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

Michael König   Zheng (Michael) Song
Kjetil Storesletten   Fabrizio Zilibotti

ABFER
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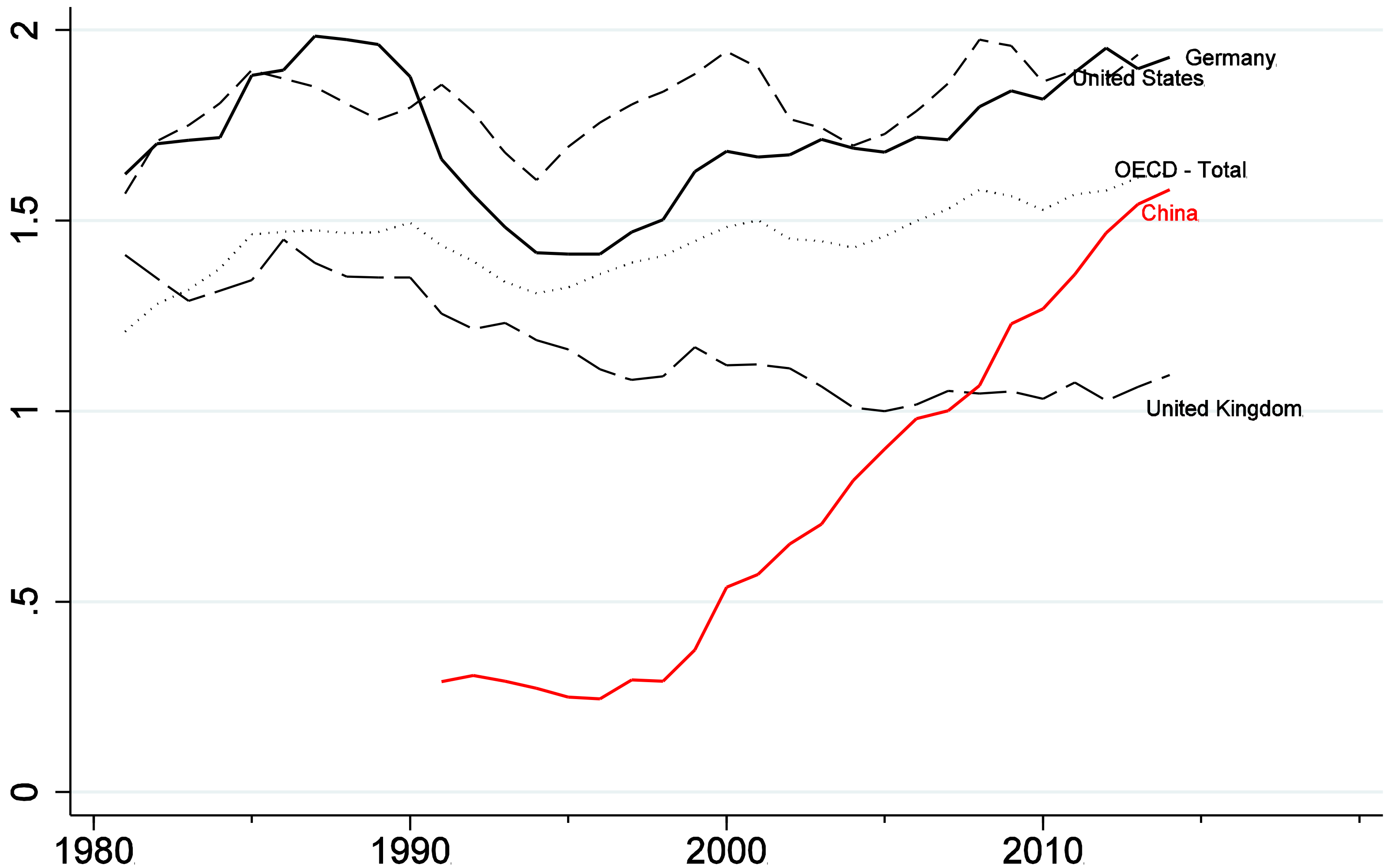
Business enterprise expenditure on R&D (in % of GDP)



Source: OECD Science, Technology and Industry Outlook (latest available year)

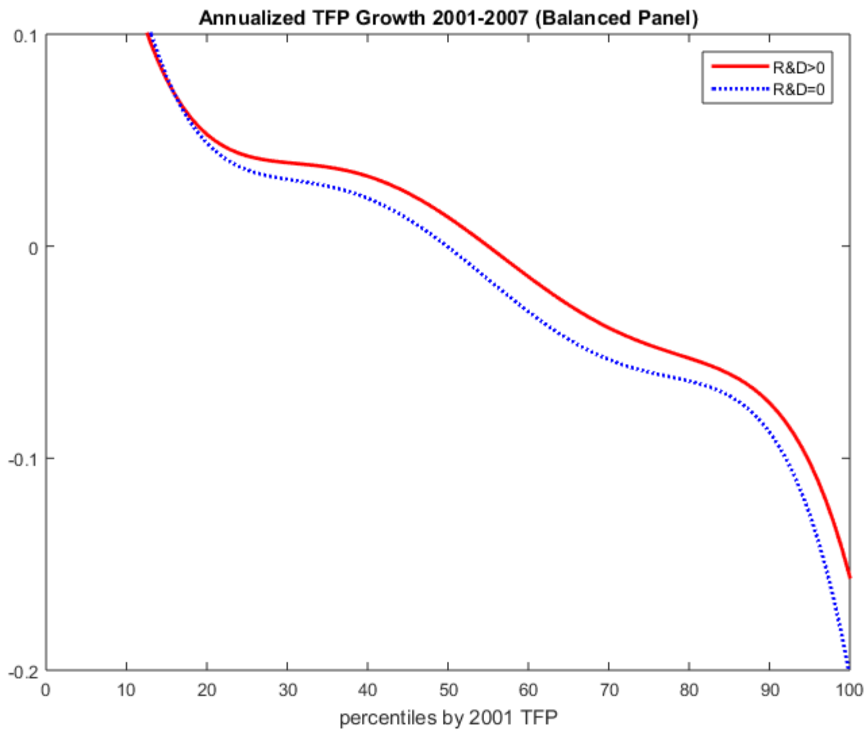
R&D Misallocation?

- 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?

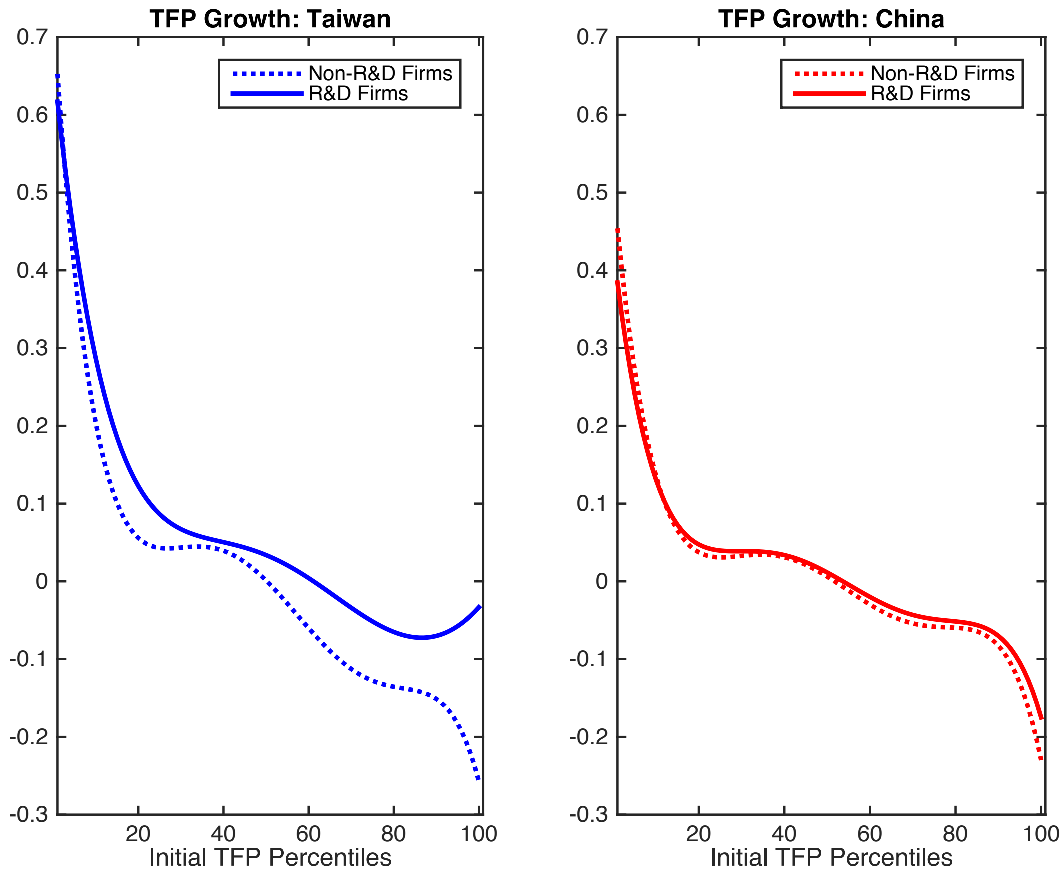
- Example: targeted R&D subsidies and industrial policies can increase aggregate R&D but possibly induce the wrong firms to invest in R&D

