Missing Growth from Creative Destruction

Philippe Aghion (LSE)   Antonin Bergeaud (PSE-BdF)
Timo Boppart (IIES)     Peter J. Klenow (Stanford)
Huiyu Li (FRB SF)\(^1\)

Bank of Italy Seminar, April 2018

\(^1\)DISCLAIMER: Opinions and conclusions herein are those of the authors and do not necessarily represent the views of the U.S. Census Bureau or the Federal Reserve System. All results have been reviewed to ensure that no confidential information is disclosed.
Creative Destruction (CD)

CD is a key source of growth in many models

- New producer of a product has higher quality or productivity, eclipsing incumbent producer
- See the survey by Aghion, Akcigit and Howitt (2014)

Does CD show up in measured growth?

- Standard measurement assumes new producers have same quality-adjusted price as products they replace
- But creative destruction $\Rightarrow$ new producers have lower quality-adjusted prices
IMPUTATION
Stylized Numerical Example

- 80% of items: 4% inflation (no innovation)
- 10% of items: −6% inflation (innovation w/o CD)
- 10% of items: −6% inflation (CD)
- True inflation = 2%, True growth = 2%
- Imputation for CD = $\frac{8}{9} \cdot 4\% + \frac{1}{9} \cdot (-6\%) = 2.9\%$
- Measured growth = 1.1%, Missing Growth = 0.9%
1. How much is U.S. growth understated, on average, because of imputation for creative destruction?

2. Has “missing growth” increased a lot in recent years?
Our Answers

1. How much is U.S. growth understated, on average, because of imputation for creative destruction?

   $\sim 0.6 \text{ ppt per year}$ between 1983–2013

2. Has “missing growth” increased a lot in recent years?

   No
Roadmap

Background: BLS imputation and previous lit

Model with exogenous innovation

- True growth
- Measured growth

Quantification with U.S. Census LBD

- Market share approach with plants
- Indirect inference on firms
BLS Procedures

CPI

▸ Boskin Commission (1996)


▸ Pakes (2003), Erickson and Pakes (2011)

▸ BLS Handbook of Methods (2015, ch. 17)

PPI

▸ Pakes (2003)

▸ BLS Handbook of Methods (2015, ch. 14)
Imputation in the CPI, 1988–2004

- ~ 4% monthly exit rate of items
- ~ 1/2 of the product substitutions “noncomparable”
- ~ 20% annual “true” exit rate
- Noncomparable item substitutions:
  - ~ 1/3 direct quality adjustments
  - ~ 2/3 linking or class-mean imputation
Imputation in the PPI

2.3% monthly exit rate (Nakamura & Steisson 2008)

Missing prices

*If no price report from a participating company has been received in a particular month, the change in the price of the associated item will, in general, be estimated by averaging the price changes for the other items within the same cell (i.e., for the same kind of products) for which price reports have been received.*

Relation to Boskin Commission

Focus of Boskin Commission:

Quality bias from incumbent own-product improvements

Focus of BLS quality adjustments:

Quality bias from incumbent own-product improvements

Our focus:

Quality bias from imputation in the event of CD
Broda and Weinstein (2010)

- Packaged consumer nondurables (< 4% of GDP)
  - Low rate of product turnover
- Assume BLS makes no quality adjustments

How we differ:

- Census LBD data 1983–2013
- All private nonfarm establishments (> 80% of GDP)
- Assume BLS captures quality improvements by incumbents on their own products
Erickson and Pakes (2011)

- BLS micro data + scanner data


- Digital cameras 2007–2009

- Falling prices induce exit

- Correct hedonics for this selection
ROADMAP

Model with exogenous innovation

- True growth
- Measured growth

Quantification with U.S. Census LBD

- Market share approach with plants
- Indirect inference on firms
Environment

Discrete time

Representative consumer with $C_t = Y_t$

Exogenous aggregate supply of labor $L_t$

$M_t$ units of money, with $M_t = P_t Y_t$
Production

Aggregate

\[ Y = \left[ \int_{0}^{N} \left[ q(j) y(j) \right]^{1-1/\sigma} dj \right]^{\frac{\sigma}{\sigma-1}} \]

Product level

\[ y(j) = l(j) \]
PRODUCT VS. PROCESS INNOVATION

If all innovation is process innovation:

- Unit prices fall with innovation
- Easier to measure growth from CD (at least in CPI)

Data: elasticity of unit prices wrt revenue $\approx 0$.

