How Destructive is Innovation?

Daniel Garcia-Macia\textsuperscript{1}  Chang-Tai Hsieh\textsuperscript{2}  Pete Klenow\textsuperscript{3}

\textsuperscript{1}Stanford University
\textsuperscript{2}University of Chicago and NBER
\textsuperscript{3}Stanford University and NBER

January 5, 2015 — ASSA Meetings
Polar models in the endogenous growth literature:

- Creative destruction
- Creation of new varieties
  - Romer (1990)
- Own-variety improvements
Literature

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- Empirical literature with accounting decompositions:
  - Baily et al. (1992), Foster et al. (2001)
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We consider all three channels in an exogenous growth model and try to infer their contribution from data on U.S. manufacturing plants.
Research Question

- How important is creative destruction as a proximate source of innovation?
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- Use plant-level data to infer the contribution of these types of innovation:

<table>
<thead>
<tr>
<th>Innovation Type</th>
<th>Entrants</th>
<th>Incumbents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creative destruction of existing varieties</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Creation of new varieties</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Own-variety improvements</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

Why do we care?

- Optimal innovation policy depends on knowledge spillovers vs. business stealing, which differ across channels.
Research Question

- How important is creative destruction as a proximate source of innovation?

- Use plant-level data to infer the contribution of these types of innovation:

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<tr>
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Method

Start from a leading model of creative destruction (Klette & Kortum 2004), then add creation of new varieties and own-variety improvements.
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- To infer the forces driving plant growth, match model and data moments:
  - growth rate of aggregate TFP
  - exit rate by age
  - employment by age
  - growth in the number of plants
  - exit rate by size (employment)
  - distribution of employment growth
  - distribution of employment
Main findings

- In terms of their contributions to aggregate TFP growth:
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  1. incumbents $\gg$ entrants
Main findings

In terms of their contributions to aggregate TFP growth:

1. incumbents ≫ entrants
2. quality improvements ≫ new varieties
Main findings

In terms of their contributions to aggregate TFP growth:

1. incumbents ≫ entrants
2. quality improvements ≫ new varieties
3. own innovation > creative destruction
Model: innovation channels

quality level

$q$

firm $j$ (3 initial varieties)

$M_t$
Model: innovation channels

- Quality level: $q$
- Firm $j$ (3 initial varieties)
- $s_q$
- Own improvements

Diagram showing the quality level and the initial varieties for firm $j$.
Model: innovation channels

- Own improvements
- Creative destruction

Graph showing quality level $q$ on the y-axis and $Mt$ on the x-axis, with three initial varieties for firm $j$.
Model: innovation channels

- own improvements
- creative destruction
- new varieties

Quality level $q$

Firm $j$ (3 initial varieties)

$M_{t+1}$
Model: innovation channels

- Own improvements
- Creative destruction
- New varieties

Entrant firms

Quality level $q$ vs. $M_t + 1$
Model: built on KK

- Start with discretized version of Klette & Kortum (2004):
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  - Undirected innovation by entrants and incumbents
  - Only factor of production is labor
  - Monopolistic competition, CES $\sigma$
    $\Rightarrow$ employment, profits and revenues proportional to sum of $q^{\sigma-1}$ for a firm
    $\Rightarrow$ employment growth is proportional to innovation
Model: production

- Variety-level:
  \[ y_j = l_j \]
Model: production

- Variety-level:
  \[ y_j = l_j \]

- Firm-level:
  \[ Y_f = \frac{\sum_{j=1}^{M_f} p_j y_j}{P} \]
Model: production

- Variety-level:
  \[ y_j = l_j \]

- Firm-level:
  \[ Y_f = \frac{\sum_{j=1}^{M_f} p_j y_j}{P} \]

- Aggregate:
  \[ Y = \left[ \sum_{j=1}^{M} (q_j y_j)^{1-1/\sigma} \right]^{\sigma \over \sigma-1} \]
We add creation of new varieties and own-variety improvements:

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<thead>
<tr>
<th>channel</th>
<th>probability</th>
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<tbody>
<tr>
<td>own-variety improvements by incumbents</td>
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<td>$\delta_e$</td>
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<td>$s_{\kappa}$</td>
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Model: innovation channels

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Note 1: Exogenous innovation rates.
Model: innovation channels

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Note 1: Exogenous innovation rates.