Today's presentation

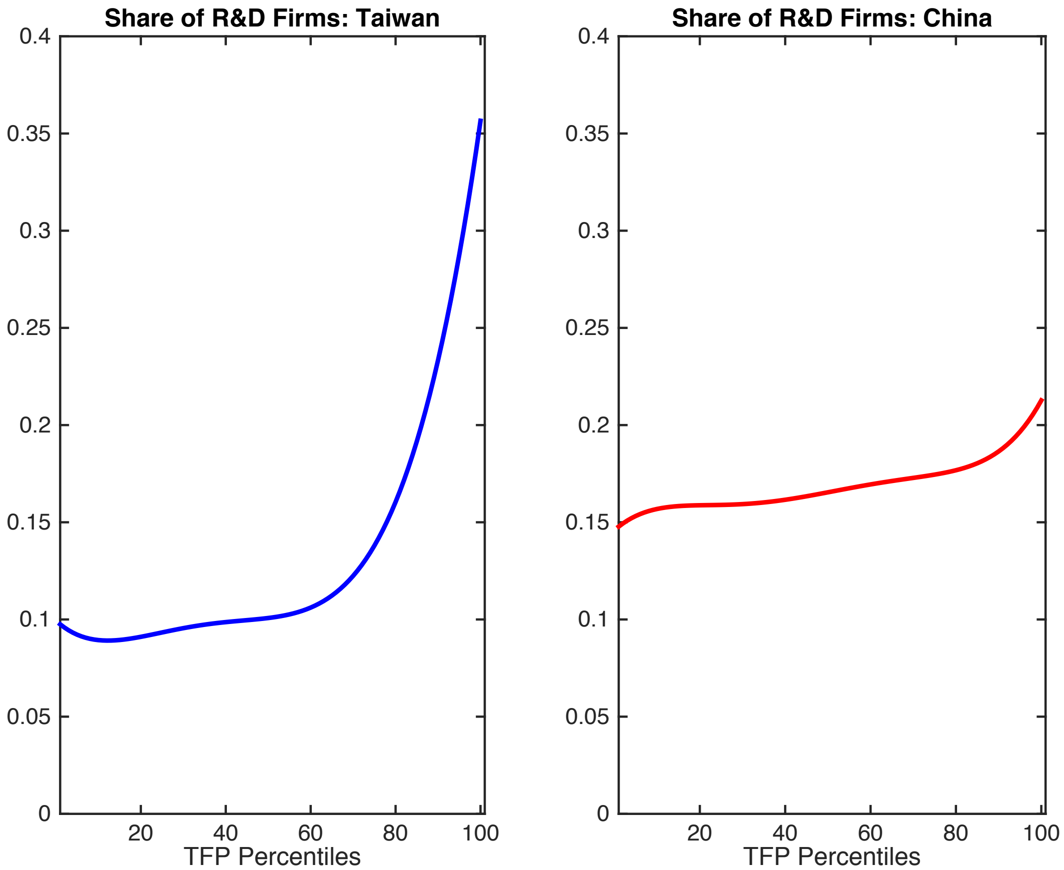
- Some facts on R&D from Chinese and Taiwanese firm-level data
- A theoretical model
- Model estimation and policy counterfactuals

Stylized facts

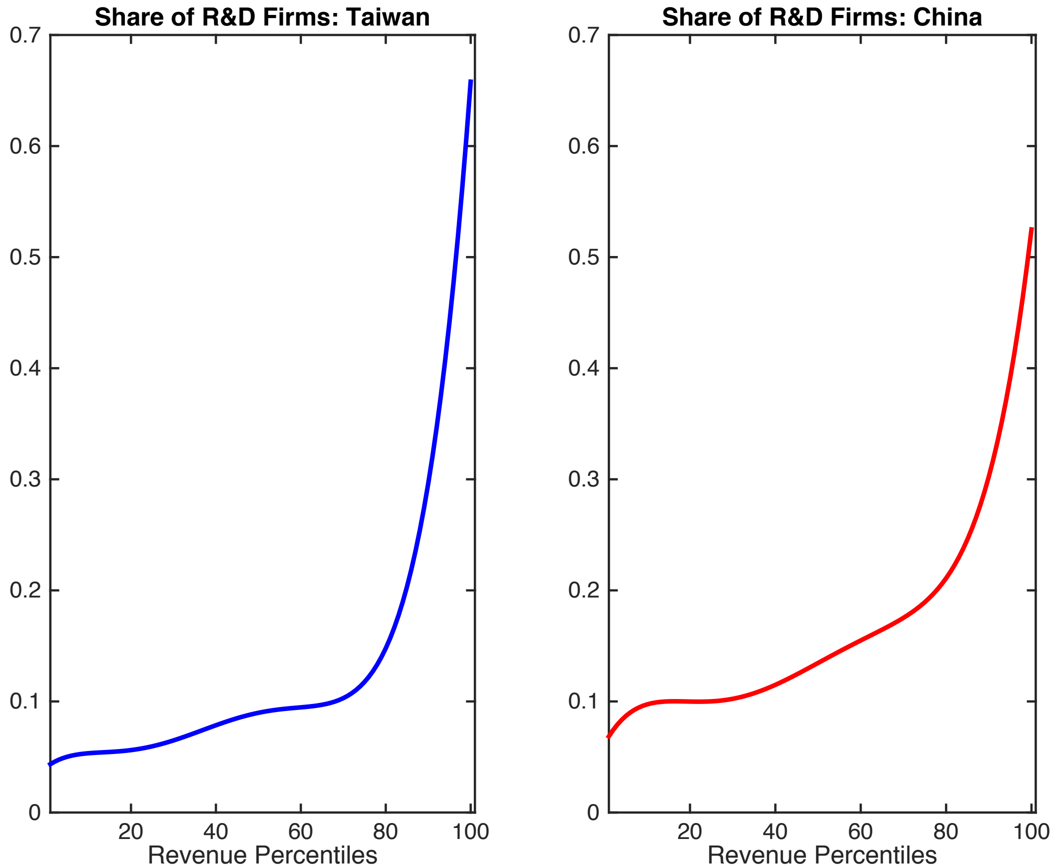
1. Growth rates for non-R&D firms is falling in TFP
   - Roughly the same rate of decline in China and Taiwan
2. R&D firms grow faster than non-R&D firms.
   - The gap is growing in the TFP level.
3. R&D firms grow faster in Taiwan than in China.
   - Especially so for high TFP firms
4. R&D probability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



TFP Growth: Taiwan
Non-R&D Firms
R&D Firms
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
20
40
60
80
100
Initial TFP Percentiles
TFP Growth: China
Non-R&D Firms
R&D Firms
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
20
40
60
80
100
Initial TFP Percentiles



Share of R&D Firms: Taiwan
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
20
40
60
80
100
TFP Percentiles
Share of R&D Firms: China
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
20
40
60
80
100
TFP Percentiles


Share of R&D Firms: Taiwan
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
20
40
60
80
100
Revenue Percentiles
Share of R&D Firms: China
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
20
40
60
80
100
Revenue Percentiles

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 δ.

