From imitation to innovation: Where is all that Chinese R&D going?

Michael König  Zheng (Michael) Song  Kjetil Storesletten  Fabrizio Zilibotti  

ABFER  
May 24, 2017
Business enterprise expenditure on R&D (in % of GDP)

Source: OECD Science, Technology and Industry Outlook (latest available year)
R&D Misallocation?

• Does R&D investment translate into productivity growth?

• Is the allocation of R&D investment efficient?
  • E.g., SOE vs. DPE, connected firms, etc.

• More general question:
  • Which firms do R&D?
  • What is R&D misallocation? Is it quantitatively important?
China: R&D Investments Enhance Firms’ TFP Growth

Hsieh-Klenow TFP (robust to Olley-Pakes TFP)
R&D, TFP, and Misallocation

Three strands of literature:

1. **Technological convergence** through innovation/imitation is an important determinant of growth and cross-country productivity differences (Acemoglu, Aghion and Zilibotti 2006)

2. **Misallocation**: Hsieh and Klenow (2009) misallocation of resources is important to understand development
   - In Hsieh and Klenow: distribution of TFP across firms is exogenous

3. **Theories of firm productivity dynamics**: study *which firms* invest in the adoption of better technologies (Perla and Tonetti 2014; Lucas and Moll 2015; König, Lorenz, and Zilibotti 2016)

How do policy/market distortions affect the allocation of R&D and technological change?

- Example: targeted R&D subsidies and industrial policies can increase aggregate R&D but possibly induce the wrong firms to invest in R&D
Today’s presentation

• Some facts on R&D from Chinese and Taiwanese firm-level data

• A theoretical model

• Model estimation and policy counterfactuals
Stylized facts

1. Growth rates for non-R&D firms is falling in TFP
   • Roughly the same rate of decline in China and Taiwan
2. R&D firms grow faster than non-R&D firms.
   • The gap is growing in the TFP level.
3. R&D firms grow faster in Taiwan than in China.
   • Especially so for high TFP firms
4. R&D probability is increasing in TFP.
   • More steeply so in Taiwan
5. R&D probability is increasing in revenue.
   • Similar pattern in China and Taiwan
Share of R&D Firms: Taiwan

Share of R&D Firms: China
Conceptual Framework on R&D Decision

• A model with both innovation and imitation (cf. AAZ 2006, KLZ 2016)
• R&D proxies for investment in innovation
  • Simplification: R&D is an extensive margin (binary) choice
• Distance to *local* frontier determines imitation success rate
  • Implication: high-TFP firms invest in R&D because of low return on imitation
• Adding firm heterogeneity
  • (i) wedges; (ii) innovation capacities; (iii) R&D costs …
• Obtain predictions about which firms do R&D and how fast they grow
The Economy (KLZ, 2016)

• Each variety is produced by a firm (monopolist), whose profit increases in its TFP.

• TFP growth through two channels: (i) Doing R&D + Passive Imitation; (ii) Active Imitation (cannot do both)

• Active imitation: Firms improve TFP by imitating more productive firms through a random matching process.
  • Passive Imitation: Learning efficiency discounted by $\delta$. 
Firms’ Life Cycle

• Firms are run by two-period lived OLG of (non-altruistic) entrepreneurs

• Firms are transmitted from parents to children (cf. SSZ 2011)
  • Young entrepreneurs decide on R&D-imitation
  • Old entrepreneurs choose input optimally, run the production process, earn a profit, consume and die
  • Imperfect TFP transmission

• R&D decisions only depend on CURRENT productivity distribution
  • Simplified framework eases estimation...
  • ... though the theory does not hinge on this assumption
Active Imitation

• Firm TFP distribution: $f(A)$.

• If the firm chooses active imitation:
  • The probability of meeting a more productive firm: $1 - F(A)$.
  • Imitation success (with probability $q$): the firm will improve its TFP by $\mu$ percent.
  • Imitation failure (with probability $1 - q$): its TFP remains unchanged.