Note 2: For stationarity, potentially directed creative destruction ($\rho_i$ and $\rho_e$).
Model: innovation channels

Incumbent variety: $q$
Model: innovation channels

Incumbent variety: $q$

$\lambda_i$ -> improved: $s_{\lambda}q$

$1 - \lambda_i$
Model: innovation channels

- Incumbent variety: $q$
- Improved: $s\lambda q$
- Stolen: $-\delta_e - \delta_i$
- Retained: $q$

$\lambda_i$ and $1 - \lambda_i$ distribute the variety among improved, stolen, and retained options.
Model: innovation channels

- **Incumbent variety:** $q$
  - **Improved:** $s_\lambda q$
  - **Stolen:** $-$
  - **Retained:** $q$

- **Steal existing variety:** $s_\delta q'$
- **New variety:** $s_\kappa q''$

### Equations:

- $\lambda_i$ and $\delta_e + \delta_i$
- $1 - \lambda_i$
- $1 - (\delta_e + \delta_i)$
Model: innovation channels

Entrant firm

\[ \delta_e \rightarrow \text{steal existing variety: } s_\delta q' \]

or

\[ \kappa_e \rightarrow \text{new variety: } s_\kappa q'' \]
Simulation algorithm

1. Simulate life paths for same # of plants as in the data ($\sim 350k$)
Simulation algorithm

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2. In each period, probability of each type of innovation
Simulation algorithm

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3. Iterate until the size distribution converges to a steady state
Simulation algorithm

1. Simulate life paths for same # of plants as in the data ($\sim350k$)

2. In each period, probability of each type of innovation

3. Iterate until the size distribution converges to a steady state

4. Iterate on parameter values to minimize distance between the simulated moments and the data moments
### Results: parameters

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</thead>
<tbody>
<tr>
<td>own-variety improvements by incumbents</td>
<td>29.0%</td>
<td>1.058</td>
</tr>
<tr>
<td>creative destruction by entrants</td>
<td>6.2%</td>
<td>1.010</td>
</tr>
<tr>
<td>creative destruction by incumbents</td>
<td>76.6%</td>
<td>1.010</td>
</tr>
<tr>
<td>new varieties from entrants</td>
<td>0.5%</td>
<td>1.000</td>
</tr>
<tr>
<td>new varieties from incumbents</td>
<td>0.0%</td>
<td>1.000</td>
</tr>
</tbody>
</table>
Model: contributions to growth

- Aggregate Productivity:

\[
\frac{Y_t}{L_t} = M_t^{\frac{1}{\sigma-1}} \left[ \frac{\sum_{j=1}^{M_t} q_{j,t}^{\sigma-1}}{M_t} \right]^{\frac{1}{\sigma-1}}
\]
Model: contributions to growth

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\]

- Aggregate growth rate:

\[
1 + g_{Y/L} = [(1 + \kappa_e + \kappa_i)(1 + g_q)]^{1/(\sigma-1)}
\]
Model: contributions to growth

- Aggregate Productivity:

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\frac{Y_t}{L_t} = M_t^{\frac{1}{\sigma-1}} \left[ \frac{\sum_{j=1}^{M_t} q_{j,t}^{\sigma-1}}{M_t} \right]^{\frac{1}{\sigma-1}}
\]

- Aggregate growth rate:

\[
1 + \frac{g_Y}{L} = \left[ (1 + \kappa_e + \kappa_i) (1 + g_q) \right]^{\frac{1}{\sigma-1}}
\]

where

\[
1 + g_q = \frac{s_k^{\sigma-1} \kappa_e + s_k^{\sigma-1} \kappa_i + 1 + (s_q^{\sigma-1} - 1) \lambda_i + (s_q^{\sigma-1} - 1) (1 - \lambda_i) (\rho_e \delta_e + \delta_i)}{1 + \kappa_e + \kappa_i}
\]
## Results: contributions to growth