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 μ percent.
  - Imitation failure (with probability $1 - q$): its TFP remains unchanged.

- The value of active imitation for a young entrepreneur:

$$\beta \left[\begin{array}{l} q\big(1 - F(A)\big)\pi\big((1+\mu)A\big) \\ + \Big(1 - q\big(1 - F(A)\big)\Big)\pi(A) \end{array} \right]$$

R&D

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

- The value of R&D:

$$-c + \beta \begin{bmatrix} \Big(p + (1-p)\delta q\big(1 - F(A)\big)\Big)\pi\big((1+\mu)A\big) \\ +\Big((1-p)\Big(1 - \delta q\big(1 - F(A)\big)\Big)\Big)\pi(A) \end{bmatrix}$$

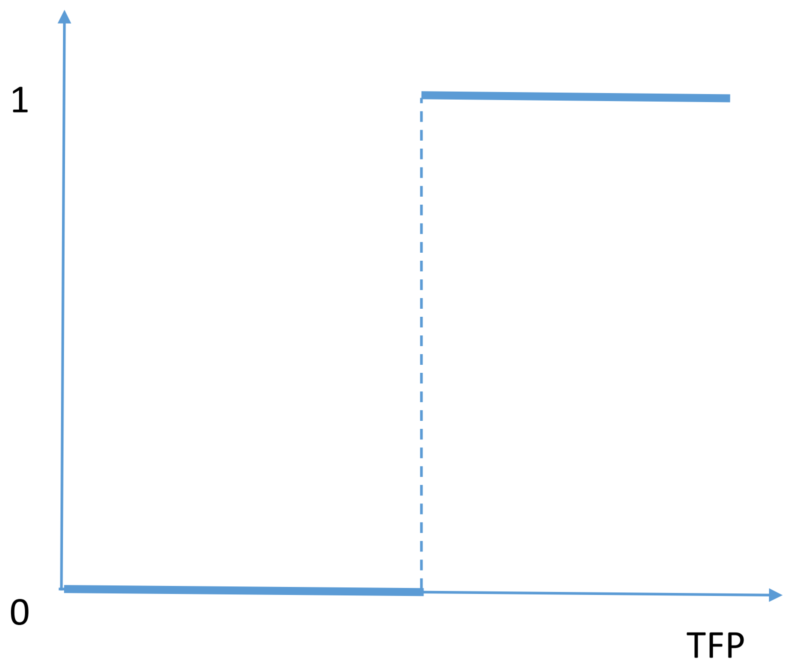
Firm Decision

- R&D/Active Imitation choice:

$$
argmax \left\{ \begin{array}{c|c}
\beta \begin{bmatrix} q\big(1 - F(A)\big)\pi\big((1+\mu)A\big) \\ + \Big(1 - q\big(1 - F(A)\big)\Big)\pi(A) \end{bmatrix} & \begin{array}{c} Active \\ Imitation \end{array} \\
 & \\
-c + \beta \begin{bmatrix} \Big(p + (1-p)\delta q\big(1 - F(A)\big)\Big)\pi\big((1+\mu)A\big) \\ + \Big((1-p)\Big(1 - \delta q\big(1 - F(A)\big)\Big)\Big)\pi(A) \end{bmatrix} & R\&D
\end{array} \right\}
$$

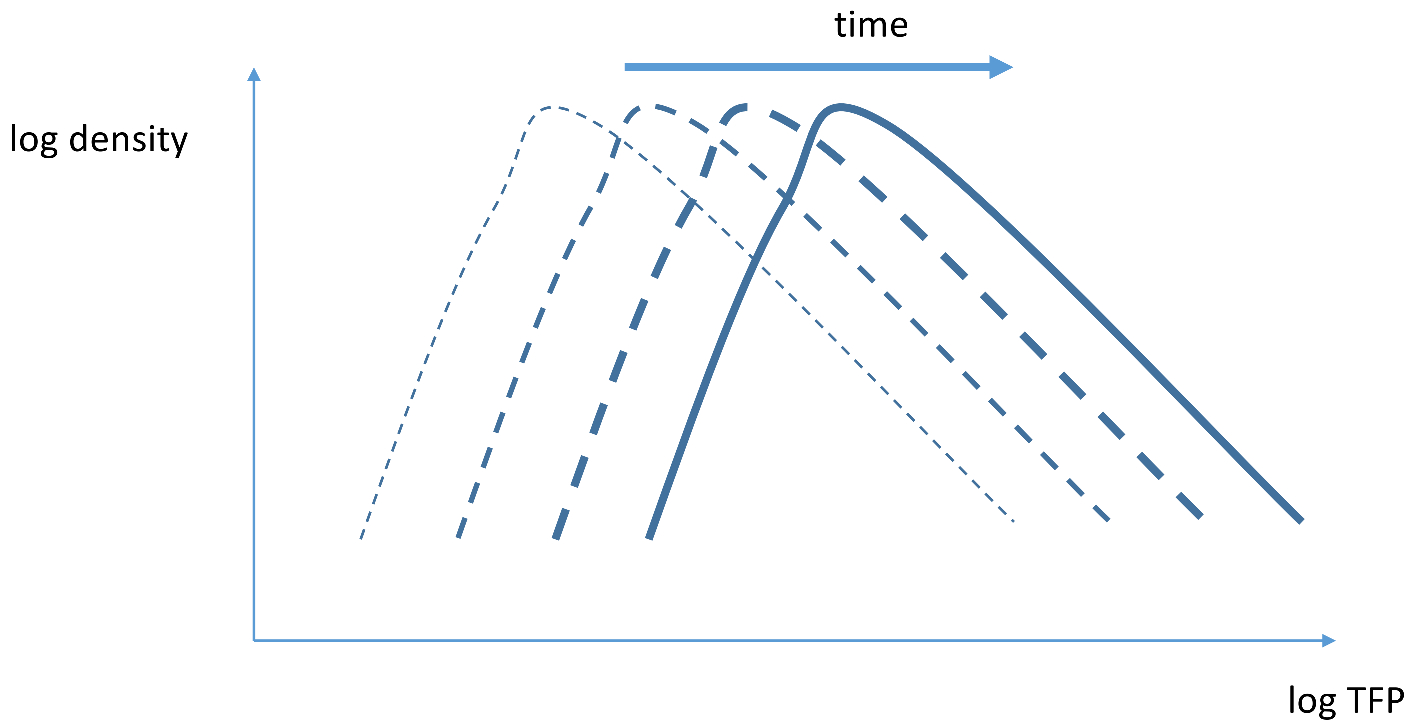
The TFP-R&D Profile

The Fraction of R&D Firms in KLZ



The Stationary TFP Distribution

- ”Traveling waves”



