Missing Growth from Creative Destruction

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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 measured 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

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 $= 0.9\%$

Our Questions

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

   $\sim$ **0.5 ppt per year** between 1983–2013

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

   No

Competing views on growth

Grounds for despair:

- Declining TFP growth recently (BLS)
- Declining business dynamism (Decker et al. 2014)
- Running out of ideas (Gordon 2016; Bloom et al. 2016)

Reasons for hope:

- Surging patents (USPTO)
- IT revolution may not be well-captured
  - Varian; Byrne, Oliner and Sichel (2013, 2015); Byrne, Kovak and Michaels (2015)

Annual TFP Growth

1980–2016	1.37
1980–1995	0.87
1996–2005	2.68
2006–2016	0.91

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

Product exit in the CPI and PPI

Monthly exit rates of products in the sample:

3.9% in the CPI (Klenow and Kryvtsov, 2008)

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

In the CPI from 1988–2004, 48% of the product substitutions were deemed "noncomparable"

- So 22.5% average annual "true" exit in the CPI

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 imputation
- plugs in inflation for surviving products

What we aim to quantify

Missing growth due to

- Creative Destruction (CD) – separately if we can
- New varieties (NV)

We assume Own Innovation (OI) is measured well

- Conservative (miss more growth from CD otherwise)

Boskin Commission (1996) focused on bias from OI and NV

U.S. CPI and PPI Practices

CPI

- Boskin Commission (1996)
- Moulton and Moses (1997), GAO Report (1999)
- Klenow (2002), Bils (2009)
- 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

Noncomparable item substitutions from 1988–2004:

- 31% direct quality adjustments
- 36% linking to inflation of all items in the category
- 32% mean-class imputation to category substitutions

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 $\sim 90\%$ of 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) Erickson & Pakes (2011)	Consumer durables	Average bias
Broda & Weinstein (2010) Redding & Weinstein (2016)	Consumer nondurables	Average bias
Byrne, Fernald & Reinsdorf (2016) Syverson (2016)	Mostly ICT	Change in bias
Groshen et al. (2017)	Health, ICT	Both
Our paper	All sectors	Both

Broda and Weinstein (2010)

- AC Nielsen Scanner data 1994, 1999–2003
- Packaged consumer nondurables ($< 4\%$ of GDP)
  - Low rate of product exit in the CPI
- 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
- Televisions 2000–2003, 2005–2006
- Digital cameras 2007–2009
- Falling prices induce exit
- Correct hedonics for this selection

Groshen, Moyer, Aizcorbe, Bradley and Friedman (2017)

- Focus on health, ICT
- Share of GDP in these sectors rose from 2000 to 2015
- Falling bias within each sector (BEA/BLS changes)
- Conclude bias stable at ~ 0.4 percent per year
- Ignores imputation in the CPI, PPI

Roadmap

Model with exogenous innovation

- True growth
- Measured growth

Quantification with U.S. Census LBD

- Market share approach with plants
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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

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

Product-level output

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

Product vs. process innovation

If all innovation is process innovation:

- Unit prices fall with innovation
- 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

	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

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

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

$$\frac{P_{t+1}}{P_t} = \frac{W_{t+1}}{W_t} \cdot \left[\underbrace{1 + \lambda_d \left(\gamma_d^{\sigma-1} - 1 \right)}_{\text{CD}} + \underbrace{(1-\lambda_d)\lambda_i \left(\gamma_i^{\sigma-1} - 1 \right)}_{\text{own innovation}} + \underbrace{\lambda_n \gamma_n^{\sigma-1}}_{\text{new varieties}} \right]^{\frac{1}{1-\sigma}}$$

Missing Growth

Measured inflation

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

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

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

Cobb-Douglas case

True growth

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

Measured growth

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

Cobb-Douglas case

Missing growth:

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

Missing growth is increasing in

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

Cobb-Douglas case

Sources of bias from CD:

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

Understated growth from CD:

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

What we aim to quantify

Missing growth due to

- Creative Destruction (CD) – separately if we can
- New varieties (NV)