<table>
<thead>
<tr>
<th></th>
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<th>incumbents</th>
</tr>
</thead>
<tbody>
<tr>
<td>creative destruction</td>
<td>2.6%</td>
<td>34.1%</td>
</tr>
<tr>
<td>creation of new varieties</td>
<td>9.5%</td>
<td>0.0%</td>
</tr>
<tr>
<td>own-variety improvements</td>
<td>-</td>
<td>53.8%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>12.1%</td>
<td><strong>87.9%</strong></td>
</tr>
</tbody>
</table>
Simulated models

- Sequentially depart from KK to arrive at general model:

<table>
<thead>
<tr>
<th></th>
<th>KK</th>
<th>KK 3</th>
<th>New Varieties</th>
<th>Own Innov.</th>
<th>General</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>σ</strong></td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>creative destruction by entrants</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>creative destruction by incumb.</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
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<td></td>
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<td>√</td>
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<td></td>
<td></td>
<td></td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>(partially) directed innovation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>√</td>
</tr>
</tbody>
</table>
Model fit: fraction of firms by age
Model fit: employment share by age
A firm with a single variety exits if all of these things happen:

- does not improve its own variety
- loses its own variety to another incumbent or to an entrant
- does not create a brand new variety
- does not creatively destroy another firm’s variety

\[(1 - \lambda_i)(\delta_e + \delta_i)(1 - \kappa_i)(1 - \delta_i(1 - \lambda_i))\]
Model exit rate

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- does not creatively destroy another firm’s variety

\[(1 - \lambda_i) (\delta_e + \delta_i) (1 - \kappa_i) (1 - \delta_i (1 - \lambda_i))\]

or

- current profits go below the overhead cost
Model fit: exit by size
Model fit: exit by size
Model fit: exit by size
Model fit: exit by size
Model variety vs. size
Data: distribution of employment growth
Model fit: distribution of employment growth
Model fit: distribution of employment growth
Model fit: distribution of employment growth
Model fit: distribution of employment growth
Model fit: distribution of firm size
Recap of main findings

In terms of their contributions to aggregate TFP growth:

1. incumbents $\gg$ entrants
2. quality improvements $\gg$ new varieties
3. own innovation $>$ creative destruction
Recap of main findings

- In terms of their contributions to aggregate TFP growth:

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Recap of main findings

In terms of their contributions to aggregate TFP growth:

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Recap of main findings

In terms of their contributions to aggregate TFP growth:

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3. own innovation > creative destruction
Work to be done

- Measure variety using the number of product categories
  - elasticity between 0.15 and 0.40 wrt firm size. Plants?

- Robustness to different specifications
  - correlated exit of varieties for each firm?
  - adjustment costs (especially for entrants)

- Repeat the estimation with data from China and India
  - Bigger contribution from entrants? More creative destruction?
  - In China: massive entry of private firms and exit of SOEs

- Repeat the estimation with data from other U.S. sectors
  - e.g. retail trade (Wal-Mart and Amazon)
## Parameter values

<table>
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<tr>
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<tr>
<td>$\lambda_i$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>35.5%</td>
<td>43.0%</td>
</tr>
<tr>
<td>$\delta_e$</td>
<td>2.4%</td>
<td>2.3%</td>
<td>1.9%</td>
<td>3.3%</td>
<td>3.6%</td>
</tr>
<tr>
<td>$\delta_i$</td>
<td>41%</td>
<td>41%</td>
<td>41%</td>
<td>41.6%</td>
<td>47.0%</td>
</tr>
<tr>
<td>$s_q$</td>
<td>1.058</td>
<td>1.057</td>
<td>1.051</td>
<td>1.035</td>
<td>1.032</td>
</tr>
<tr>
<td>$\kappa_e$</td>
<td>-</td>
<td>-</td>
<td>0.5%</td>
<td>0.5%</td>
<td>0.5%</td>
</tr>
<tr>
<td>$\kappa_i$</td>
<td>-</td>
<td>0.001%</td>
<td>0.001%</td>
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<td>0.001%</td>
</tr>
<tr>
<td>$s_\kappa$</td>
<td>-</td>
<td>1</td>
<td>1.051</td>
<td>0.980</td>
<td>0.980</td>
</tr>
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</table>