr>
<td>Management of companies</td>
<td>0.981</td>
<td>0.974</td>
<td>-0.007***</td>
<td>-17.60</td>
</tr>
<tr>
<td><strong>Commodities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical products</td>
<td>0.966</td>
<td>0.962</td>
<td>-0.004***</td>
<td>-9.89</td>
</tr>
<tr>
<td>Oil and gas extraction</td>
<td>0.978</td>
<td>0.972</td>
<td>-0.007**</td>
<td>-2.78</td>
</tr>
<tr>
<td>Petroleum and coal products</td>
<td>0.980</td>
<td>0.973</td>
<td>-0.007***</td>
<td>-3.48</td>
</tr>
<tr>
<td>Food, beverage, tobacco</td>
<td>0.956</td>
<td>0.976</td>
<td>0.020***</td>
<td>6.07</td>
</tr>
<tr>
<td><strong>All commodities and services</strong></td>
<td>0.982</td>
<td>0.983</td>
<td>0.001</td>
<td>1.25</td>
</tr>
</tbody>
</table>

* : \( p < 0.05 \), ** : \( p < 0.01 \), *** : \( p < 0.001 \).
Pre vs. post-97: detailed results

<table>
<thead>
<tr>
<th></th>
<th>1997-2018</th>
<th></th>
<th></th>
<th>1947-1996</th>
<th></th>
<th></th>
<th>∆g Z (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ˆgQ₂ (%)</td>
<td>gZ (%)</td>
<td>μ</td>
<td>η</td>
<td>ˆgQ₂ (%)</td>
<td>gZ (%)</td>
<td>μ</td>
</tr>
<tr>
<td>No adj., no markups</td>
<td>0</td>
<td>0.86</td>
<td>1.00</td>
<td>0</td>
<td>0</td>
<td>1.36</td>
<td>1.00</td>
</tr>
<tr>
<td>No adj., markups</td>
<td>0</td>
<td>0.95</td>
<td>1.06</td>
<td>0</td>
<td>0</td>
<td>1.36</td>
<td>1.00</td>
</tr>
<tr>
<td>Prof. serv.</td>
<td>0.49</td>
<td>1.07</td>
<td>1.15</td>
<td>0.33</td>
<td>0.49</td>
<td>1.40</td>
<td>1.05</td>
</tr>
<tr>
<td>Prof. serv.+Manag.</td>
<td>0.68</td>
<td>1.14</td>
<td>1.18</td>
<td>0.44</td>
<td>0.68</td>
<td>1.43</td>
<td>1.07</td>
</tr>
<tr>
<td>Prof. serv.+Manag.+Admin.</td>
<td>0.55</td>
<td>1.18</td>
<td>1.22</td>
<td>0.60</td>
<td>0.55</td>
<td>1.43</td>
<td>1.08</td>
</tr>
</tbody>
</table>

\[
\Delta g_Z = 1.18 - 1.43 = -25\text{bps (adj.)} \quad \text{vs.} \quad \Delta g_Z = 0.86 - 1.36 = -50\text{bps (unadj.)}
\]