Structural Adjustments and International Trade:

Theory and Evidence from China[1]

Hanwei Huang[1] Jiandong Ju[2] Vivian Yue [3]

[1]London School of Economics

[2]Tsinghua University and Shanghai University of Finance and Economics

[3]Emory University, Atlanta Fed and NBER

April 2016

[1]The views expressed herein are those of the authors and should not be interpreted as reflecting the views of the Federal Reserve Bank of Atlanta.

Motivation

- China has experienced fast capital deepening and trade liberalization
- How do manufacturing production and exports adjust to trade liberalization and capital deepening in China?
- Study structural adjustment in production and trade for China in recent years
  - Reallocation across industries
  - Reallocation across firms in an industry

Motivation

- China has experienced fast capital deepening and trade liberalization
- How do manufacturing production and exports adjust to trade liberalization and capital deepening in China?
- Study structural adjustment in production and trade for China in recent years
  - Reallocation across industries
  - Reallocation across firms in an industry

This Paper

- Provide new empirical facts
  Compare production and export in China's manufactural industries between 1999 and 2007

- Construct a theoretical model
  - Embed heterogeneous firm (Melitz 2003) into continuous Ricardian and Heckscher-Ohlin framework

- Analyze the driving forces behind these structural adjustments
  - Equilibrium properties and numerical comparative statics
  - Structural estimation and counterfactuals to isolate the driving forces of the structural adjustments
  - Welfare analysis and productivity decomposition

This Paper

- Provide new empirical facts
  Compare production and export in China's manufactural industries between 1999 and 2007

- Construct a theoretical model
  - Embed heterogeneous firm (Melitz 2003) into continuous Ricardian and Heckscher-Ohlin framework

- Analyze the driving forces behind these structural adjustments
  - Equilibrium properties and numerical comparative statics
  - Structural estimation and counterfactuals to isolate the driving forces of the structural adjustments
  - Welfare analysis and productivity decomposition

This Paper

- Provide new empirical facts
  Compare production and export in China's manufactural industries between 1999 and 2007

- Construct a theoretical model
  - Embed heterogeneous firm (Melitz 2003) into continuous Ricardian and Heckscher-Ohlin framework

- Analyze the driving forces behind these structural adjustments
  - Equilibrium properties and numerical comparative statics
  - Structural estimation and counterfactuals to isolate the driving forces of the structural adjustments
  - Welfare analysis and productivity decomposition

Main Findings

- Chinese manufacturing production shifts toward capital intensive industries.
- Chinese firms in labor intensive industries increase the export participation and export intensity.
- China's TFP growth is biased toward labor intensive industry.
- Capital deepening, trade liberalization and technology progress account for structural adjustment in China.
- Endogenous firm selection contributes 12 percent of total productivity growth and affects Ricardian comparative advantage.
- China and RoW benefit from China's structural adjustment.

Main Findings

- Chinese manufacturing production shifts toward capital intensive industries.
- Chinese firms in labor intensive industries increase the export participation and export intensity.
- China's TFP growth is biased toward labor intensive industry.
- Capital deepening, trade liberalization and technology progress account for structural adjustment in China.
- Endogenous firm selection contributes 12 percent of total productivity growth and affects Ricardian comparative advantage.
- China and RoW benefit from China's structural adjustment.

Main Findings

- Chinese manufacturing production shifts toward capital intensive industries.
- Chinese firms in labor intensive industries increase the export participation and export intensity.
- China's TFP growth is biased toward labor intensive industry.
- Capital deepening, trade liberalization and technology progress account for structural adjustment in China.
- Endogenous firm selection contributes 12 percent of total productivity growth and affects Ricardian comparative advantage.
- China and RoW benefit from China's structural adjustment.

Main Findings

- Chinese manufacturing production shifts toward capital intensive industries.
- Chinese firms in labor intensive industries increase the export participation and export intensity.
- China's TFP growth is biased toward labor intensive industry.
- Capital deepening, trade liberalization and technology progress account for structural adjustment in China.
- Endogenous firm selection contributes 12 percent of total productivity growth and affects Ricardian comparative advantage.
- China and RoW benefit from China's structural adjustment.

Data and Motivating Evidence

- Chinese Annual Industrial Survey
  - Manufacturing firms in year 1999 and 2007

- Changes in production and export participation
  Capital intensity $(1 - \frac{\text{labor cost}}{\text{value added}}) \in [0, 1]$

Variables	mean in 1999	mean in 2007
capital income share	0.669	0.707
proportion of exporters	0.252	0.248
exports/gross sales	0.181	0.207
capital income share for exporters	0.624	0.619

Industry and Capital Intensity

Capital Intensity by Industries according to China Industry Code

industry code	description	mean	std	non-exporters	exporters
18	Manufacture of of Apparel, Footwear & Caps	0.51	0.24	0.60	0.24
25	Processing of Petroleum, Coking, &Fuel	0.78	0.20	0.85	0.16
37	Manufacture of Transport Equipment	0.65	0.21	0.70	0.21
39	Electrical Machinery & Equipment	0.61	0.23	0.73	0.21
40	Computers & Other Electronic Equipment	0.58	0.25	0.65	0.23

- "Heckscher-Ohlin Aggregates" (Schott (2003), Ju, Lin and Wang (2015))
- Regroup Firms into 100 bins according to their *capital* intensity