- e.g. Hottman, Redding and Weinstein (2015)

Consistent with product innovation.
# Types of Innovation

<table>
<thead>
<tr>
<th></th>
<th>Creative destruction</th>
<th>New varieties</th>
<th>Incumbents on own products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrival rate</td>
<td>$\lambda_d$</td>
<td>$\lambda_n$</td>
<td>$\lambda_i$</td>
</tr>
<tr>
<td>Step size $\frac{q_{t+1}(j)}{q_t(j)}$</td>
<td>$\gamma_d$</td>
<td>$\gamma_n$</td>
<td>$\gamma_i$</td>
</tr>
</tbody>
</table>
Market structure and pricing

Competitive final goods ($P_t$) and labor ($W_t/P_t$) markets

Monopolistic competition in market for intermediate goods:

$$p_t(j) = \mu \cdot W_t$$

- $\mu = \frac{\sigma}{\sigma - 1}$ when $\sigma > 1$
- $\mu$ determined by limit pricing when $\sigma = 1$
**True Inflation**

Price level

\[ P_t = \mu \cdot W_t \cdot \left( \int_0^{N_t} q_t(j)^{\sigma-1} \, dj \right)^{\frac{1}{1-\sigma}} \]

If the quality of new varieties is \( q_t(j) = \gamma_n \bar{q}_t \) then

\[ \frac{P_{t+1}}{P_t} = \frac{W_{t+1}}{W_t} \cdot \left[ 1 + \lambda_d \left( \gamma_d^{\sigma-1} - 1 \right) + (1 - \lambda_d) \lambda_i \left( \gamma_i^{\sigma-1} - 1 \right) + \lambda_n \gamma_n^{\sigma-1} \right] \]

CD

own innovation (OI)

new varieties (NV)
TRUE VS. MEASURED GROWTH

True

\[
\frac{Y_{t+1}}{Y_t} = \frac{M_{t+1}}{M_t} \frac{P_t}{P_{t+1}}
\]

Measured

\[
\left( \frac{Y_{t+1}}{Y_t} \right) = \frac{M_{t+1}}{M_t} \left( \frac{P_t}{P_{t+1}} \right)
\]

Missing growth \(\Leftrightarrow\) overstated inflation

\[
\log \frac{Y_{t+1}}{Y_t} - \log \left( \frac{Y_{t+1}}{Y_t} \right) = \log \left( \frac{P_{t+1}}{P_t} \right) - \log \frac{P_{t+1}}{P_t}
\]
True vs. Measured Growth

True growth

\[
\frac{Y_{t+1}}{Y_t} = \left[ 1 + \underbrace{\lambda_d (\gamma_d^{\sigma-1} - 1)}_{\text{CD}} + (1 - \lambda_d) \underbrace{\lambda_i (\gamma_i^{\sigma-1} - 1)}_{\text{OI}} + \underbrace{\lambda_n \gamma_n^{\sigma-1}}_{\text{NV}} \right]^{\frac{1}{\sigma-1}}
\]

Measured growth

\[
\frac{\widehat{Y}_{t+1}}{Y_t} = \left[ 1 + \widehat{\lambda}_i (\widehat{\gamma}_i^{\sigma-1} - 1) \right]^{\frac{1}{\sigma-1}}
\]
Cobb-Douglas case

True growth

\[ \lambda_d \cdot \log \gamma_d \ + \ (1 - \lambda_d) \cdot \lambda_i \cdot \log \gamma_i \]

Measured growth

\[ \underbrace{\lambda_d \ \hat{\lambda}_i \ \log \hat{\gamma}_i} \ + \ \underbrace{(1 - \lambda_d) \ \hat{\lambda}_i \ \log \hat{\gamma}_i} \ = \ \hat{\lambda}_i \ \log \hat{\gamma}_i \]

imputation for CD  incumbent innovation
**Cobb-Douglas Case**

Missing growth:

$$\lambda_d \left( \log \gamma_d - \hat{\lambda}_i \log \hat{\gamma}_i \right) + (1 - \lambda_d) \left( \lambda_i \log \gamma_i - \hat{\lambda}_i \log \hat{\gamma}_i \right)$$