We assume Own Innovation (OI) is measured well

- Conservative (miss more growth from CD otherwise)

Boskin Commission (1996) focused on bias from OI and NV

Quantifying missing growth

$$\frac{1}{\sigma-1}\left[\underbrace{\log\left(\frac{1+\lambda_i(\gamma_i^{\sigma-1}-1)}{1+\widehat{\lambda}_i(\widehat{\gamma}_i^{\sigma-1}-1)}\right)}_{\text{OI quality bias}}+\underbrace{\log\left(\frac{S_{I_t,t}}{S_{I_t,t+1}}\right)}_{\text{CD + NV bias}}\right]$$

$S_{I_t,t}$ = market share in t of goods sold in t and $t+1$

$S_{I_t,t+1}$ = market share in $t+1$ of goods sold in t and $t+1$

$\downarrow$ market share of surviving products $\Rightarrow$ missing growth

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RELATIVE PRICES $\Leftrightarrow$ MARKET SHARES

CES structure $\Rightarrow$ market share of a product is isoelastic with respect to prices

$$\frac{\frac{Y_{t+1}}{Y_t}}{\widehat{\frac{Y_{t+1}}{Y_t}}} = \frac{\widehat{\frac{P_{t+1}}{P_t}}}{\frac{P_{t+1}}{P_t}} = \frac{\frac{P^S_{t+1}}{P^S_t}}{\frac{P_{t+1}}{P_t}} = \left(\frac{S_{I_t,t}}{S_{I_t,t+1}}\right)^{\frac{1}{\sigma-1}}$$

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

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

Going from model to data

Strong assumptions:

- Existing plants carry out OI but not CD or NV
- All CD occurs through new plants
- All NV occurs through new plants

One product per plant is sufficient but not necessary.

Market Share: Surviving Plants

$$\frac{\frac{Y_{t+1}}{Y_t}}{\widehat{\frac{Y_{t+1}}{Y_t}}} = \frac{\widehat{\frac{P_{t+1}}{P_t}}}{\frac{P_{t+1}}{P_t}} = \frac{\frac{P^S_{t+1}}{P^S_t}}{\frac{P_{t+1}}{P_t}} = \left(\frac{S_{I_t,t}}{S_{I_t,t+1}}\right)^{\frac{1}{\sigma-1}}$$

$S_{I_t,t}$ = 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 $t+1$

U.S. Census Data

- Longitudinal Business Database (LBD)
- all nonfarm private sector plants
- employment, wage bill, firm, industry
- results for 1983–2013
  - drop 1976–1977 due to suspiciously high entry rates
  - allow 5 years for entrants to grow
  - 2013 is the latest year to which we have access

Summary Statistics: LBD plants

	Total Emp.	# of Estab.	Average Emp.	Emp. Growth
1976–1986	74.1 m	4.14 m	17.9	2.73%
2003–2013	114.3 m	6.36 m	18.0	0.70%