• The value of active imitation for a young entrepreneur:

$$\beta \left[ q (1 - F(A)) \pi (1 + \mu A) \right. \\
\left. + \left( 1 - q (1 - F(A)) \right) \pi (A) \right]$$
R&D

• If the firm chooses R&D:
  • Innovation success (with probability $p$): the firm will improve its TFP by $\mu$ percent.
  • Innovation failure (with probability $1 - p$):
    • Passive imitation success (with probability $\delta q (1 - F(A))$), the firm will improve its TFP by $\mu$ percent.

• The value of R&D:

\[-c + \beta \left[ (p + (1 - p)\delta q (1 - F(A))) \pi ((1 + \mu)A) \\
+ (1 - p) (1 - \delta q (1 - F(A))) \pi (A) \right] \]
Firm Decision

• R&D/Active Imitation choice:

\[
\begin{array}{c}
\text{argmax} \left\{ \begin{array}{c}
-c + \beta \left[ (p + (1-p)\delta q(1-F(A)))\pi((1+\mu)A) \\
+ (1-p)\left(1-\delta q(1-F(A))\right)\pi(A) \right]
\end{array} \right. \\
\beta \left[ q(1-F(A))\pi((1+\mu)A) \\
+ (1-q(1-F(A)))\pi(A) \right]
\end{array}
\]

Active Imitation

R&I

R&D
The TFP-R&D Profile

The Fraction of R&D Firms in KLZ
The Stationary TFP Distribution

• "Traveling waves"
Adding Heterogeneities

• Output wedges: $\tau_i$
  • $\pi(\tau_i, A_i)$ will be specified later

• Heterogeneous R&D chances: $p_i$

• Heterogeneous R&D costs: $c_i$
Heterogeneity in technology and wedges: TFP-R&D Profile

The Fraction of R&D Firms w/o heterogeneity (KLZ 2016)

The Fraction of R&D Firms with heterogeneity
Stylized facts Revisited

1. Growth rates for non-R&D firms is falling in TFP
   • Roughly the same rate of decline in China and Taiwan
2. R&D firms grow faster than non-R&D firms.
   • The gap is growing in the TFP level.
3. R&D firms grow faster in Taiwan than in China.
   • Especially so for high TFP firms
4. R&D probability is increasing in TFP.
   • More steeply so in Taiwan
5. R&D probability is increasing in revenue.
   • Similar pattern in China and Taiwan
Data

• Industrial Firm Survey Data for China and Taiwan (census)

• Taiwan: 1999-2004 balanced panel with 11,000 firms (truncated by China’s firm size standard)
  • Taiwan is used for the benchmark estimation

• Later, China: 2001-2007 balanced panel with 78,000 firms.

• Analysis based on data after removing industry fixed effects
TFP and Wedges

• Final good production: \( Y(t) = \left( \int_0^1 Y_i(t)^{1-\eta} \, di \right)^{\frac{1}{1-\eta}} \)

• This yields iso-elastic demands for each good: \( P_i(t) = \left( \frac{Y_i(t)}{Y(t)} \right)^{-\eta} \)

• Production function of each good is Cobb-Douglas

\[
Y_i(t) = A_i(t)K_i(t)^{\alpha}L_i(t)^{1-\alpha}
\]
Towards estimating the model

STEP 1: infer wedges and TFP

• Given info about firms’ revenue and wage bill, retrieve TFP and output wedges

\[ 1 - \tau_i \propto \frac{1}{\left( \frac{P_i Y_i}{K_i} \right) \left( \frac{P_i Y_i}{wL_i} \right)^{1-\alpha}} \]

\[ A_i \propto \frac{1}{\left( \frac{P_i Y_i}{K_i} \right)^{1-\eta} \left( wL_i \right)^{1-\alpha}} \]