- CD bias
- Quality bias
**Cobb-Douglas case**

Sources of bias from CD:

\[ \lambda_d \left( 1 - \hat{\lambda}_i \right) \log \hat{\gamma}_i + \lambda_d \left( \log \gamma_d - \log \hat{\gamma}_i \right) \]

- not all incumbents innovate
- different stepsize for CD

Understated growth from CD:

- even if CD and own-innovation have the same step size
- but exacerbated by lower \( \hat{\lambda}_i \) and any quality bias
Roadmap

Model with exogenous innovation

▶ True growth
▶ Measured growth

Quantification with U.S. Census LBD

▶ Market share approach with plants
▶ Indirect inference on firms
Roadmap

Model with exogenous innovation

- True growth
- Measured growth

Quantification with U.S. Census LBD

- Market share approach with plants
- Indirect inference on firms
Relative prices ⇔ market shares

CES ⇒ market share isoelastic with respect to price

\[ \text{Missing Growth} = \frac{Y_{t+1}}{Y_t} = \frac{P_{t+1}^S}{P_{t+1}} = \left( \frac{S_{I_t,t+1}}{S_{I_t,t}} \right)^{\frac{1}{1-\sigma}} \]

\( S_{I_t,t} \) = market share in \( t \) of all goods sold in both \( t \) and \( t + 1 \)

\( S_{I_t,t+1} \) = market share in \( t + 1 \) of all goods sold in \( t \) & \( t + 1 \)

Shrinking share of non-CD goods ⇒ missing growth
**GOING FROM MODEL TO DATA**

IF existing plants carry out OI but not CD or NV:

\[
\text{Missing Growth} = \frac{Y_{t+1}}{Y_t} = \frac{P_{t+1}^S}{P_{t+1}} = \left( \frac{S_{I_{t,t+1}}}{S_{I_{t,t}}} \right)^{\frac{1}{1-\sigma}}
\]

\(S_{I_{t,t}} = \text{market share in } t \text{ of all establishments operating in both } t \text{ and } t + 1\)

\(S_{I_{t,t+1}} = \text{market share in } t + 1 \text{ of all establishments operating in both } t \text{ and } t + 1\)
U.S. Census Data

- Longitudinal Business Database (LBD)

- all nonfarm private sector plants

- employment, wage bill, firm, industry

- results for 1983–2013
Some details

Use employment share; plant-level revenue is not available

In Census of Mfg, bigger MG with rev. than emp.

“Entrants” = plants who are 5 years old

σ = 4 based on Hottman, Redding and Weinstein (2016)
## Missing Growth Implied by Survivor Market Shares

<table>
<thead>
<tr>
<th>Period</th>
<th>% Points per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983–2013</td>
<td>0.64</td>
</tr>
<tr>
<td>1983–1995</td>
<td>0.66</td>
</tr>
<tr>
<td>1996–2005</td>
<td>0.55</td>
</tr>
<tr>
<td>2006–2013</td>
<td>0.74</td>
</tr>
</tbody>
</table>
### Measured vs. True Growth

<table>
<thead>
<tr>
<th>Period</th>
<th>Measured</th>
<th>“True”</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983–2013</td>
<td>1.87</td>
<td>2.51</td>
</tr>
<tr>
<td>1983–1995</td>
<td>1.80</td>
<td>2.46</td>
</tr>
<tr>
<td>1996–2005</td>
<td>2.68</td>
<td>3.23</td>
</tr>
<tr>
<td>2006–2013</td>
<td>0.98</td>
<td>1.72</td>
</tr>
</tbody>
</table>
## Robustness Checks

<table>
<thead>
<tr>
<th></th>
<th>Lower $\sigma = 3$</th>
<th>Baseline $\sigma = 4$</th>
<th>Higher $\sigma = 5$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1983–2013</strong></td>
<td>0.96</td>
<td>0.64</td>
<td>0.48</td>
</tr>
<tr>
<td><strong>Employment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Payroll</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1989–2013</strong></td>
<td>0.70</td>
<td>0.72</td>
<td></td>
</tr>
</tbody>
</table>
Missing Growth:
1 Sector vs. Weighted Sectors

<table>
<thead>
<tr>
<th>Year</th>
<th>1-sector</th>
<th>2-digit</th>
<th>3-digit</th>
<th>4-digit</th>
<th>5-digit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983–2013</td>
<td>0.64</td>
<td>0.64</td>
<td>0.66</td>
<td>0.74</td>
<td>0.77</td>
</tr>
</tbody>
</table>