Adding Heterogeneities

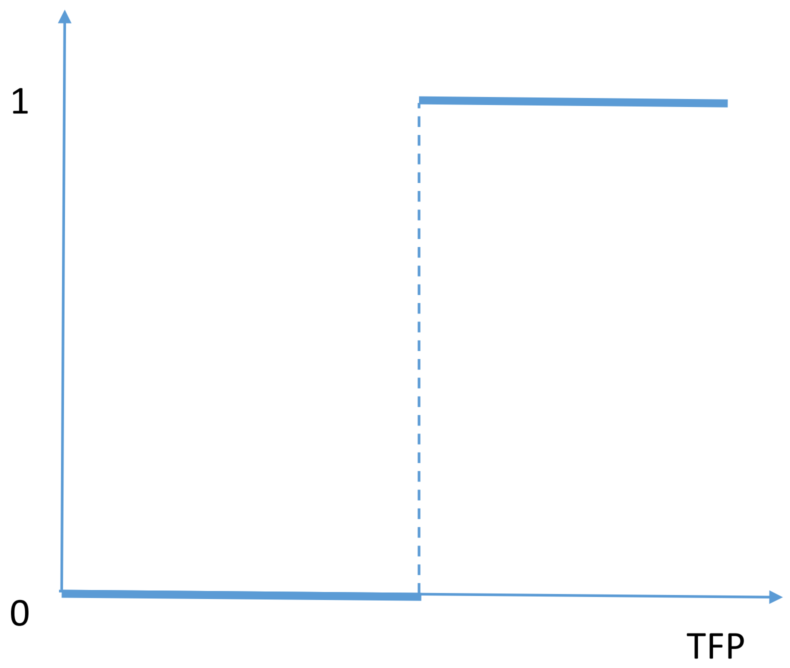
- Output wedges: τ_i
  - $\pi(\tau_i, A_i)$ will be specified later

- Heterogeneous R&D chances: p_i

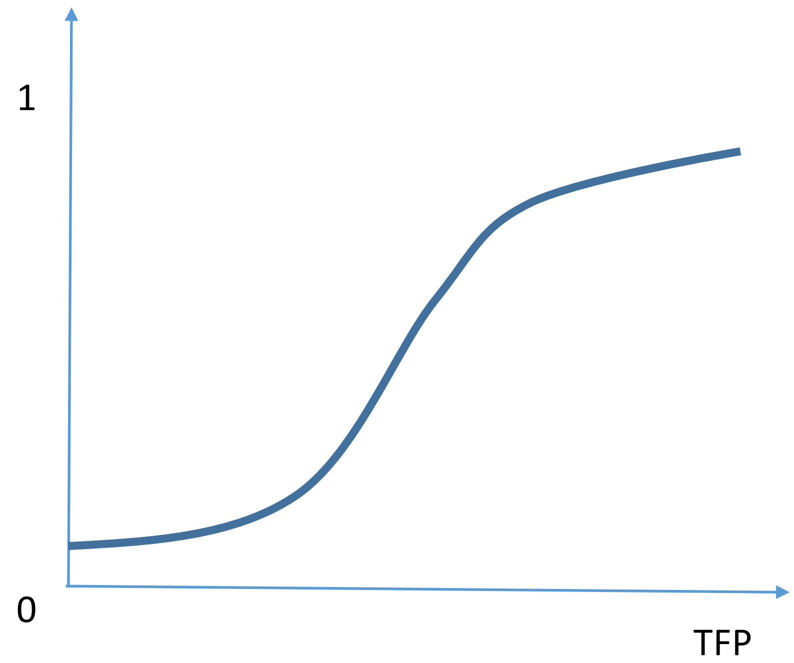
- Heterogeneous R&D costs: c_i

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

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5. R&D probability is increasing in revenue.
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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

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

$$A_i \propto \frac{(P_i Y_i)^{\frac{1}{1-\eta}}}{K_i{}^{\alpha}(wL_i)^{1-\alpha}}$$

- Retrieve empirical joint distribution of τ and A

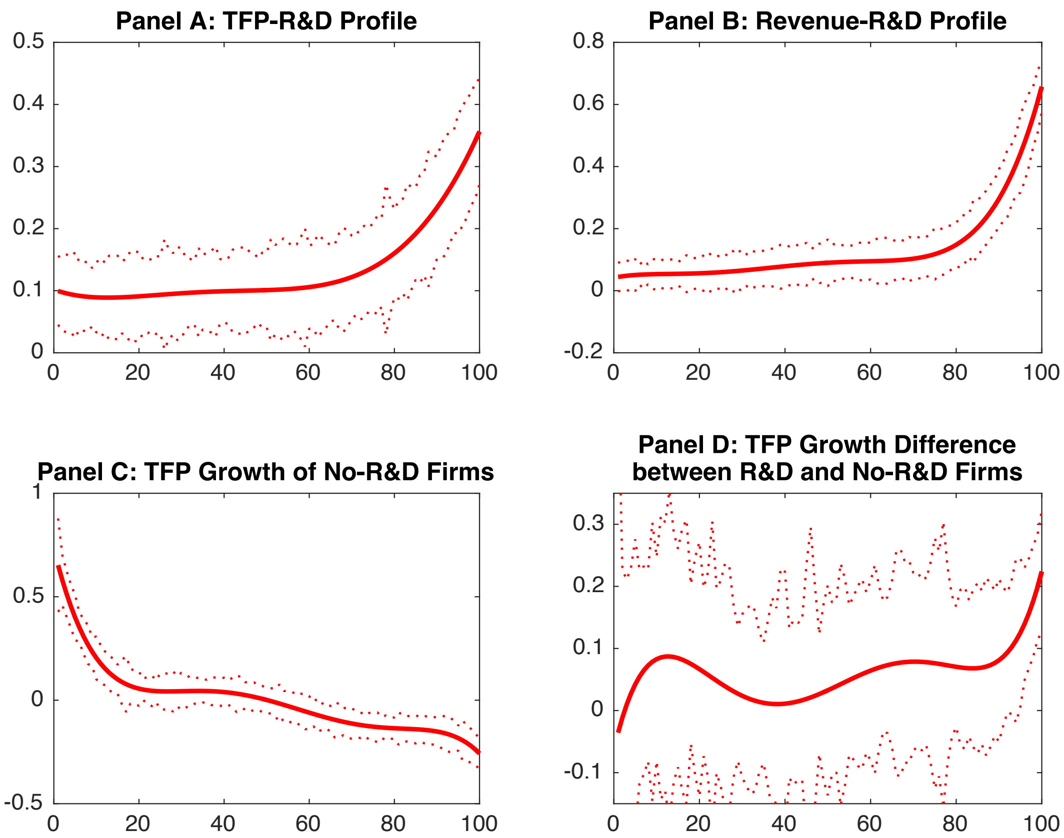
(adjusting for classical measurement error to deal with “division bias”)

Towards estimating the model

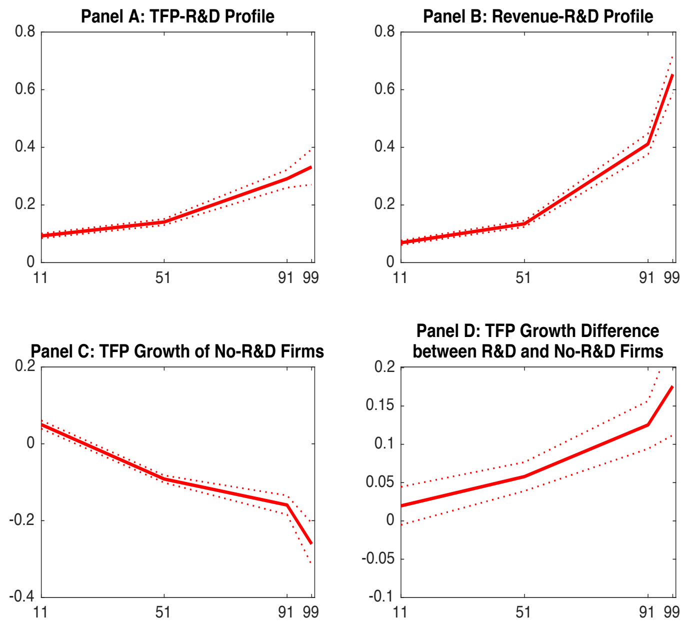
STEP 2: derive moments

- 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 ($\left(A_i(1-\tau_i)\right)^{\frac{1}{\eta}}$). For each percentile, calculate
  4) R&D probability (extensive margin)