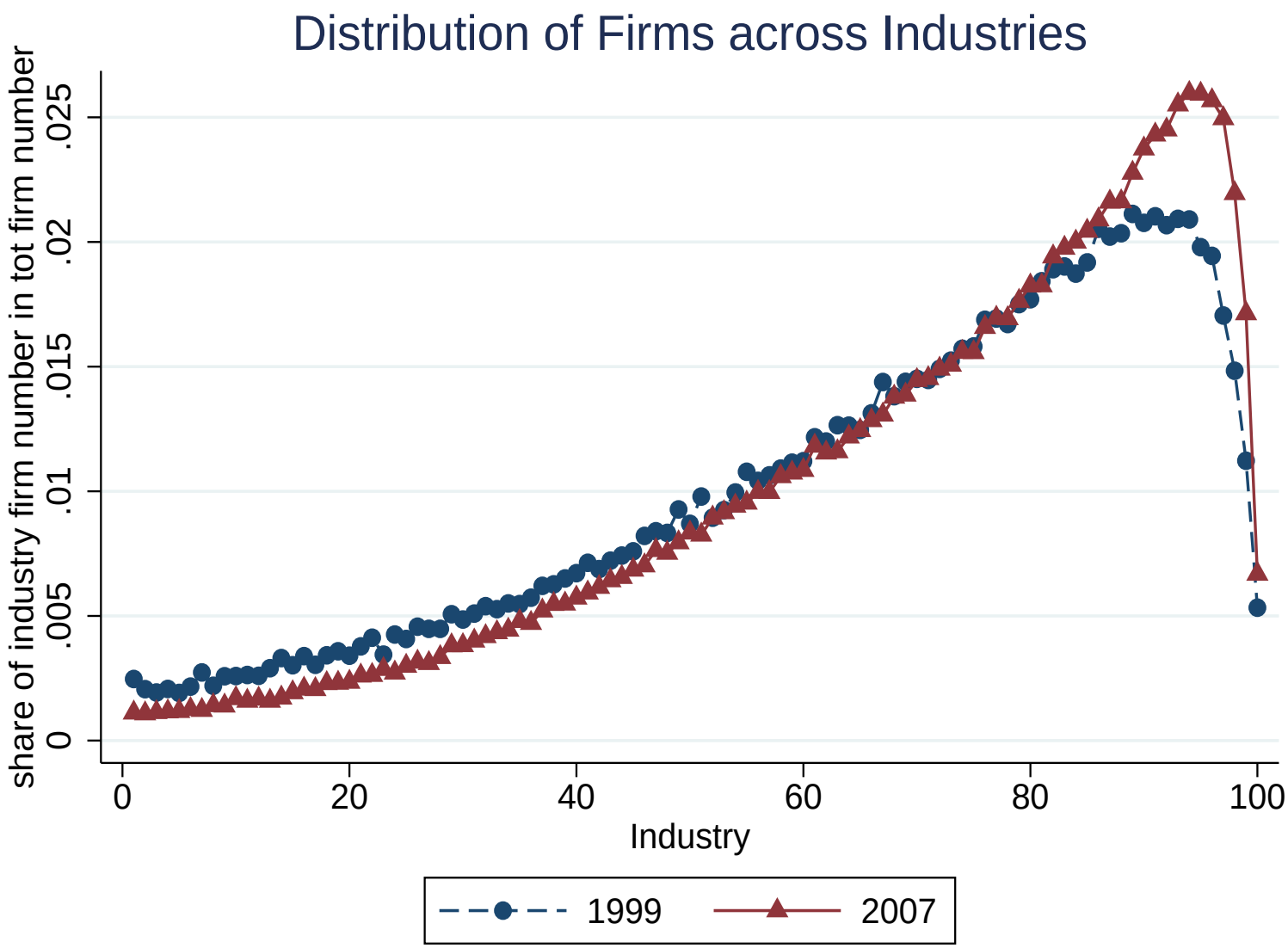
Industry and Capital Intensity

Capital Intensity by Industries according to China Industry Code

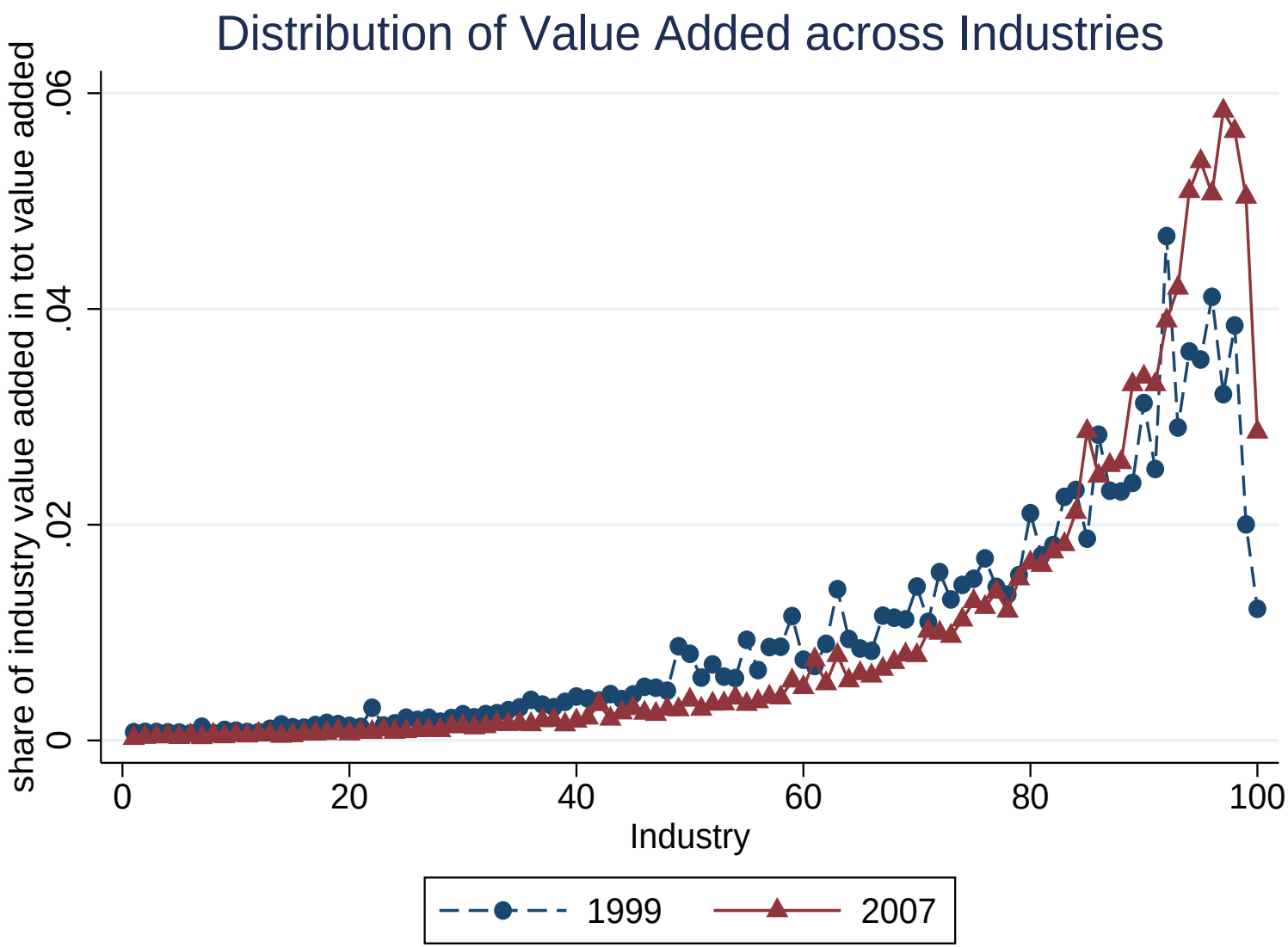
industry code	description	mean	std	non-exporters	exporters
18	Manufacture of of Apparel, Footwear & Caps	0.51	0.24	0.60	0.24
25	Processing of Petroleum, Coking, &Fuel	0.78	0.20	0.85	0.16
37	Manufacture of Transport Equipment	0.65	0.21	0.70	0.21
39	Electrical Machinery & Equipment	0.61	0.23	0.73	0.21
40	Computers & Other Electronic Equipment	0.58	0.25	0.65	0.23

- "Heckscher-Ohlin Aggregates" (Schott (2003), Ju, Lin and Wang (2015))
- Regroup Firms into 100 bins according to their *capital* intensity