Summary Statistics: LBD firms

	# of Firms	Average Emp.	# of Estab. per Firm
1976–1986	3.30 m	22.4	1.25
2003–2013	4.77 m	24.0	1.33

Allowing entrants to mature

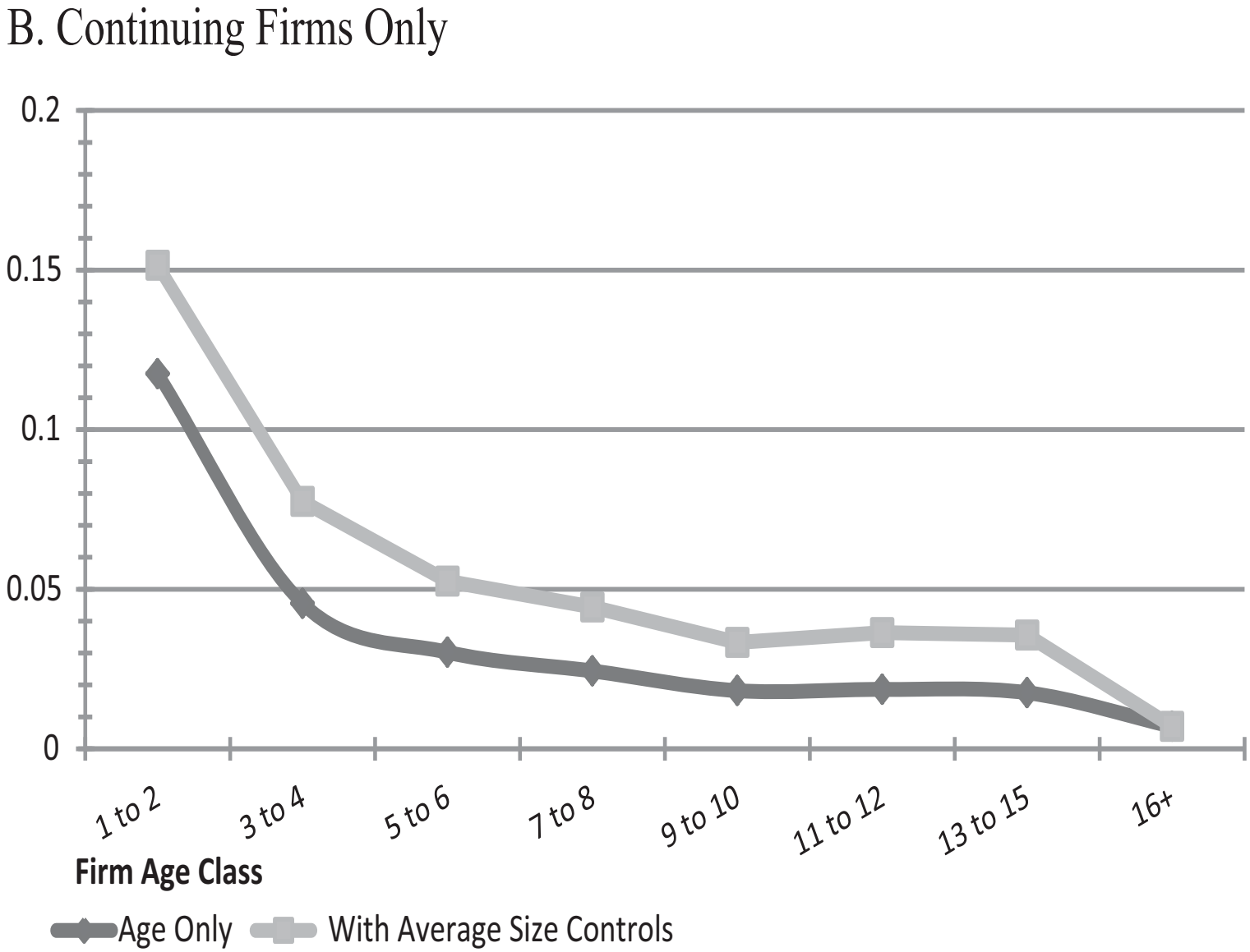
Young plants may take time to:

- 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

Growth of Young Firms



Dropping Plants $\leq$ 5 years

Growth of survivors' employment share

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

- 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 Implied by Survivor Market Shares

% points per year with $\sigma = 4$

1983–2013	0.64
1983–1995	0.66
1996–2005	0.55
2006–2013	0.74

Measured vs. True Growth

% points per year

	Measured	"True"
1983–2013	1.87	2.51
1983–1995	1.80	2.46
1996–2005	2.68	3.23
2006–2013	0.98	1.72

Missing Growth and σ

	Lower $\sigma = 3$	Baseline $\sigma = 4$	Higher $\sigma = 5$
1983–2013	**0.96**	**0.64**	**0.48**
1983–1995	0.99	0.66	0.44
1996–2005	0.82	0.55	0.37
2006–2013	1.11	0.74	0.49

Missing Growth: different lags

	5 year old plants	3 year old plants	0 year old plants
1983–2013	**0.64**	**0.56**	**0.22**
1983–1995	0.66	0.62	0.26
1996–2005	0.55	0.52	0.26
2006–2013	0.74	0.53	0.13

