Missing Growth from Creative Destruction

Philippe Aghion (LSE) Antonin Bergeaud (LSE)

Timo Boppart (IIES) Peter J. Klenow (Stanford)

Huiyu Li (FRB SF) [1]

January 17, 2017

[1]DISCLAIMER: Opinions and conclusions herein are those of the authors and do not necessarily represent the views of the Federal Reserve System or the U.S. Census Bureau. 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 producers of a product have higher quality and/or productivity, eclipsing competing incumbent products
- See the survey by Aghion, Akcigit and Howitt (2014)

Does CD show up in <u>measured</u> growth?

- standard measurement assumes new producers have same quality-adjusted price as producers they replace
- but creative destruction $\Rightarrow$ new producers have a *lower* quality-adjusted price

Our Questions

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

2. Has such "missing growth" increased in recent years?

Competing views on growth

Grounds for despair:

- Declining TFP growth recently (BLS)
- Declining business dynamism (Decker et al.)
- Running out of ideas (Gordon; Bloom et al.)

Reasons for hope:

- Surging patents (USPTO)
- IT revolution may not be well-captured
  - Varian, Byrne/Oliner/Sichel, Byrne/Kovak/Michaels

Annual TFP Growth

1980–2015	1.45
1980–1995	1.04
1996–2005	2.65
2006–2015	0.89

Source: BLS MFP series + R&D contribution; labor-augmenting

Why does standard measurement miss growth through CD?

Monthly exit rates of products in the sample:

3.4% in the CPI (Bils and Klenow, 2004)

2.3% in the PPI (Nakamura and Steinsson, 2008)

Imputation is the norm when the producer changes

Assumes same inflation as for surviving products

U.S. CPI and PPI Practices

CPI:

- GAO Report (1999)
- Klenow (2002), Bils (2009)
- BLS Handbook of Methods (2015, ch. 17)

PPI:

- BLS Handbook of Methods (2015, ch. 14)

Imputation in the CPI

Noncomparable item substitutions in 1997:

- 1/3 direct quality adjustments
- 1/3 linking to inflation of all items in the category
- 1/3 mean-class imputation to comparable substitutions and direct quality adjustments in the category

Direct quality adjustments largely apply to incumbent innovation on their own products.

If comparable substitutions involve no innovation, mean-class imputation is very close to linking.

Upshot: Imputation in virtually all cases likely to be CD.

Imputation in the PPI

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.

– BLS Handbook of Methods (2015, ch. 14, p. 10)

Estimates of missing growth

	Coverage	Focus
Bils & Klenow (2001) Bils (2009)	Consumer durables	Average bias
Broda & Weinstein (2010)	Consumer nondurables	Average bias
Syverson (2016) Byrne/Fernald/Reinsdorf (2016)	ICT	Change in bias
Our paper	All sectors	Both

Broda and Weinstein (2010)

- AC Nielsen Scanner data 1994, 1999–2003
- Packaged consumer nondurables ($\sim$ 6% of GDP)
  - Low rate of product exit in the CPI
- Assume BLS makes no quality adjustments

How we differ from them:

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

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

$\boxed{\text{Model with innovation}}$

- 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 $M_t = P_t Y_t$

Technology

Aggregate output

$$Y = \left[\int_0^N \left[\, q(j)\, y(j) \,\right]^{\frac{\sigma-1}{\sigma}} dj \right]^{\frac{\sigma}{\sigma-1}}$$

Product-level output

$$y(j) = l(j)$$

Product vs. process innovation

If all innovation is process innovation:

- Unit prices fall with innovation
- Might be easy to measure growth from CD

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

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

Consistent with product innovation.