Taiwan data

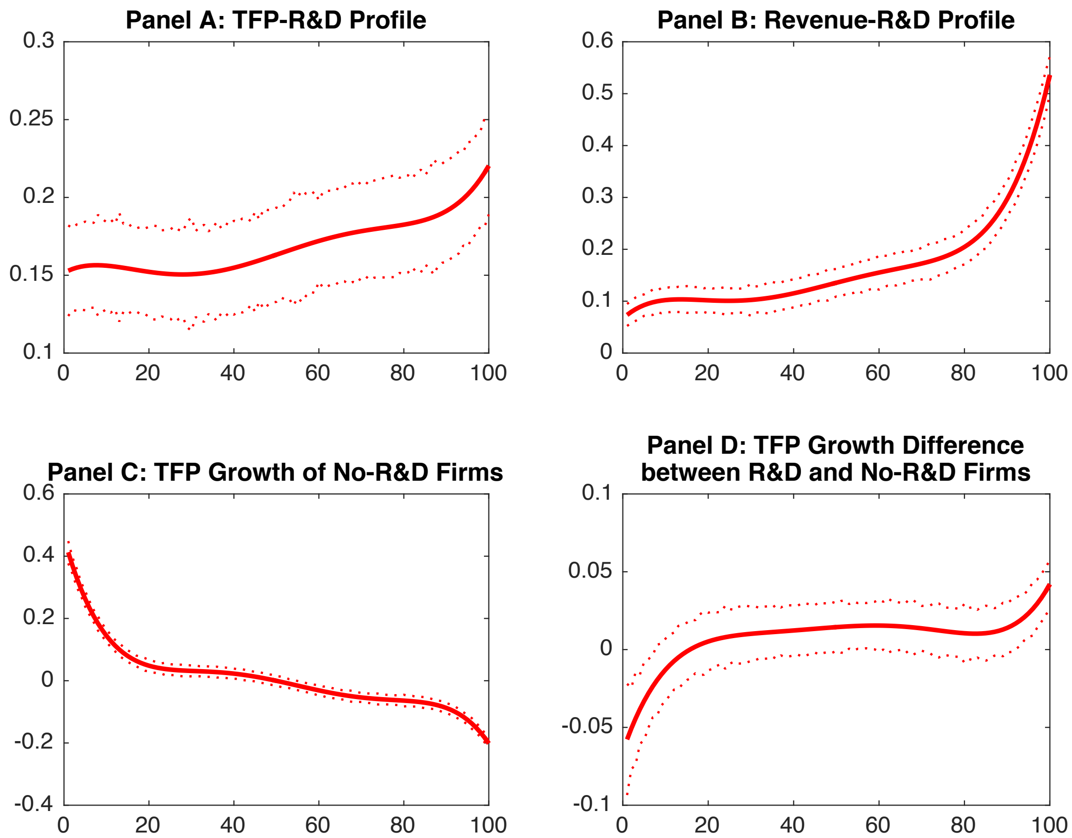


Panel A: TFP-R&D Profile
0.5
0.4
0.3
0.2
0.1
0
0 20 40 60 80 100
Panel B: Revenue-R&D Profile
0.8
0.6
0.4
0.2
0
-0.2
0 20 40 60 80 100
Panel C: TFP Growth of No-R&D Firms
1
0.5
0
-0.5
0 20 40 60 80 100
Panel D: TFP Growth Difference between R&D and No-R&D Firms
0.3
0.2
0.1
0
-0.1
0 20 40 60 80 100

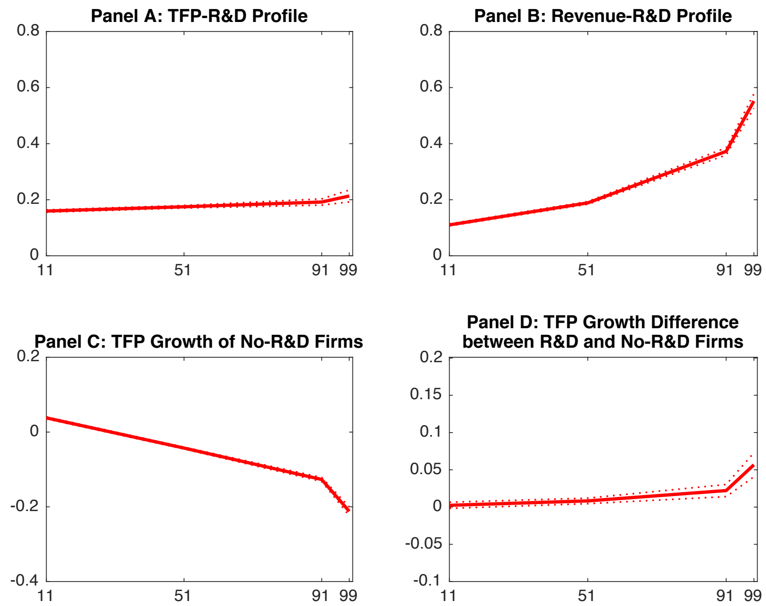


Panel A: TFP-R&D Profile
0.8
0.6
0.4
0.2
0
11 51 91 99
Panel B: Revenue-R&D Profile
0.8
0.6
0.4
0.2
0
11 51 91 99
Panel C: TFP Growth of No-R&D Firms
0.2
0
-0.2
-0.4
11 51 91 99
Panel D: TFP Growth Difference between R&D and No-R&D Firms
0.2
0.15
0.1
0.05
0
-0.05
-0.1
11 51 91 99

China data



Panel A: TFP-R&D Profile
0.3
0.25
0.2
0.15
0.1
0 20 40 60 80 100
Panel B: Revenue-R&D Profile
0.6
0.5
0.4
0.3
0.2
0.1
0
0 20 40 60 80 100
Panel C: TFP Growth of No-R&D Firms
0.6
0.4
0.2
0
-0.2
-0.4
0 20 40 60 80 100
Panel D: TFP Growth Difference between R&D and No-R&D Firms
0.1
0.05
0
-0.05
-0.1
0 20 40 60 80 100



Panel A: TFP-R&D Profile
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0
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0.2
0
-0.2
-0.4
11 51 91 99
Panel D: TFP Growth Difference between R&D and No-R&D Firms
0.2
0.15
0.1
0.05
0
-0.05
-0.1
11 51 91 99

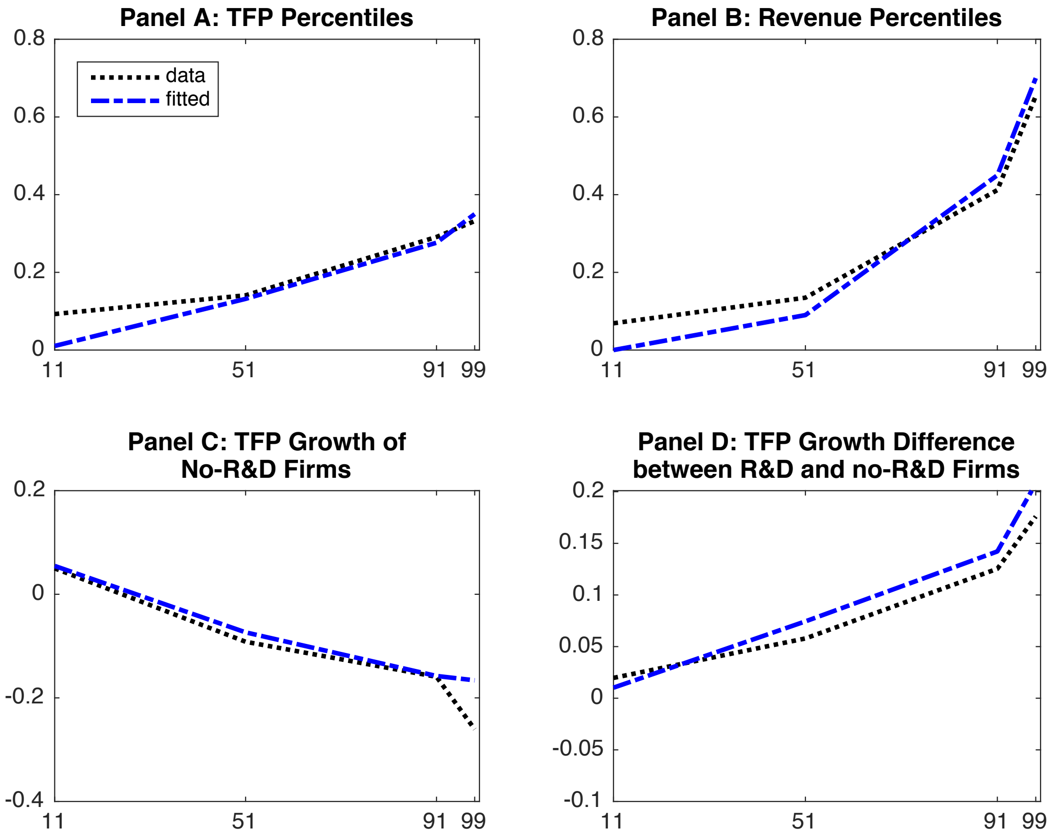
Estimating the model (SMM)