Missing Growth: New Plants vs. New Firms

	New Plants	New Firms
1983–2013	**0.64**	**0.22**
1983–1995	0.66	0.33
1996–2005	0.55	0.17
2006–2013	0.74	0.09

Missing Growth vs. Declining Dynamism

1. Establishments vs. firms
2. Size of entrants/exiters vs. surviving incumbents
3. Net entry vs. gross entry

Why Missing Growth did not fall

	Plants	Firms	Net Entry	Gross Entry
1983–1995	0.66	0.33	0.54	0.70
1996–2005	0.55	0.17	0.40	0.06
2006–2013	0.74	0.09	0.06	-0.49

Net Entry assumes equal-sized firms

Gross entry assumes equal-sized firms and a fixed exit rate

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

The Census of Manufacturing has plant-level revenue

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

Missing Growth by sector, 1983–2013

	MG	% Emp.
Manufacturing	0.04	17%
Health Care	0.80	13%
Retail Trade	0.91	12%
Education	0.06	11%
Restaurants & Hotels	1.64	7%

Missing Growth: One Sector vs. Weighted Sectors

	1-sector	2-digit	3-digit	4-digit	5-digits
1983–2013	**0.64**	**0.64**	**0.65**	**0.73**	**0.72**
1983–1995	0.66	0.61	0.62	0.68	0.67
1996–2005	0.55	0.55	0.57	0.64	0.63
2006–2013	0.74	0.78	0.80	0.91	0.92

Missing Growth: One Sector vs. Fixed Weighted Sectors

	1-sector	2-digit	3-digit	4-digit	5-digits
1983–2013	**0.64**	**0.64**	**0.66**	**0.74**	**0.77**
1983–1995	0.66	0.69	0.70	0.84	0.93
1996–2005	0.55	0.53	0.55	0.61	0.59
2006–2013	0.74	0.71	0.71	0.75	0.72

Roadmap

Model with exogenous innovation

- True growth
- Measured growth

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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

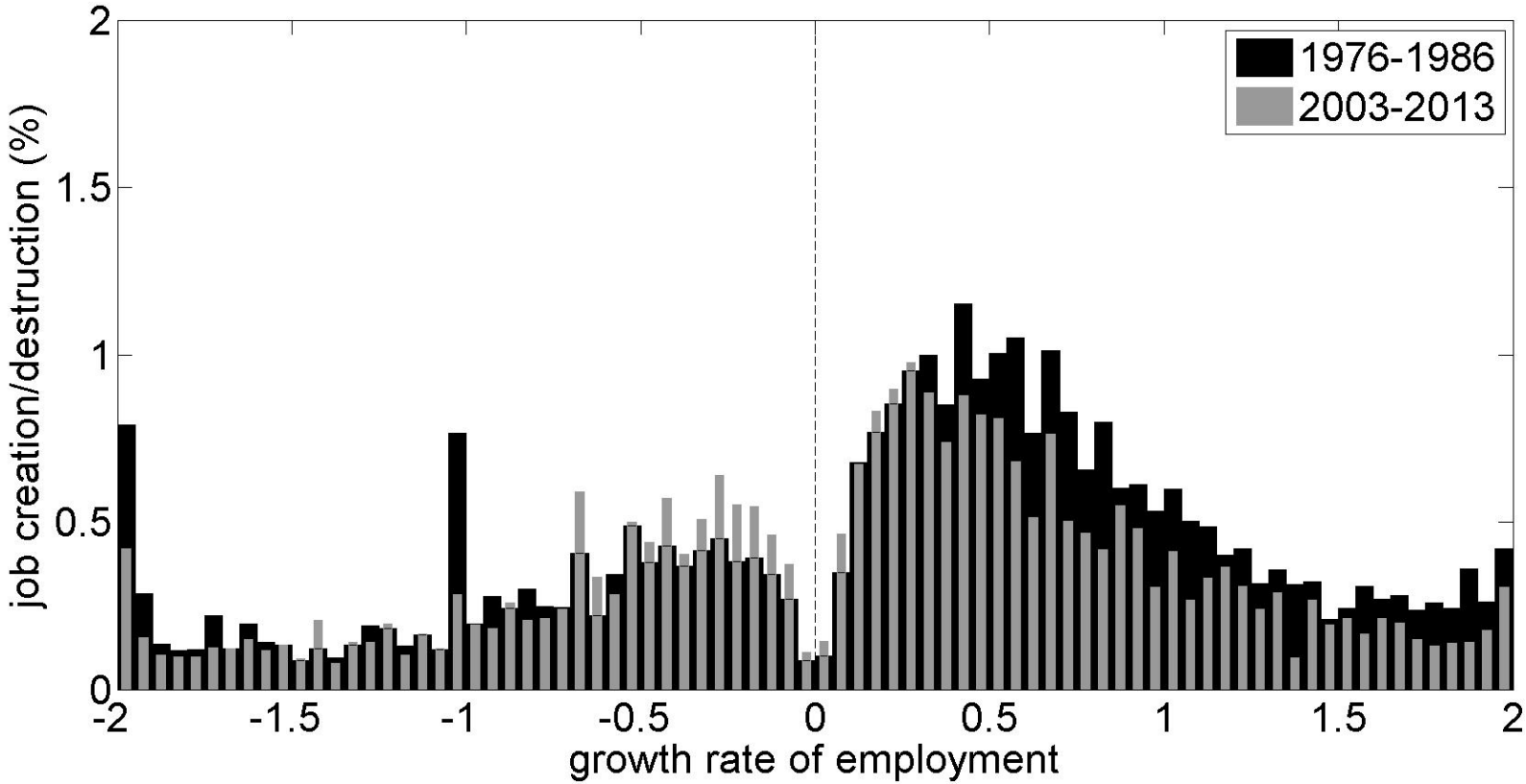
We follow Garcia-Macia, Hsieh and Klenow (2016):