Types of Innovation

	Creative destruction	New varieties	Incumbents on own products
Arrival rate	λ_d	λ_n	λ_i
Step size $\frac{q_{t+1}(j)}{q_t(j)}$	γ_d	γ_n	γ_i

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 $\sigma > 1$
- μ determined by limit pricing when $\sigma = 1$

True vs. Measured Growth

True
$$\frac{Y_{t+1}}{Y_t} = \frac{M_{t+1}}{M_t}\frac{P_t}{P_{t+1}}$$

Measured
$$\widehat{\left(\frac{Y_{t+1}}{Y_t}\right)} = \frac{M_{t+1}}{M_t}\widehat{\left(\frac{P_t}{P_{t+1}}\right)}$$

Missing growth $\Leftrightarrow$ overstated inflation

$$\log\frac{Y_{t+1}}{Y_t} - \log\widehat{\left(\frac{Y_{t+1}}{Y_t}\right)} = \log\widehat{\left(\frac{P_{t+1}}{P_t}\right)} - \log\frac{P_{t+1}}{P_t}$$

U.S. Inflation measurement

Brand new varieties

- rotated into the sample with a lag of 1-4 years
- no attempt to measure surplus from them

Products that are creatively destroyed

- standard treatment is <u>imputation</u>
- plugs in inflation for surviving products

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

$$\frac{P_{t+1}}{P_t} = \frac{W_{t+1}}{W_t} \cdot$$

$$\Bigg[\underbrace{1 + \lambda_d \left(\gamma_d^{\sigma-1} - 1 \right)}_{\text{CD}} + \underbrace{(1-\lambda_d)\lambda_i \left(\gamma_i^{\sigma-1} - 1 \right)}_{\text{own innovation}} + \underbrace{\lambda_n \gamma_n^{\sigma-1}}_{\text{new varieties}} \Bigg]^{\frac{1}{1-\sigma}}$$

Missing Growth

Measured inflation

$$\widehat{\left(\frac{P_{t+1}}{P_t}\right)} = \left(\frac{W_{t+1}}{W_t}\right)\left[1 + \hat{\lambda}_i\left(\hat{\gamma}_i^{\sigma-1} - 1\right)\right]^{\frac{1}{1-\sigma}}$$

When $\hat{\lambda}_i = \lambda_i$ and $\hat{\gamma}_i = \gamma_i$, missing growth is

$$\text{MG} = \frac{1}{\sigma-1}\log\left(1 + \frac{\lambda_d\left[\gamma_d^{\sigma-1} - 1 - \lambda_i\left(\gamma_i^{\sigma-1} - 1\right)\right] + \lambda_n\gamma_n^{\sigma-1}}{1 + \lambda_i\left(\gamma_i^{\sigma-1} - 1\right)}\right)$$

Cobb-Douglas case

True growth

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

Measured growth

$$\underbrace{(1-\lambda_d)\,\hat{\lambda}_i\;\log\hat{\gamma}_i}_{\text{incumbent innovation}}\quad+\quad\underbrace{\lambda_d\;\hat{\lambda}_i\;\log\hat{\gamma}_i}_{\text{imputation for CD}}\quad=\quad\hat{\lambda}_i\log\hat{\gamma}_i$$

Cobb-Douglas case

Missing growth

$$\underbrace{(1-\lambda_d)(\lambda_i \log \gamma_i - \hat{\lambda}_i \log \hat{\gamma}_i)}_{\text{quality bias}} \quad + \quad \underbrace{\lambda_d(\log \gamma_d - \hat{\lambda}_i \log \hat{\gamma}_i)}_{\text{CD bias}}$$

Missing growth is increasing in

- λ_d, γ_d
- $\gamma_i - \hat{\gamma}_i$, $\lambda_i - \hat{\lambda}_i$

Cobb-Douglas case

Sources of bias from CD:

$$\underbrace{\lambda_d\,(1-\hat{\lambda}_i)\log\hat{\gamma}_i}_{\text{not all incumbents innovate}} \quad + \quad \underbrace{\lambda_d\,(\log\gamma_d - \log\hat{\gamma}_i)}_{\text{different stepsize for CD}}$$