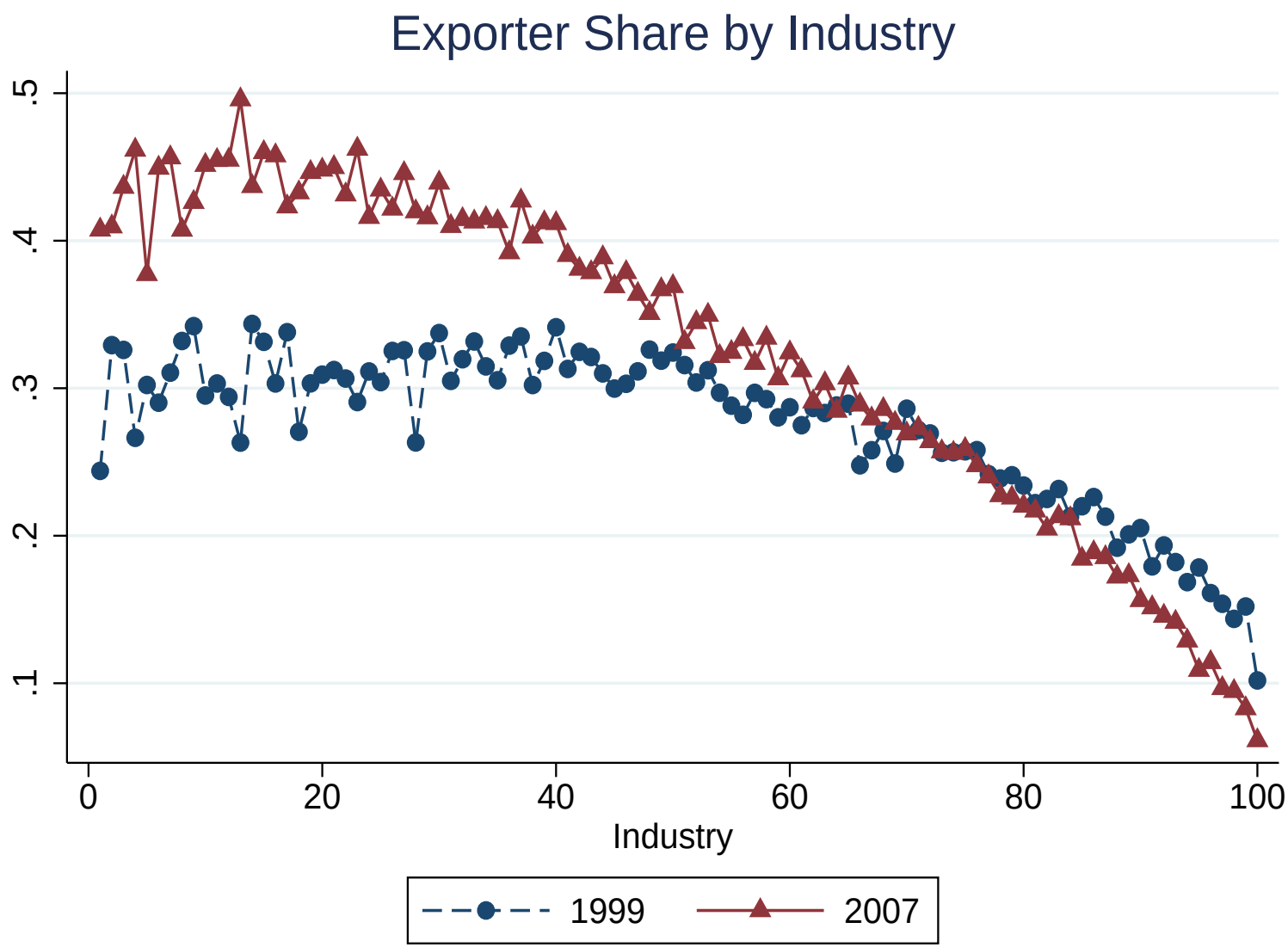
Motivating Evidence: Production Pattern



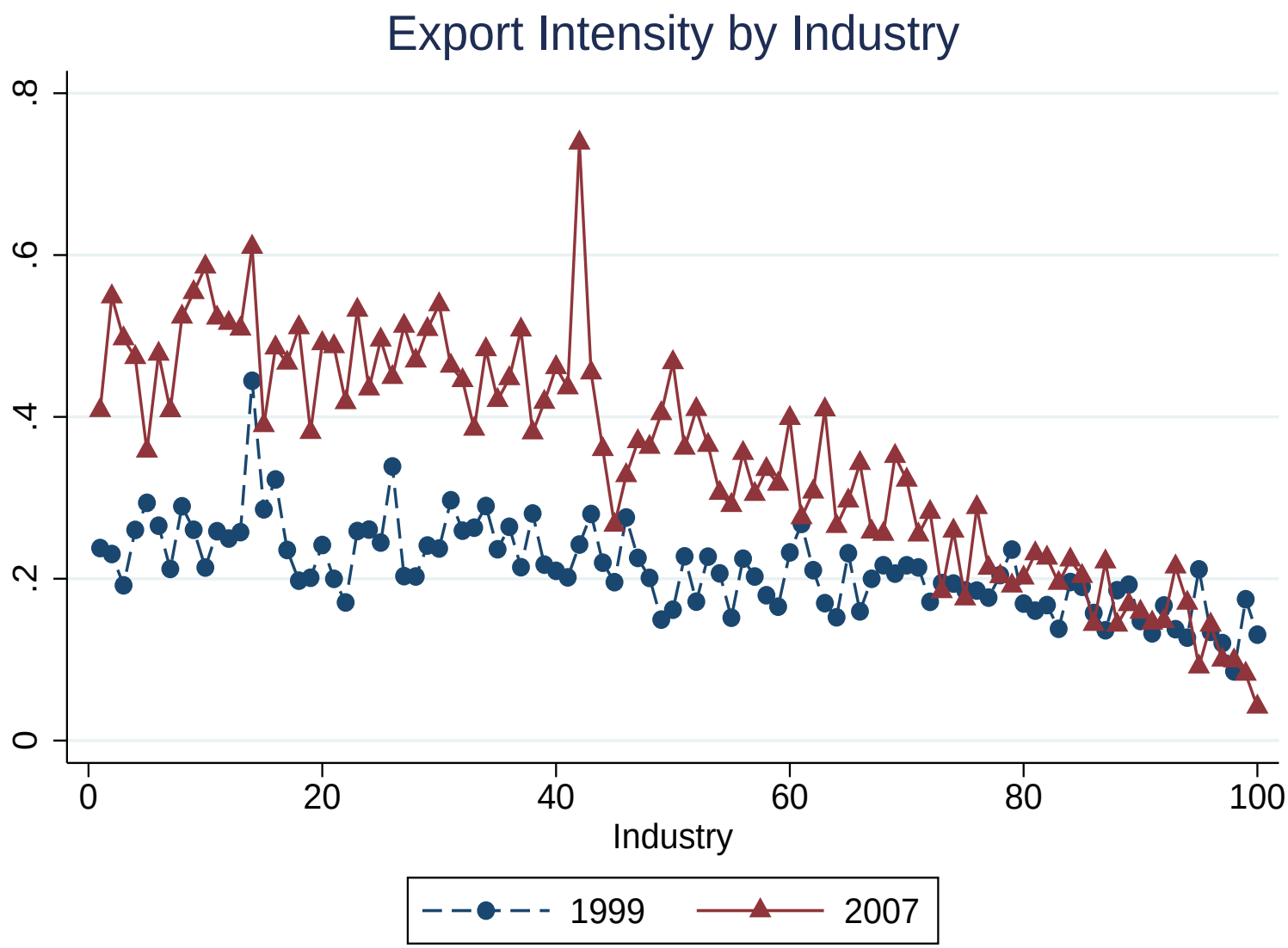
Motivating Evidence: Production Pattern



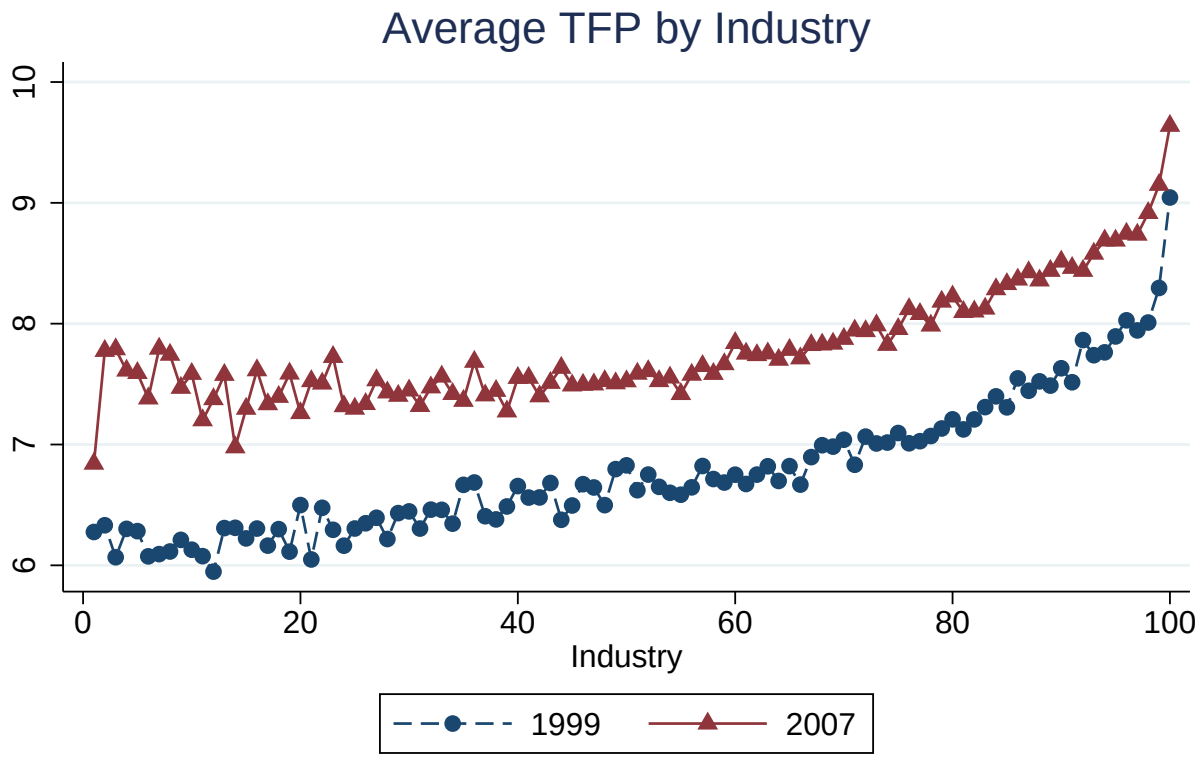
Motivating Evidence: Trade Pattern



Motivating Evidence: Trade Pattern



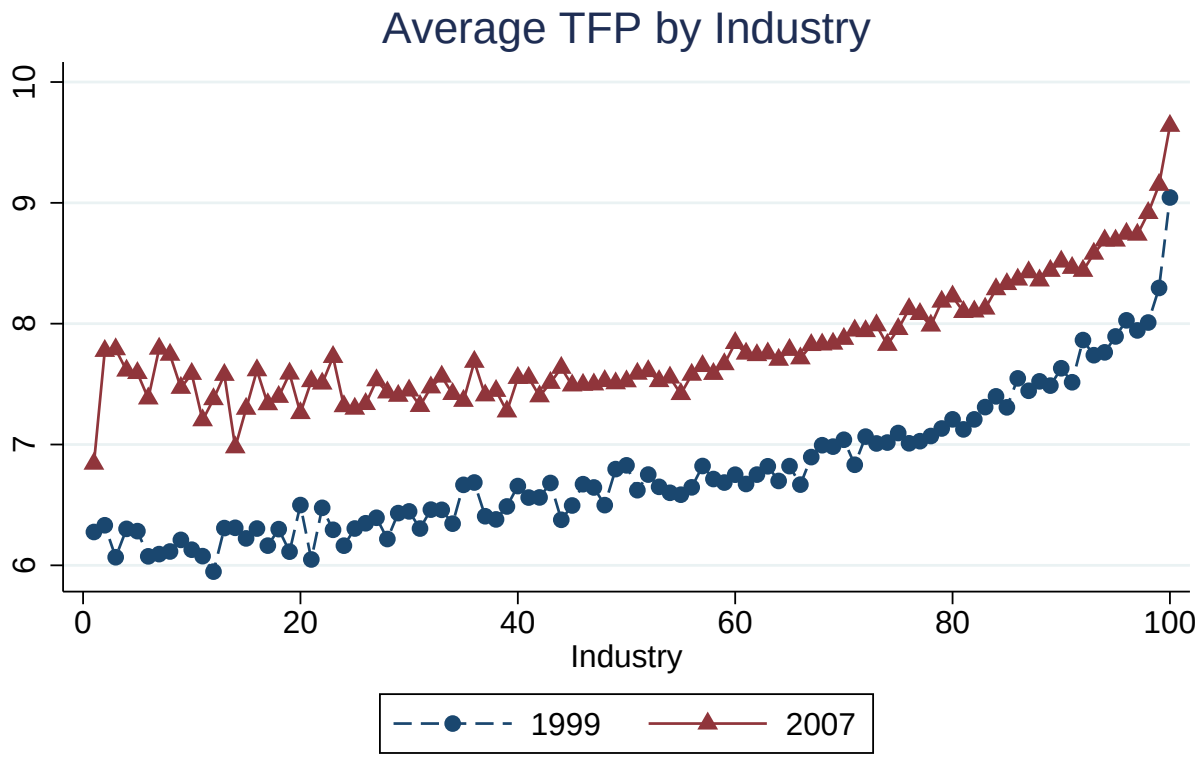
Motivating Evidence: Productivity Growth



value in log, weighted average of firm TFP estimated by LP

- TFP calculated using Levinsohn and Petrin (2003) method
- TFP growth drives China's growth Zhu (2012)

Motivating Evidence: Productivity Growth



value in log, weighted average of firm TFP estimated by LP

- TFP calculated using Levinsohn and Petrin (2003) method
- TFP growth drives China's growth Zhu (2012)

Empirical Findings

- Chinese manufacturing production shifts toward capital intensive industries.
- Chinese firms in labor intensive industries increase the export participation and export intensity.
- China's TFP growth is biased toward labor-intensive industry .

Model Overview

- DFS Heckscher-Ohlin and Ricardian
  - 2 countries,2 factors, continuum of industries, continuum of firms
  - Country H is more labor-abundant than Country F
  - Industries differ in factor intensity

- Melitz
  - Sunk cost of entry (uses both factors)