• Retrieve empirical joint distribution of \( \tau \) and \( A \)
  (adjusting for classical measurement error to deal with “division bias”)
Towards estimating the model

**STEP 2: derive moments**

- Sort firms on estimated TFP \((A_i)\). For each TFP percentile, calculate
  1) R&D probability (extensive margin)
  2) TFP growth rate conditional on zero R&D
  3) TFP growth rate conditional on R&D > 0

- Sort firms on revenue \(((A_i(1 - \tau_i))^{\frac{1}{\eta}})\). For each percentile, calculate
  4) R&D probability (extensive margin)
Taiwan data

Panel A: TFP-R&D Profile

Panel B: Revenue-R&D Profile

Panel C: TFP Growth of No-R&D Firms

Panel D: TFP Growth Difference between R&D and No-R&D Firms
China data

Panel A: TFP-R&D Profile

Panel B: Revenue-R&D Profile

Panel C: TFP Growth of No-R&D Firms

Panel D: TFP Growth Difference between R&D and No-R&D Firms
Estimating the model (SMM)

Estimate model by Simulated Method of Moments (for Taiwan)

• Estimate four parameters:
  • q (imitation efficiency)
  • p distribution (probability of success of innovation), assume uniform distribution on $[0, \bar{p}]$
  • δ (passive imitation parameter)
  • c (R&D cost) level (no heterogeneity)

• Target 16 (-400) moments, efficient weighting
  (percentiles of distributions in 4 panels above)
Estimates for Taiwan: Constant $c$

Panel A: TFP Percentiles

Panel B: Revenue Percentiles

Panel C: TFP Growth of No-R&D Firms

Panel D: TFP Growth Difference between R&D and no-R&D Firms

<table>
<thead>
<tr>
<th>Estimates for Taiwan</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$q$</td>
<td>0.45</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.40</td>
</tr>
<tr>
<td>$\bar{p}$</td>
<td>0.25</td>
</tr>
<tr>
<td>$c_0$</td>
<td>0.52</td>
</tr>
</tbody>
</table>
Estimates for Taiwan: Heterogeneous $c$

Panel A: TFP Percentiles

Panel B: Revenue Percentiles

Panel C: TFP Growth of No-R&D Firms

Panel D: TFP Growth Difference between R&D and no-R&D Firms

| Estimates for Taiwan |  
|----------------------|---|
| $q$                  | 0.45 |
| $\delta$             | 0.50 |
| $\bar{p}$            | 0.26 |
| mean of $c$          | 0.75 |
| std of $c$           | 0.59 |
China Benchmark (Taiwan Based, Re-estimating $c$ Level)

Panel A: TFP Percentiles

Panel B: Revenue Percentiles

Panel C: TFP Growth of No-R&D Firms

Panel D: TFP Growth Difference between R&D and no-R&D Firms

<table>
<thead>
<tr>
<th></th>
<th>Estimates for Taiwan</th>
</tr>
</thead>
<tbody>
<tr>
<td>$q$</td>
<td>0.45</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.40</td>
</tr>
<tr>
<td>$\bar{p}$</td>
<td>0.25</td>
</tr>
<tr>
<td>$c_0$</td>
<td>Re-estimated for China</td>
</tr>
<tr>
<td></td>
<td>1.50</td>
</tr>
</tbody>
</table>
China Benchmark (Taiwan Based, Re-estimating $c$ Level)

<table>
<thead>
<tr>
<th>Estimates for Taiwan</th>
</tr>
</thead>
<tbody>
<tr>
<td>$q$</td>
</tr>
<tr>
<td>$\delta$</td>
</tr>
<tr>
<td>$\bar{p}$</td>
</tr>
<tr>
<td>std of $c$</td>
</tr>
<tr>
<td>mean of $c$</td>
</tr>
</tbody>
</table>

Panel A: TFP Percentiles
Panel B: Revenue Percentiles
Panel C: TFP Growth of No-R&D Firms
Panel D: TFP Growth Difference between R&D and no-R&D Firms
Counterfactuals