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

Cobb-Douglas case

Sources of bias from CD:

$$\underbrace{\lambda_d\,(1-\hat{\lambda}_i)\log\hat{\gamma}_i}_{\text{not all incumbents innovate}} \quad + \quad \underbrace{\lambda_d\,(\log\gamma_d-\log\hat{\gamma}_i)}_{\text{different stepsize for CD}}$$

Numerical example:

- same step sizes for CD and OI
- OI of survivors and CD arrive at rate 10%
- measured growth $= \hat{\lambda}_i \log\hat{\gamma}_i = 1\% \rightarrow \log\hat{\gamma}_i = 10\%$
- missing growth from CD $= 10\% \cdot 90\% \cdot 10\% = 0.9\%$

Roadmap

Model with innovation

- True growth
- Measured growth

$\boxed{\text{Quantification with U.S. Census LBD}}$

- Market share approach with plants
- Indirect inference on firms

What we aim to quantify

Our focus is missing growth due to

- Creative Destruction (CD)
- New varieties (NV) if necessary

We assume Own Innovation (OI) is measured well

- Conservative (miss more growth from CD otherwise)

U.S. Census Data

- Longitudinal Business Database (LBD)
- results for 1983–2013
- all nonfarm private sector plants
- employment, wage bill, firm, industry

Roadmap

Model with innovation

- True growth
- Measured growth

Quantification with U.S. Census LBD

- $\boxed{\text{Market share approach with plants}}$
- Indirect inference on firms

Market Share of Survivors

$$\frac{\frac{Y_{t+1}}{Y_t}}{\widehat{\frac{Y_{t+1}}{Y_t}}} = \left(\frac{s_{I_t,t}}{s_{I_t,t+1}}\right)^{\frac{1}{\sigma-1}}$$

$s_{I_t,t}$ = market share in t of all establishments operating in both t and $t+1$

$s_{I_t,t+1}$ = market share in $t+1$ of all establishments operating in both t and $t+1$

Market Share Intuition

$$\frac{\frac{Y_{t+1}}{Y_t}}{\widehat{\frac{Y_{t+1}}{Y_t}}} = \left(\frac{s_{I_t,t}}{s_{I_t,t+1}}\right)^{\frac{1}{\sigma-1}}$$

Falling survivor market share $\Rightarrow$ BLS imputes too much inflation to entrants $\Rightarrow$ missing growth

Assumes that CD and NV come from new establishments

Allowing entrants to mature

Young plants may take time to

- Build capital
- Hire and train workers
- Accumulate customers

We thus define plants who are 5 years old as “entrants”

- In the LBD, employment growth is higher than average for the first 5 years of plant life

Dropping Plants $\leq$ 5 years

Growth of survivors' employment share

$$\left(\frac{L(t, B \leq t, D \geq t+1)}{L(t, B \leq t, D \geq t+1) + L(t, B \leq t, D = t)}\right) \Big/ \left(\frac{L(t+1, B \leq t, D \geq t+1)}{L(t+1, B \leq t, D \geq t+1) + L(t+1, B = t+1, D \geq t+1)}\right)$$

- B = year of "birth" (first year in the dataset + 5)
- D = year of exit (last year in the dataset)