- Fit employment dynamics in LBD firms
- Infer arrival rates and step sizes

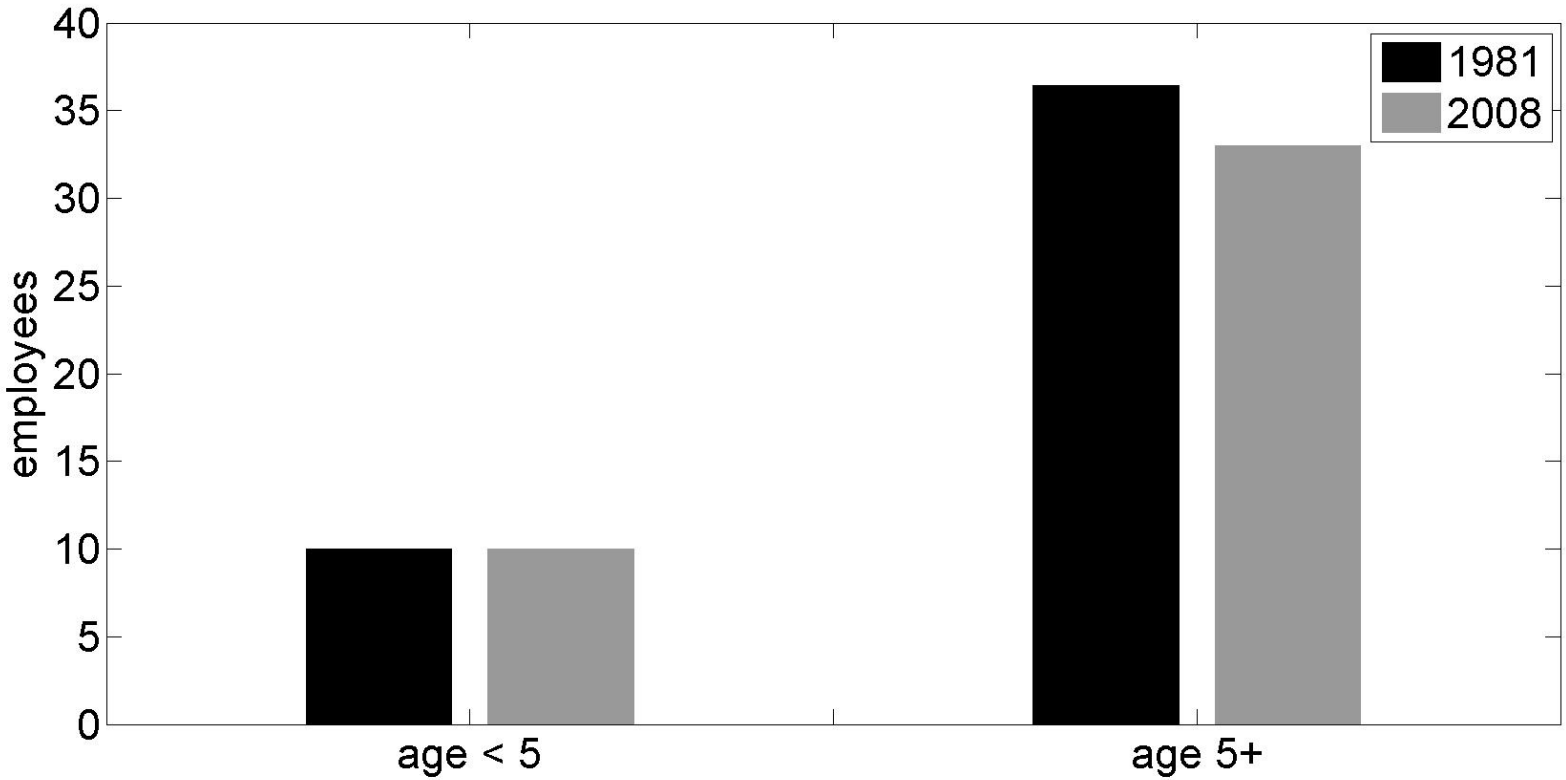
LBD Facts to Fit by Year

- 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

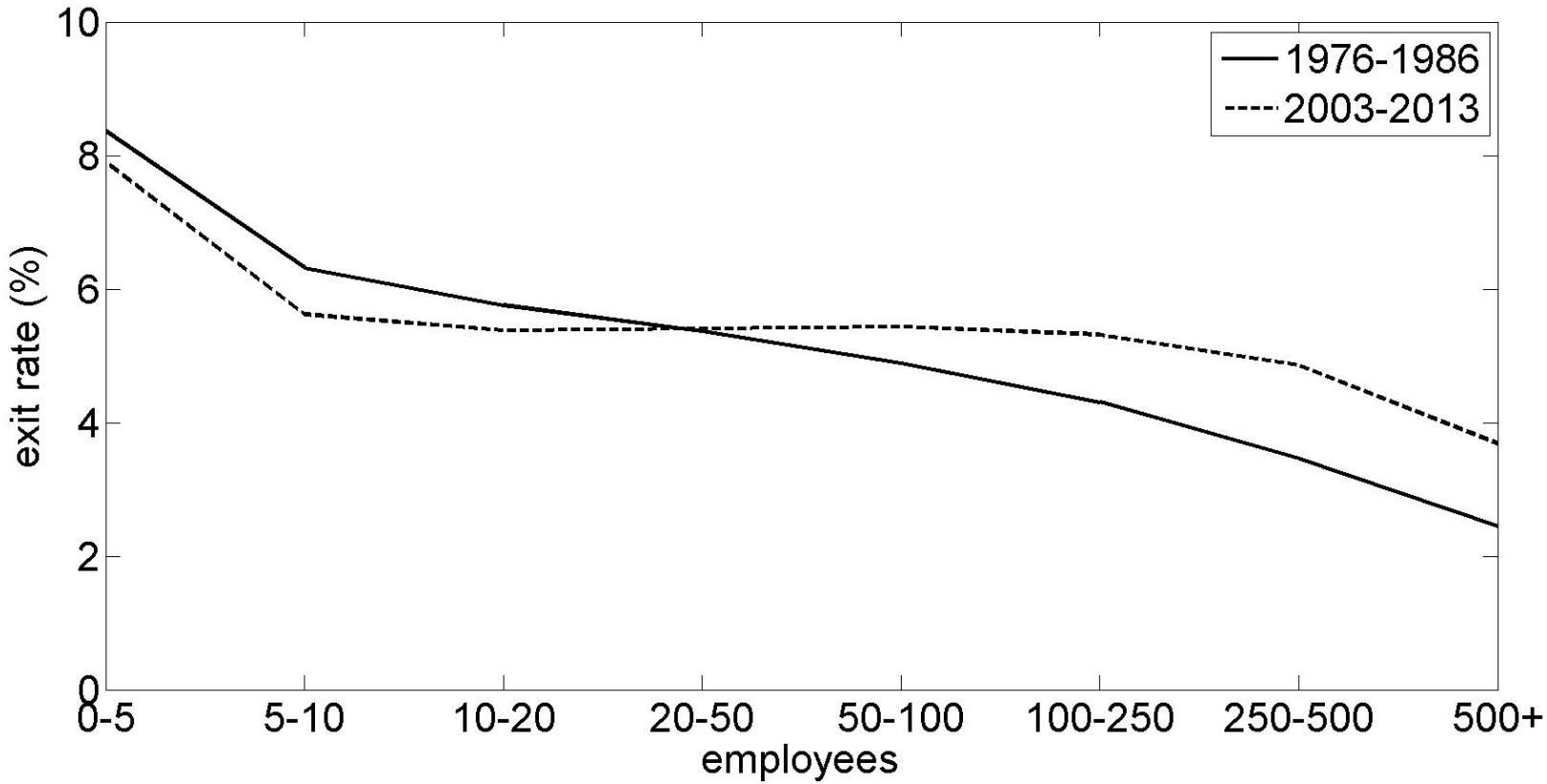
Job Creation and Destruction



Employment: young vs. old firms



Exit by size


10
8
6
4
2
0
exit rate (%)
1976-1986
2003-2013
0-5
5-10
10-20
20-50
50-100
100-250
250-500
500+
employees

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 infer more true growth, higher step sizes

Indirect Inference

Parameter	Definition	1976–1986	2003–2013
λ_d	CD arrival	0.010	0.006
λ_i	OI arrival	0.024	0.027
λ_n	NV arrival	0.004	0.002
γ_i, γ_d	Step size of CD, OI	1.014	1.017