And still no surge in missing growth
CONTRIBUTION TO MISSING GROWTH

1. Retail Trade 17.6%
2. Restaurants & Hotels 17.4%
3. Health Care 16.0%
4. Admin support services 12.2%
5. Professional services 8.1%

15. Manufacturing 1.1%
### Missing Growth vs. Declining Dynamism

<table>
<thead>
<tr>
<th></th>
<th>Plants</th>
<th>Firms</th>
<th>Net Entry</th>
<th>Gross Entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983–1995</td>
<td>0.66</td>
<td>0.33</td>
<td>0.54</td>
<td>0.70</td>
</tr>
<tr>
<td>1996–2005</td>
<td>0.55</td>
<td>0.17</td>
<td>0.40</td>
<td>0.06</td>
</tr>
<tr>
<td>2006–2013</td>
<td>0.74</td>
<td>0.09</td>
<td>0.06</td>
<td>-0.49</td>
</tr>
</tbody>
</table>

Net Entry assumes equal-sized firms

Gross Entry assumes equal-sized firms and a fixed exit rate
Roadmap

Model with exogenous innovation

- True growth
- Measured growth

Quantification with U.S. Census LBD

- Market share approach with plants
- Indirect inference on firms
**Indirect inference on firms**

Key advantage:

- Need not assume CD and NV come from new plants
- Bernard, Redding and Schott (2010) find that manufacturing plants do add SIC’s

We extend Garcia-Macia, Hsieh and Klenow (2016)

- Infer arrival rates and step sizes to fit employment dynamics in LBD firms
LBD Facts to Fit by Year

- Growth in the number of firms (tied to NV)

- Employment share of young firms (tied to NV, CD)

- Distribution of employment growth across firms
  - Job creation and destruction rates
    - CD shows up in the tails
    - OI shows up in the middle
Job Creation and Destruction
Employment: young vs. old firms

- **Age < 5**
  - 1981: [chart value]
  - 2008: [chart value]

- **Age 5+**
  - 1981: [chart value]
  - 2008: [chart value]
EXIT BY SIZE

The graph shows the exit rate (%) as a function of the number of employees for two different time periods: 1976-1986 (solid line) and 2003-2013 (dashed line). The exit rate decreases as the number of employees increases, with the 2003-2013 period generally having a lower exit rate compared to 1976-1986.
HOW WE DEVIATE FROM GHK

- GHK assume measured growth = true growth

- 1) We argue CD and NV are missed;
   2) Set the combined arrival rates of CD and OI to match the CPI’s noncomparable substitution rate

- We infer more true growth, higher step sizes
## Indirect Inference

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CD arrival</td>
<td>0.014</td>
<td>0.011</td>
<td>0.010</td>
</tr>
<tr>
<td>OI arrival</td>
<td>0.024</td>
<td>0.027</td>
<td>0.027</td>
</tr>
<tr>
<td>NV arrival</td>
<td>0.004</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>Step size of CD, OI</td>
<td>1.106</td>
<td>1.125</td>
<td>1.074</td>
</tr>
<tr>
<td>Step size of NV</td>
<td>0.328</td>
<td>0.482</td>
<td>0.366</td>
</tr>
</tbody>
</table>

Note: These arrival rates are bimonthly.
Missing growth from indirect inference

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing growth (ppt)</td>
<td>1.25</td>
<td>1.13</td>
<td>0.60</td>
</tr>
<tr>
<td>% of MG from CD</td>
<td>79%</td>
<td>80%</td>
<td>81%</td>
</tr>
<tr>
<td>% of growth missed</td>
<td>43%</td>
<td>33%</td>
<td>31%</td>
</tr>
</tbody>
</table>
Conclusions

Missing growth from CD and new varieties:

- at least 0.6% per year, mostly from CD

At least one-fourth of true growth is missed

No surge in missing growth since 2005
Why do we care?

1. Relating growth to policy

2. Gauging the proportional decline in growth / whether ideas are getting harder to find (Gordon, Jones)

3. Assessing how many people are better off than their parents (Chetty et al.’s Fading American Dream)

4. Setting the Fed’s inflation target

5. Indexing Social Security and tax brackets