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

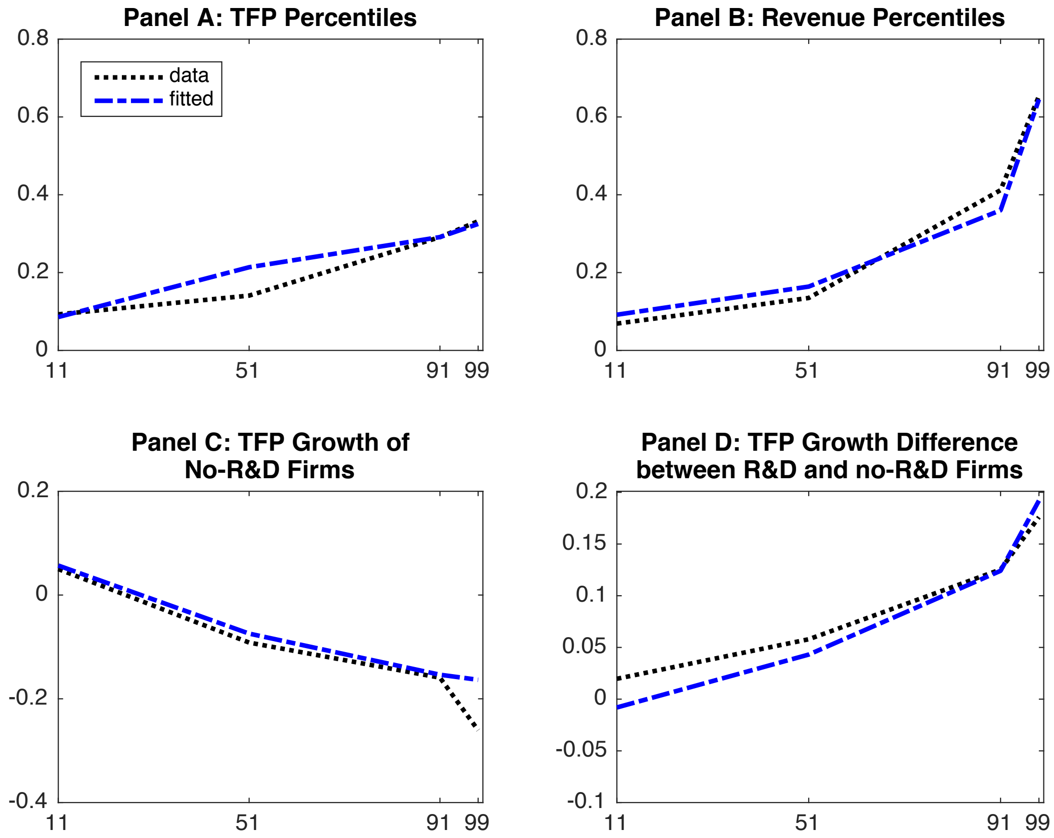
  (percentiles of distributions in 4 panels above)

Estimates for Taiwan: Constant *c*



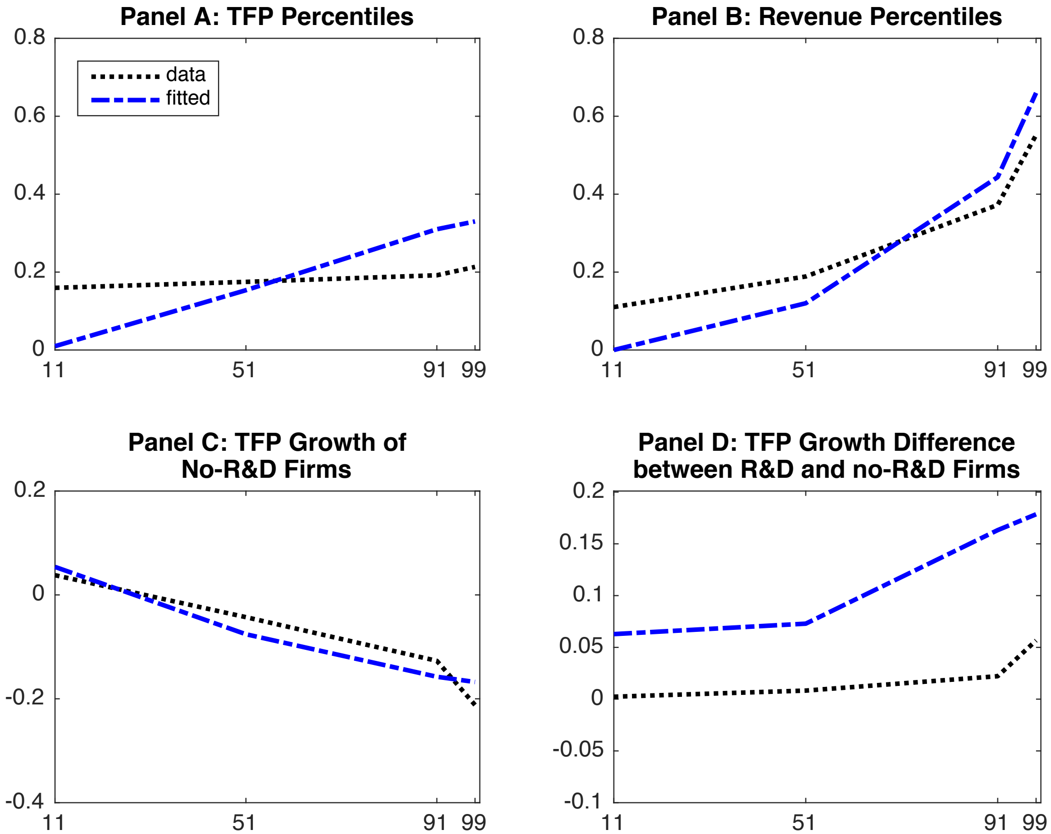
	Estimates for Taiwan
q	0.45
δ	0.40
$\bar{p}$	0.25
c_0	0.52

Estimates for Taiwan: Heteogeneous c



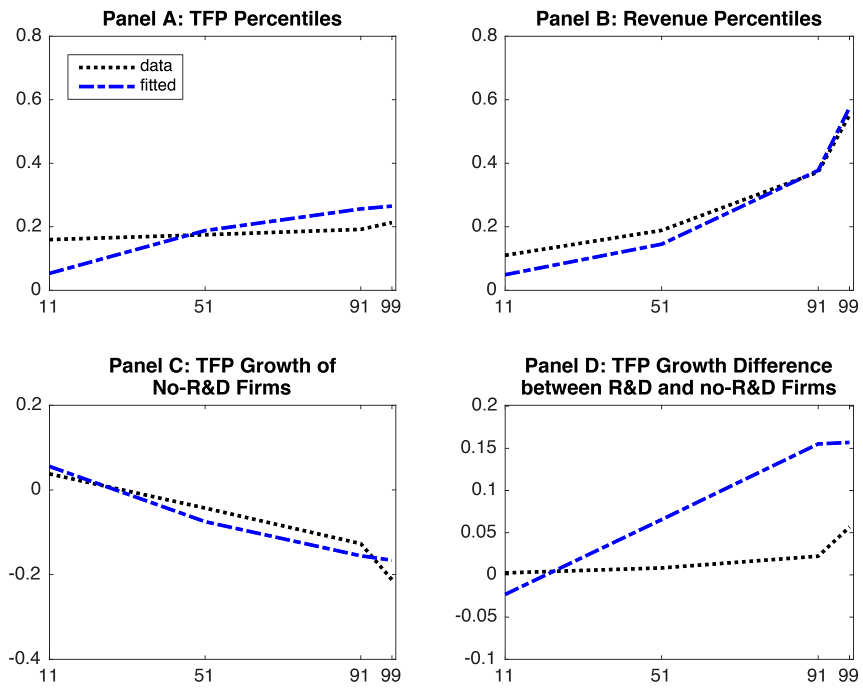
	Estimates for Taiwan
q	0.45
δ	0.50
$\bar{p}$	0.26
mean of c	0.75
std of c	0.59