γ_n	Step size of NV	0.289	0.376

Missing growth (in PPT per year) from indirect inference

1976–1986	all	0.52
	from CD	0.41
	market share*	0.46
2003–2013	all	0.42
	from CD	0.33
	market share	0.76

* average over 1983-1986.

Measured vs. True Growth
indirect inference

	Measured	"True"
1976–1986	1.03	1.55
2003–2013	1.44	1.86

Conclusions

Missing growth from CD and new varieties:

- $\sim 0.5\%$ per year

About one-fourth of true growth is missed

No surge in missing growth since 2005

What should the BLS do?

Ideally:

- Collect data on market shares of incoming and outgoing products and estimate their substitutability

A practical alternative:

- Impute based only on those surviving products with innovations (not all surviving products)
- Might subtract $\sim 1\%$ per year from inflation

Not-so-hypothetical example

- 77.5% of items: 2.7% inflation (no innovation)
- 7.5% of items: -5.2% inflation (innovation w/o CD)
- 15% of items: -1.3% inflation (CD)
- Implicit quality growth from rotations 0.3%
- True inflation $= 1.5\%$, True growth $= 1.5\%$
- Measured inflation $= \frac{77.5}{85} \cdot 2.7\% + \frac{7.5}{85} \cdot (-5.2\%) = 2.0\%$
- Measured growth $= 1.0\%$, Missing Growth $= 0.5\%$

Recap on measured vs. true

	Measured	"True"
Unit price inflation	3.0	3.0
Inflation	2.0	1.5
Growth	1.0	1.5

Growth in Hicks-neutral (not labor-augmenting) terms.

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