A. Quantitative failure of Taiwan model for China:
   i. Model predicts that R&D firms grow faster than in the data
   ii. Model predicts steeper selection into R&D by TFP than in the data

B. Candidate additional mechanisms
   1. Policy distortions scramble decisions (increased dispersion in $c$)
   2. Scarcity of innovative talent in China (relative to Taiwan, lower)
   3. Moral hazard in R&D
China Attempt 1: Scrambling (Estimating $c$ Distribution)

Estimates for Taiwan

$q$ 0.45
$\delta$ 0.50
$\bar{\rho}$ 0.26

Re-estimated for China

mean of $c$ 7.50
std of $c$ 7.60
China Attempt 2: Talent Scarcity (Re-estimating $c$ and $p$ distributions)

### Estimates for Taiwan

- $q$: 0.45
- $\delta$: 0.50

### Re-estimated for China

- $\bar{p}$: 0.15
- Mean of $c$: 2.00
- Std of $c$: 2.40
Moral Hazard in R&D

• Assume $C_i = c + \hat{c}_i$, where $\hat{c}_i$ is a tax/subsidy to R&D

• Moral hazard: Firms can fake R&D
  - cash a subsidy and do imitation instead (avoiding cost and benefits of R&D)
  - Note: firms with low $p$ and negative $\varepsilon$ are likely to fake R&D

• Allow $\varepsilon_i$ to be correlated with $A_i$ and $\tau_i$:
  $$\hat{c}_i = \varepsilon_i + c_1 \log A_i + c_2 \log (1 - \tau_i).$$
  - $c_1 > 0$: Government supports more productive firms (subsidizes R&D in high-$A$ firms)
  - $c_2 > 0$: Government supports its darlings (subsidizes R&D in low-$\tau$ firms, e.g. SOE)
China Attempt 3: Moral Hazard in R&D

Panel A: TFP Percentiles
Panel B: Revenue Percentiles
Panel C: TFP Growth of No-R&D Firms
Panel D: TFP Growth Difference between R&D and no-R&D Firms

<table>
<thead>
<tr>
<th>Estimates for Taiwan</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$q$</td>
<td>0.45</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.40</td>
</tr>
<tr>
<td>$\bar{p}$</td>
<td>0.25</td>
</tr>
<tr>
<td>Re-estimated for China</td>
<td></td>
</tr>
<tr>
<td>mean of $c$</td>
<td>3.50</td>
</tr>
<tr>
<td>Fake R&amp;D</td>
<td></td>
</tr>
<tr>
<td>mean of $\varepsilon$</td>
<td>0.50</td>
</tr>
<tr>
<td>std of $\varepsilon$</td>
<td>0.95</td>
</tr>
<tr>
<td>$c_1$</td>
<td>-0.21</td>
</tr>
<tr>
<td>$c_2$</td>
<td>-0.23</td>
</tr>
</tbody>
</table>
Fake R&D Firms
Robustness Check (Re-estimating All Parameters for China)

| Estimates for China |  
|---------------------|---
| \( q \)              | 0.45  
| \( \delta \)         | 0.90  
| \( \bar{p} \)         | 0.05  
| mean of \( c \)       | 2.20  
| std of \( c \)        | 2.40  

Effects of Removing R&D Distortions

• Removing R&D distortion (constant $c$ re-estimated): TFP growth up by 0.8 percentage points

• Using Taiwan’s $c$ for China: TFP growth up by 1.4 percentage points
Conclusion

• Document evidence on firm-level distribution of R&D and growth in manufacturing industries in China and Taiwan
• Develop a theory of innovation (driven by R&D), imitation, and growth, with a focus on R&D misallocation
• Estimate the model using firm-level data from Taiwan and China
• Evaluate counterfactual: remove R&D distortions in China relative to Taiwan
• Next: extend analysis to Western economies (use data for Norway)