  - After entry, firms observe their productivity, φ, drawn from $G(\varphi)$
  - Constant (exogenous) probability of firm death
  - Fixed costs of production and export (common skill intensity)
  - Decide whether to produce (export) or to exit the industry

Model Overview

- DFS Heckscher-Ohlin and Ricardian
  - 2 countries,2 factors, continuum of industries, continuum of firms
  - Country H is more labor-abundant than Country F
  - Industries differ in factor intensity

- Melitz
  - Sunk cost of entry (uses both factors)
  - After entry, firms observe their productivity, φ, drawn from $G(\varphi)$
  - Constant (exogenous) probability of firm death
  - Fixed costs of production and export (common skill intensity)
  - Decide whether to produce (export) or to exit the industry

The Model:

- Factor endowment: $\frac{L}{K} > \frac{L^*}{K^*}$
- Consumption

$$U = \int_0^1 b(z) \ln Q(z) dz, \quad \int_0^1 b(z) dz = 1$$

$$Q(z) = \left(\int_{\omega \in \Omega_z} q_z(\omega)^\rho \, d\omega + \int_{\omega \in \Omega_z^*} q_z(\omega)^\rho \, d\omega \right)^{1/\rho}$$

- Production (cost) for industry z with idiosyncratic shock φ

$$\Gamma(z, \varphi) = \left(f_z + \frac{q(z, \varphi)}{A(z)\varphi} \right) r^z w^{1-z}$$

  - $A(z)$ is industry specific productivity, where $\frac{A(z)}{A^*(z)} = \lambda A^z$,

The Model:

- Factor endowment: $\frac{L}{K} > \frac{L^*}{K^*}$
- Consumption

$$U = \int_0^1 b(z) \ln Q(z) dz, \quad \int_0^1 b(z) dz = 1$$

$$Q(z) = \left(\int_{\omega \in \Omega_z} q_z(\omega)^\rho \, d\omega + \int_{\omega \in \Omega_z^*} q_z(\omega)^\rho \, d\omega \right)^{1/\rho}$$

- Production (cost) for industry z with idiosyncratic shock φ

$$\Gamma(z, \varphi) = \left(f_z + \frac{q(z, \varphi)}{A(z)\varphi} \right) r^z w^{1-z}$$

  - $A(z)$ is industry specific productivity, where $\frac{A(z)}{A^*(z)} = \lambda A^z$,

The Model:

- Factor endowment: $\frac{L}{K} > \frac{L^*}{K^*}$
- Consumption

$$U = \int_0^1 b(z) \ln Q(z) dz, \quad \int_0^1 b(z) dz = 1$$

$$Q(z) = \left(\int_{\omega \in \Omega_z} q_z(\omega)^\rho \, d\omega + \int_{\omega \in \Omega_z^*} q_z(\omega)^\rho \, d\omega \right)^{1/\rho}$$

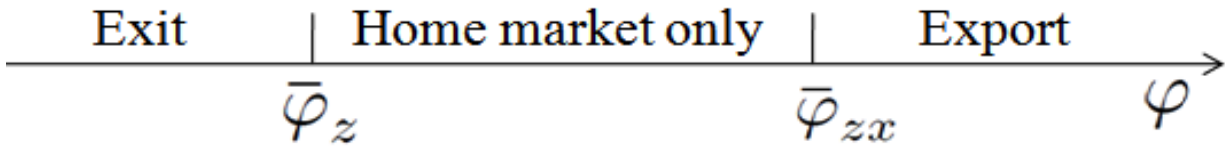
- Production (cost) for industry z with idiosyncratic shock φ

$$\Gamma(z, \varphi) = \left(f_z + \frac{q(z, \varphi)}{A(z)\varphi} \right) r^z w^{1-z}$$

  - $A(z)$ is industry specific productivity, where $\frac{A(z)}{A^*(z)} = \lambda A^z$,

The Model:

- The decision of firms:

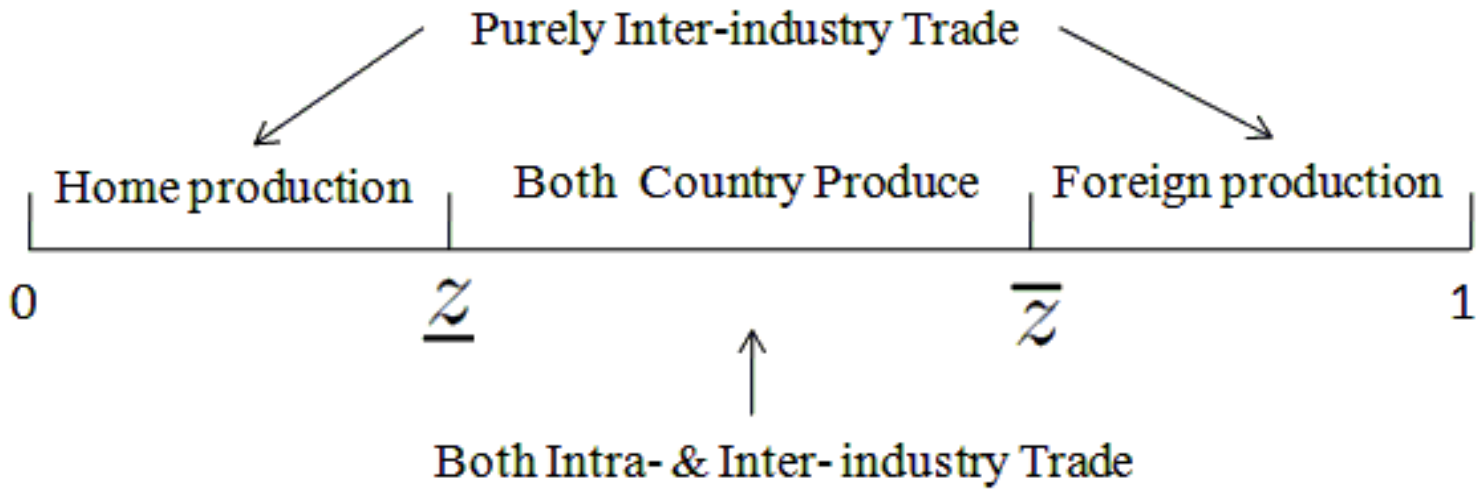


- The conditional probability of export is:

$$\chi_z \equiv \frac{1 - G(\bar{\varphi}_{zx})}{1 - G(\bar{\varphi}_z)}$$

Production and International Trade Patterns

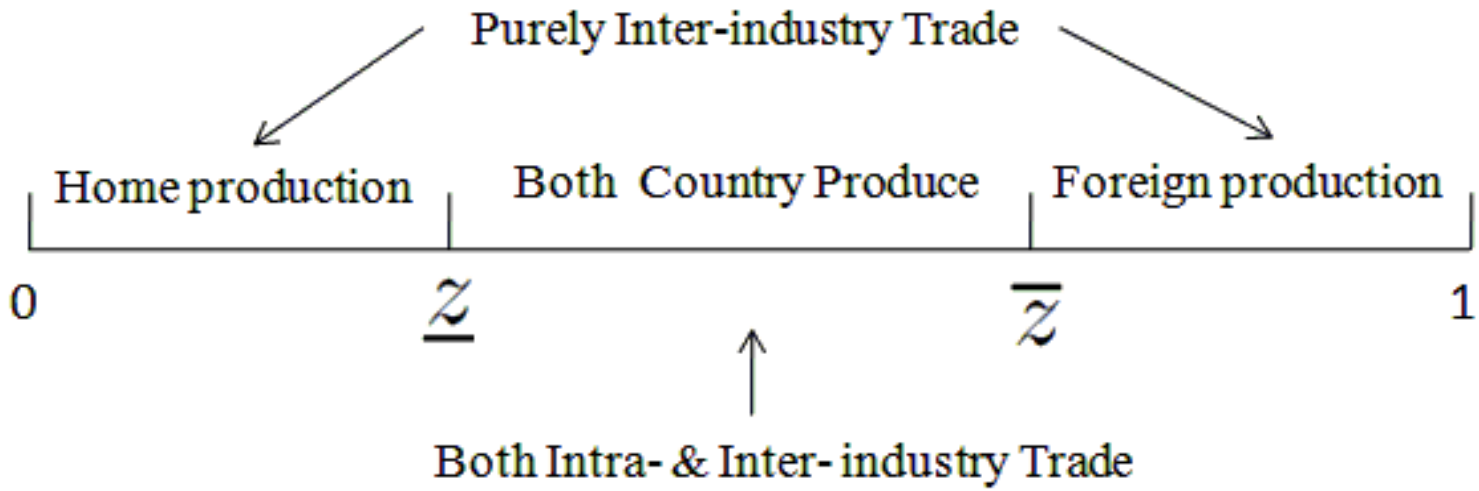
- There exist two factor intensity cut-offs $0 \leq \underline{z} < \overline{z} \leq 1$ s.t.
  country H specializes in the industries within $[0, \underline{z}]$
  country F specializes in the industries within $[\overline{z}, 1]$



- If $\tau = 1$ and $f_{zx} = f_z, \forall z$, then $\underline{z} = \overline{z}$: complete specialization.
- Generalization of Bernard, Redding and Schott (2007).