China Benchmark (Taiwan Based, Re-estimating c Level)



	Estimates for Taiwan
q	0.45
δ	0.40
$\bar{p}$	0.25
	Re-estimated for China
c_0	1.50

China Benchmark (Taiwan Based, Re-estimating c Level)



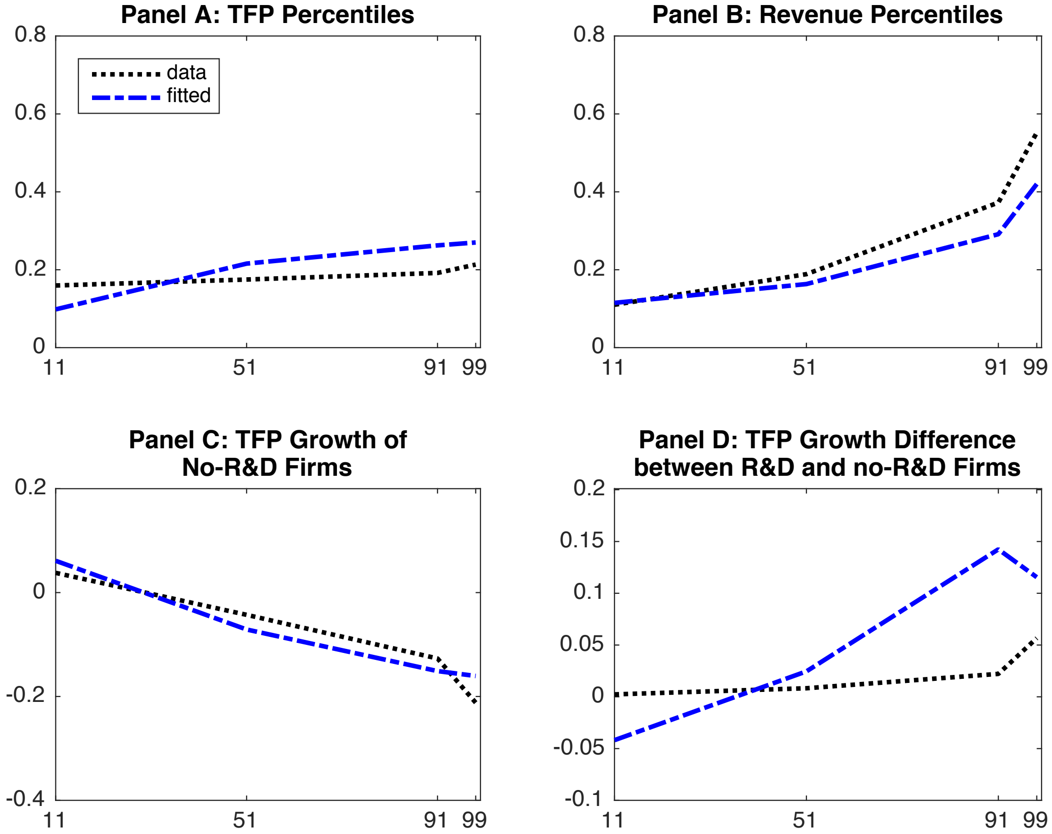
	Estimates for Taiwan
q	0.45
δ	0.50
$\bar{p}$	0.26
std of c	0.59
	Re-estimated for China
mean of c	2.25

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

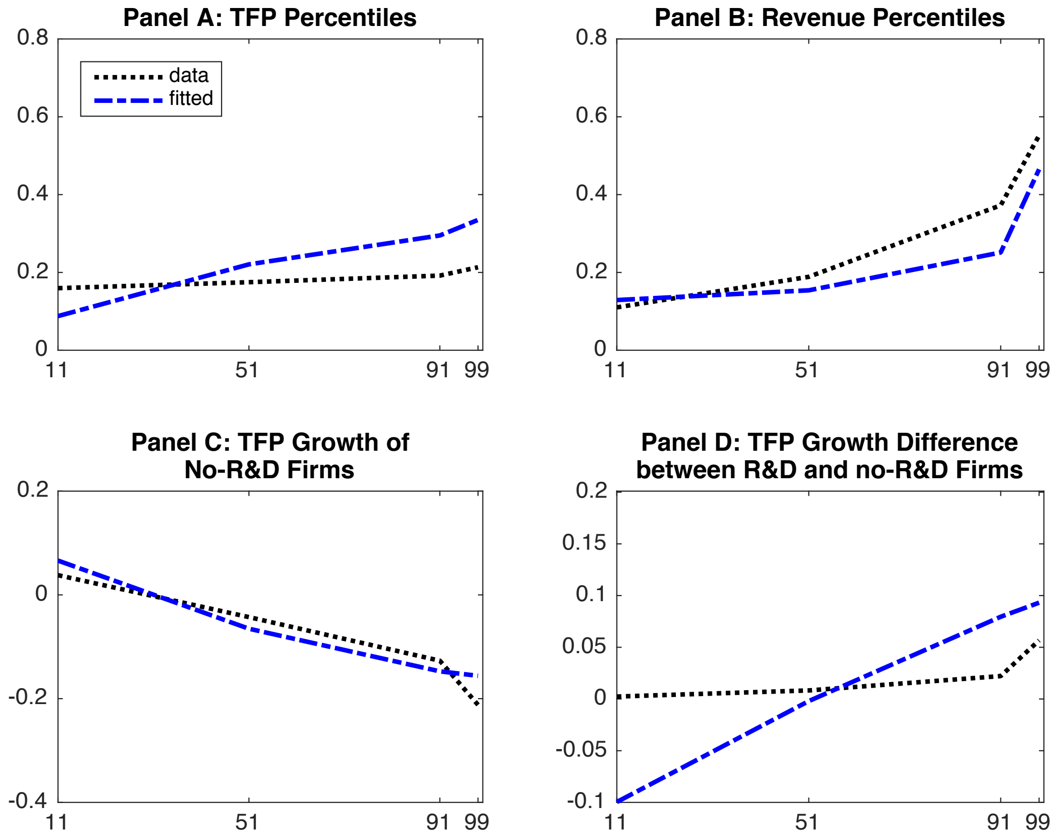
B. Candidate additional mechanisms
   1. Policy distortions scramble decisions (increased dispersion in c)
   2. Scarcity of innovative talent in China (relative to Taiwan, lower)
   3. Moral hazard in R&D

China Attempt 1: Scrambling (Estimating c Distribution)



	Estimates for Taiwan
q	0.45
δ	0.50
$\bar{p}$	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
δ	0.50
	Re-estimated for China
$\bar{p}$	**0.15**
mean of c	2.00
std of c	2.40