Choice of σ

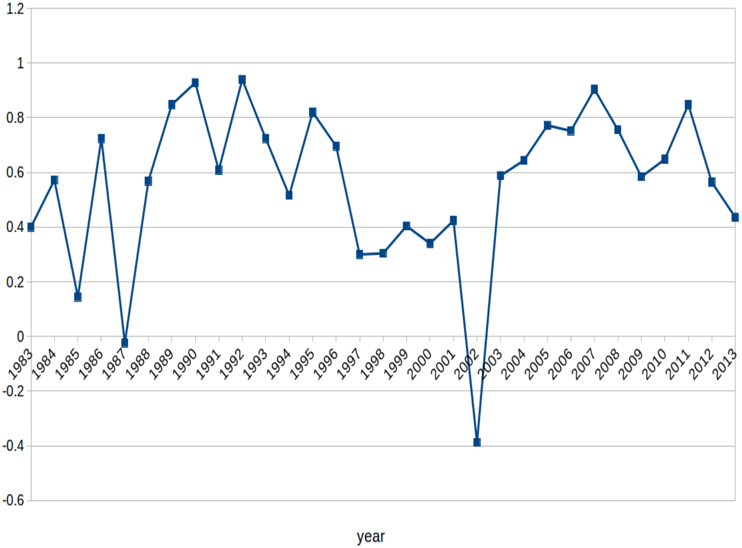
Missing Growth is decreasing in σ:

- Less love of variety
- Need less CD to explain shrinking survivor share

We choose $\sigma = 4$ as our baseline value:

- Redding and Weinstein (2016)
- Hottman, Redding and Weinstein (2016)

Missing Growth (ppt)



Missing Growth Implied by Survivor Market Shares

% points per year with $\sigma = 4$

1983–2013	0.56
1983–1995	0.60
1996–2005	0.41
2006–2013	0.69

Measured vs. True Growth

% points per year

	Measured	"True"
1984–2013	1.93	2.49
1984–1995	2.01	2.61
1996–2005	2.65	3.06
2006–2013	0.90	1.59

Missing Growth with Payroll

	Employment	Payroll
1989–2013	0.60	0.69
1989–1995	0.77	0.97
1996–2005	0.41	0.38
2006–2013	0.69	0.83

Missing Growth: Manufacturing vs. Rest

	Mfg.	Non-Mfg.
1983–2013	0.03	0.67
1983–1995	0.23	0.71
1996–2005	-0.13	0.51
2006–2013	-0.07	0.79

Missing Growth: New Plants vs. New Firms

	New Plants	New Firms
1983–2013	0.56	0.08
1983–1995	0.60	0.29
1996–2005	0.41	-0.03
2006–2013	0.69	-0.14

Missing Growth: different lags

	5 year old plants	3 year old plants	0 year old plants
1983–2013	0.56	0.47	0.20
1983–1995	0.60	0.54	0.28
1996–2005	0.41	0.38	0.20
2006–2013	0.69	0.46	0.07

Missing Growth vs. Declining Dynamism

1. Establishments vs. firms

2. Net entry vs. gross entry

3. 5-year lag vs. year entered

Revenue vs. Employment

The market share approach requires plant-level data.

Revenue is not available at the plant level in the LBD.

- Revenue is only available at the firm level in the LBD.

The Census of Manufacturing has plant-level revenue.

- Survivor market share shrinks more with revenue than with employment $\Rightarrow$ more missing growth.

Roadmap

Model with innovation

- True growth
- Measured growth

Quantification with U.S. Census LBD

- Market share approach with plants
- Indirect inference on firms

Why Indirect Inference?

Key advantage:

Need not assume CD and NV come from new plants

Follow Garcia-Macia, Hsieh, and Klenow (2016)

Employment dynamics in LBD firms

Infer arrival rates and step sizes

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

How we deviate from GHK

- GHK assume measured growth = true growth
- We argue that CD and NV are missed
- Our indirect inference differs as a result
- We estimate MG of 1.1% per year
  - 0.08% from NV
  - 1.02% from CD

Missing growth (ppt) from indirect inference

	$\sigma = 4$	1 plant = 1 variety
1976-1986	0.91	0.46*
from CD	0.85	
2003-2013	1.29	0.68
from CD	1.19	

* average over 1983-1986.

Conclusions

Missing growth from CD and new varieties:

- $> 0.5\%$ per year using plant market shares
- $> 1\%$ per year using indirect inference on firms

One-fourth or one-half of true growth is missed

No slowdown in missing growth since 2005