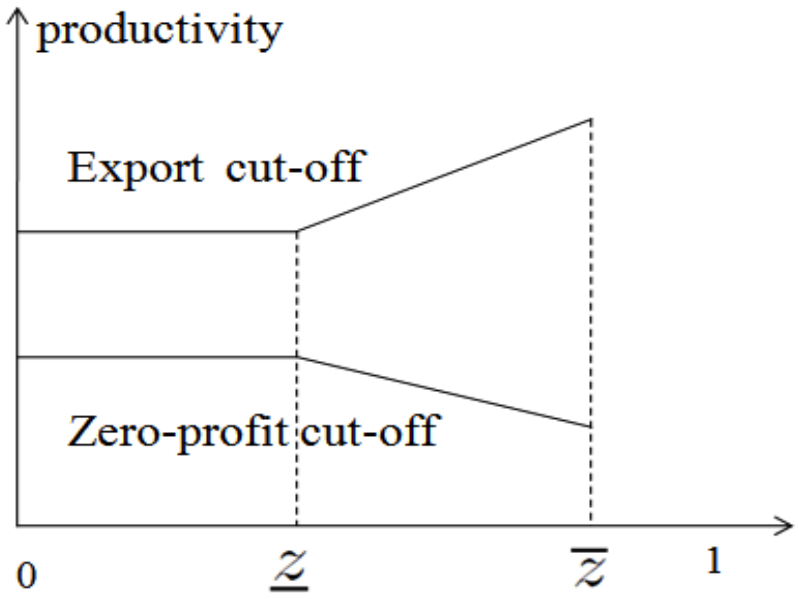
Production and International Trade Patterns

- There exist two factor intensity cut-offs $0 \leq \underline{z} < \overline{z} \leq 1$ s.t.
  country H specializes in the industries within $[0, \underline{z}]$
  country F specializes in the industries within $[\overline{z}, 1]$

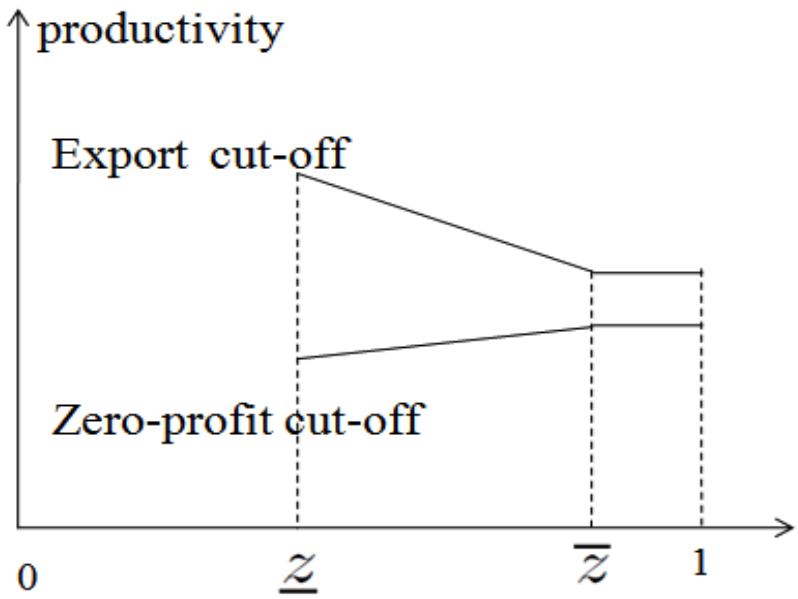


- If $\tau = 1$ and $f_{zx} = f_z, \forall z$, then $\underline{z} = \overline{z}$: complete specialization.
- Generalization of Bernard, Redding and Schott (2007).

Productivity Cut-offs across Industries in Home and Foreign Countries



(a): labor abundant home



(b): capital abundant foreign

Export Probability and Export Intensity

- Assume Pareto distribution for firm specific productivity

$$g(\varphi) = a\theta^a \varphi^{-(a+1)}, a+1 > \sigma$$

- The conditional probability of export is:

$$\chi_z = \begin{cases} \frac{R^*}{fR} & z \in [0, \underline{z}] \\ \frac{\widetilde{\tau}^{-a} f - \varepsilon(z)^a h(z)}{\varepsilon(z)^a f h(z) - \widetilde{\tau}^a} & z \in (\underline{z}, \overline{z}) \end{cases}$$

- How does export probability vary across industries?

$$\frac{\partial \chi_z}{\partial z} = \underbrace{\frac{a(1-\widetilde{\tau}^{-2a} f^2)\varepsilon(z)^a h(z)}{(\varepsilon(z)^a f h(z) - \widetilde{\tau}^a)^2}}_{(+)} [\underbrace{\ln(A)}_{\text{Ricardian CA}} - \frac{\sigma}{\sigma - 1} \underbrace{\ln(\frac{r/w}{r^*/w^*})}_{\text{HO CA}}]$$

Export Probability and Export Intensity

- Assume Pareto distribution for firm specific productivity

$$g(\varphi) = a\theta^a \varphi^{-(a+1)}, a+1 > \sigma$$

- The conditional probability of export is:

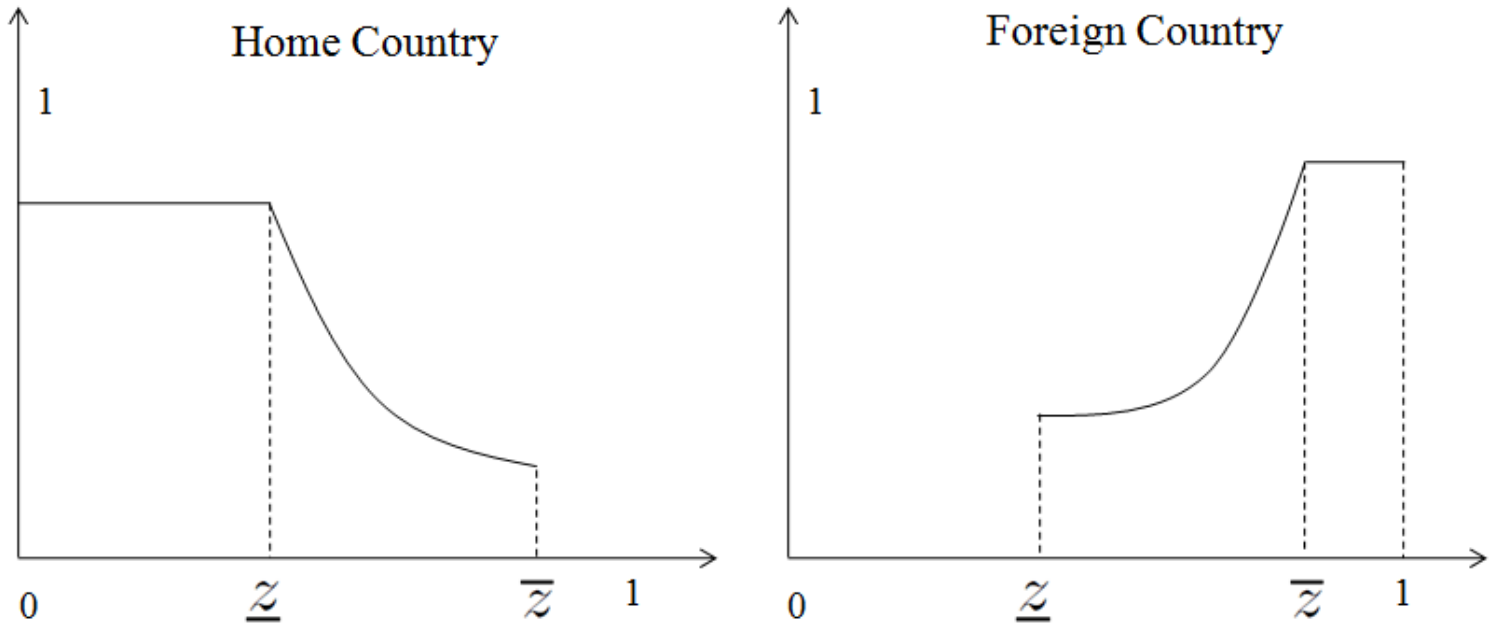
$$\chi_z = \begin{cases} \frac{R^*}{fR} & z \in [0, \underline{z}] \\ \frac{\widetilde{\tau}^{-a} f - \varepsilon(z)^a h(z)}{\varepsilon(z)^a f h(z) - \widetilde{\tau}^a} & z \in (\underline{z}, \overline{z}) \end{cases}$$