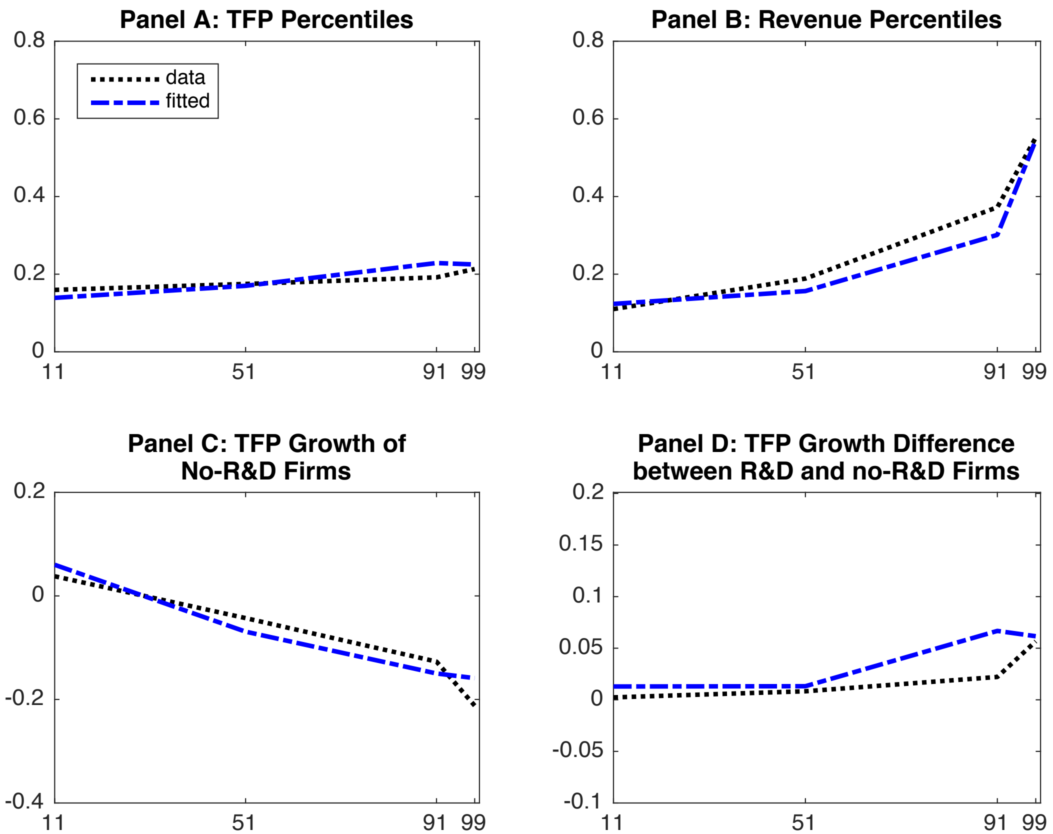
Moral Hazard in R&D

- 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 ε are likely to fake R&D
- Allow ε_i to be correlated with A_i and τ_i:

$$\hat{c}_i = \varepsilon_i + c_1 logA_i + c_2 log(1 - \tau_i).$$

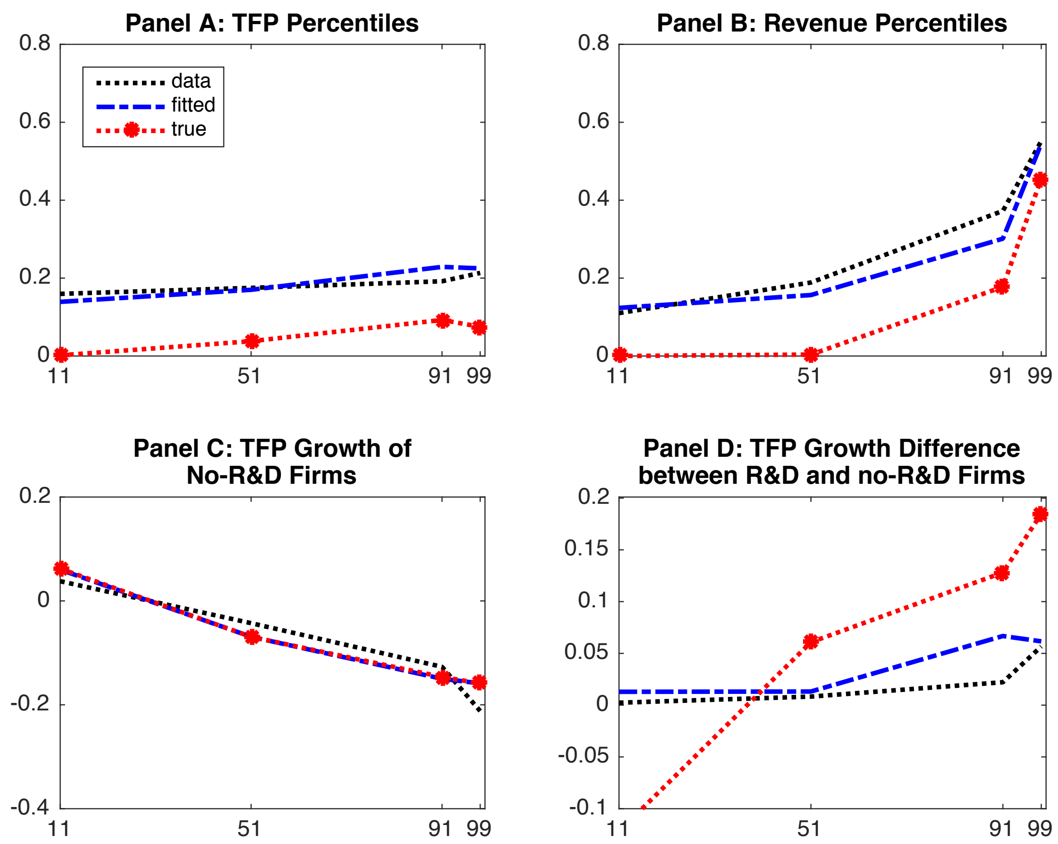
  - $c_1 > 0$: Government supports more productive firms (subsidizes R&D in high-A firms)
  - $c_2 > 0$: Government supports its darlings (subsidizes R&D in low-τ firms, e.g. SOE)

China Attempt 3: Moral Hazard in R&D

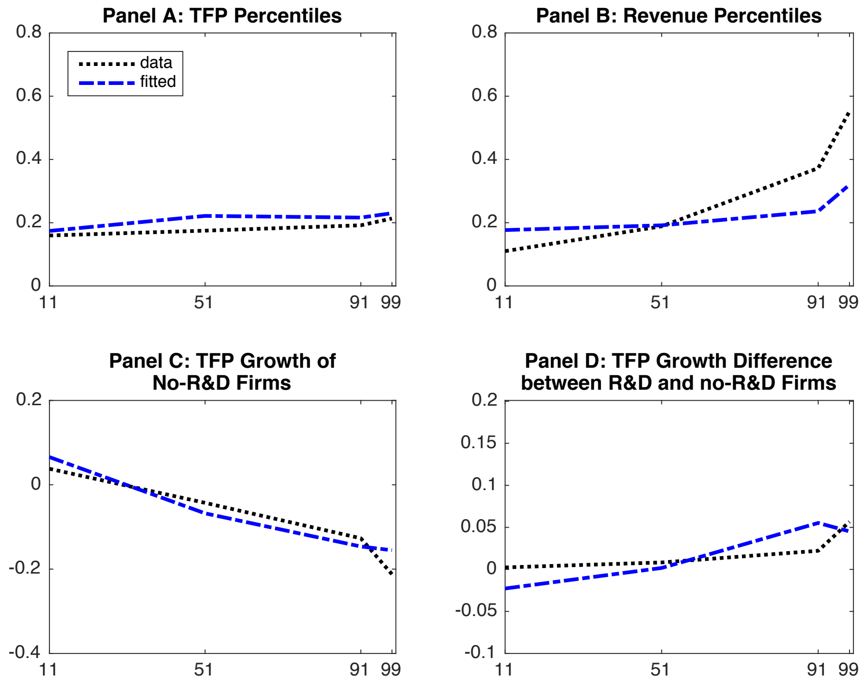


	Estimates for Taiwan
q	0.45
δ	0.40
$\bar{p}$	0.25
	Re-estimated for China
mean of c	**3.50**
	Fake R&D
mean of ε	0.50
std of ε	**0.95**
c_1	**-0.21**
c_2	**-0.23**

Fake R&D Firms



Robustness Check (Re-estimating All Parameters for China)



	Estimates for China
q	0.45
δ	**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)