- How does export probability vary across industries?

$$\frac{\partial \chi_z}{\partial z} = \underbrace{\frac{a(1-\widetilde{\tau}^{-2a} f^2)\varepsilon(z)^a h(z)}{(\varepsilon(z)^a f h(z) - \widetilde{\tau}^a)^2}}_{(+)} [\underbrace{\ln(A)}_{\textbf{Ricardian CA}} - \frac{\sigma}{\sigma - 1} \underbrace{\ln(\frac{r/w}{r^*/w^*})}_{\textbf{HO CA}}]$$

Export Probability and Export Intensity

- Export intensity $\gamma_z = \frac{f\chi_z}{1+f\chi_z}$
- Export probability and export intensity in H and F



- Labor intensive sectors in labor abundant country
  - High exporter participation. Exporter export large fraction of output

Structural Estimation for Quantitative Analysis

- parameters taken as given

parameters	value	source
σ	3.43	Broda & Weinstein (2006)
a	2.76	Defever & Riaño (2014)
L^*/L	$year_{1999}$: 2.49 $year_{2007}$: 2.22	World Bank
f	$year_{1999}$: 1.00 $year_{2007}$: 1.77	Industry average. Own calculation
$b(z)$		Linear interpolated from industry expenditure data. Own calculation

- Estimate f as the average of $\frac{\gamma_z}{\chi_z(1-\gamma_z)}$ across all sectors.
- Expenditure function $b(z)$: infer import for each industry (industry 1 to 100) by matching the firm data with the custom data for year 2000-2006.

Structural Estimation for Quantitative Analysis

- GMM estimation to fit the distribution of output and export across industries in 1999 and 2007 respectively.
- Data: Target Moments (used in the estimation)

year	1999	2007
Manufacturing output of RoW vs China: R^*/R	16.74	7.47
Mean exporter share: z$\in [0, 0.5]$	0.313	0.421
Mean exporter share: z$\in [0.5, 1]$	0.241	0.234
capital intensity weighted by firm mass	0.668	0.708
capital intensity weighted by export firm mass	0.625	0.621

Notes: R^*/R is calculated using the ratio of manufacturing output for RoW and China (World Bank)

Model Estimation Results

- Estimation results
- Estimate $\{\frac{K^*}{K}, K/L, A, \lambda, \tau\}$ to match the target moments

parameters	$\frac{K^*}{K}$	K/L	A	λ	τ
1999	3.45	0.93	1.25	0.132	2.95
2007	2.90	2.03	0.847	0.378	2.09

- We find that the TFP growth of China relative to RoW is labor-bias: the more labour intensive sectors growth enjoys a faster productivity growth relative to RoW.

Model Fit

- Target Moments: data v.s. model

year	data 1999	data 2007	model 1999	model 2007
R^*/R	16.74	7.47	16.74	7.47
exporter share: $z \leq 0.5$	0.31	0.42	0.31	0.42
exporter share: $z \geq 0.5$	0.239	0.233	0.236	0.228
capital intensity for all firms	0.67	0.71	0.66	0.69
capital intensity for exporters	0.62	0.62	0.63	0.63

Model Fit

- Non-targeted moments: data v.s. model

year	data 1999	data 2007	model 1999	model 2007
aggregate exporter share	0.252	0.248	0.240	0.230
aggregate export intensity	0.181	0.208	0.188	0.284
capital income share	0.761	0.830	0.790	0.768
wage RoW vs China: w*/w			6.43	2.90

- Wedges to explain capital income share Karabarbounis and Neiman (2014), Chang *et al* (2015)
- According to ILO, the world wage grew by 60.6% and the wage in China grew by 168% during 1999-2007.

Model Fit

- Non-targeted moments: data v.s. model

year	data 1999	data 2007	model 1999	model 2007
aggregate exporter share	0.252	0.248	0.240	0.230
aggregate export intensity	0.181	0.208	0.188	0.284
capital income share	0.761	0.830	0.790	0.768
wage RoW vs China: w*/w			6.43	2.90

- Wedges to explain capital income share Karabarbounis and Neiman (2014), Chang *et al* (2015)
- According to ILO, the world wage grew by 60.6% and the wage in China grew by 168% during 1999-2007.

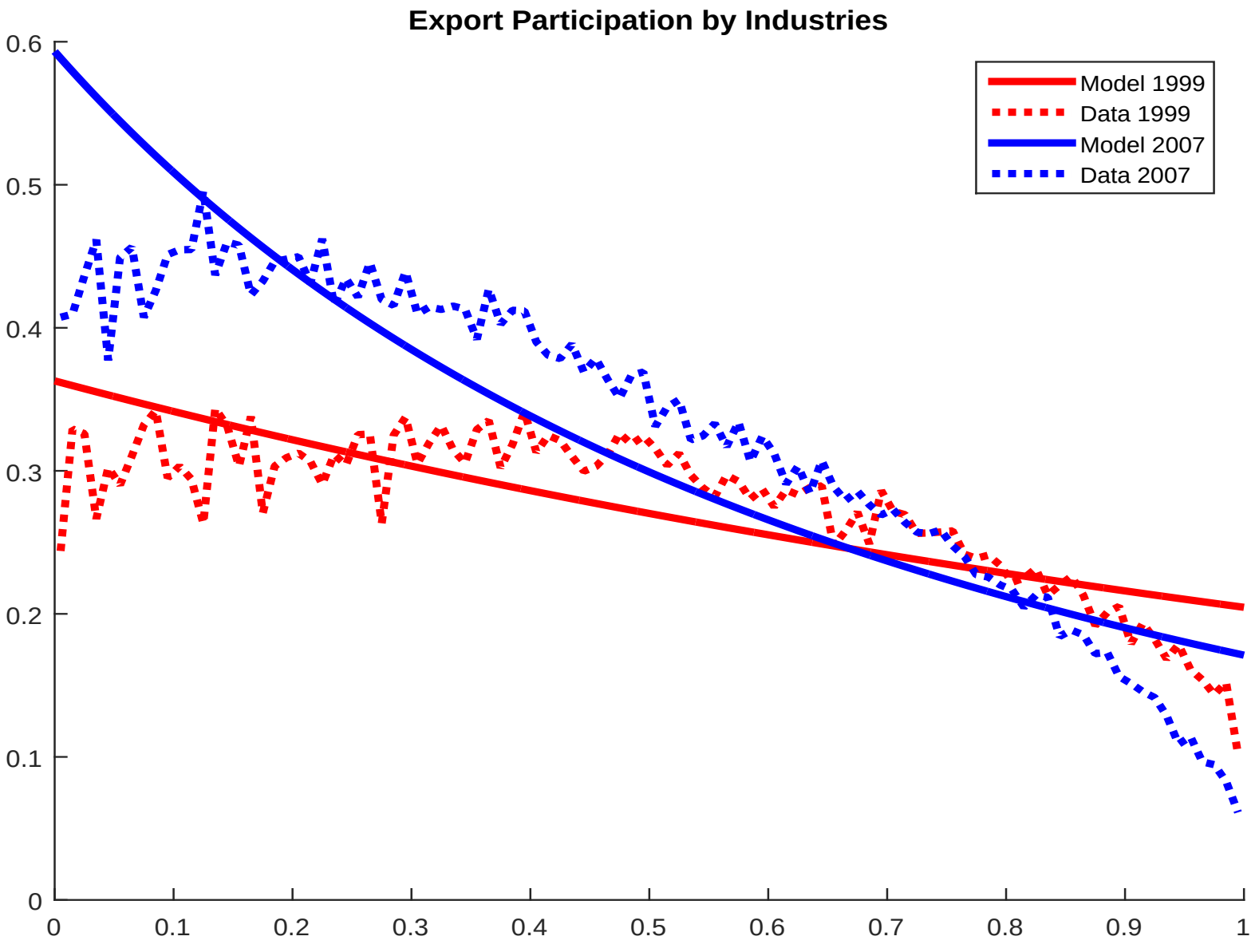
Model Fit

- Non-targeted moments: data v.s. model

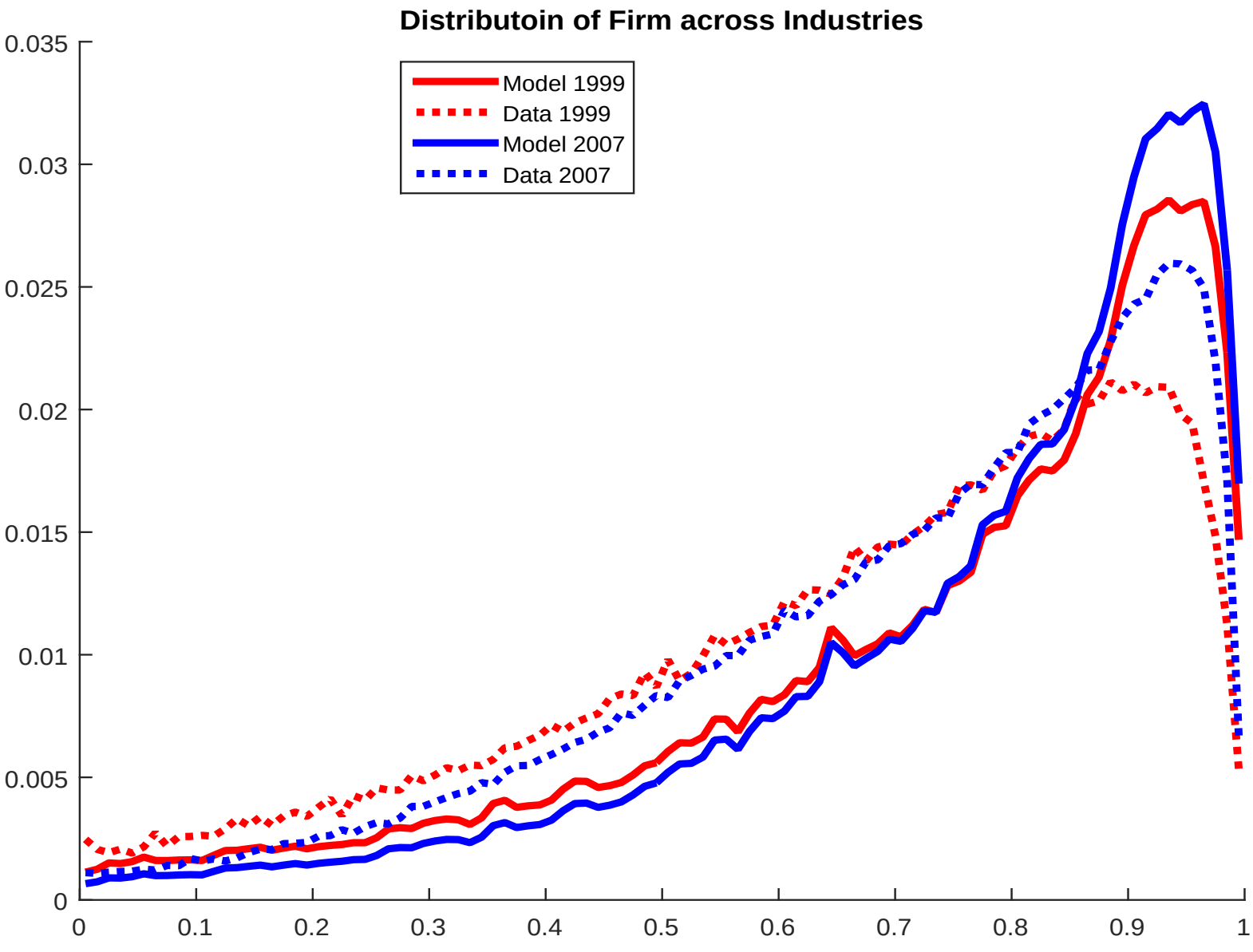
year	data 1999	data 2007	model 1999	model 2007
aggregate exporter share	0.252	0.248	0.240	0.230
aggregate export intensity	0.181	0.208	0.188	0.284
capital income share	0.761	0.830	0.790	0.768
wage RoW vs China: w*/w			6.43	2.90

- Wedges to explain capital income share Karabarbounis and Neiman (2014), Chang *et al* (2015)
- According to ILO, the world wage grew by 60.6% and the wage in China grew by 168% during 1999-2007.

Model Fit


Export Participation by Industries
Model 1999
Data 1999
Model 2007
Data 2007
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Model Fit


Distributoin of Firm across Industries
Model 1999
Data 1999
Model 2007
Data 2007
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Decompose Ricardian Comparative advantage

- First decomposition of Ricardian comparative advantage into exogenous and endogenous components (Bernard, Redding and Schott (2007)).
- Average TFP for each sector is

$$\widehat{A(z)} = E_{\varphi}\{A(z)\varphi | \varphi > \overline{\varphi}_z\} = A(z)\widetilde{\varphi}_z$$

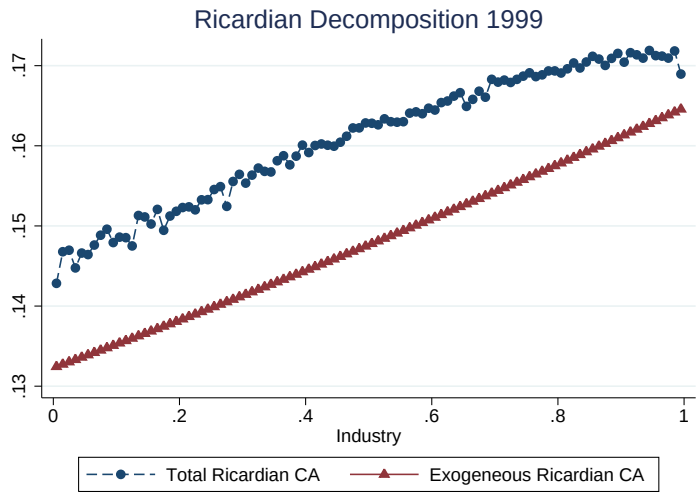
Thus the measured Ricardian Comparative advantage is

$$\frac{\widehat{A(z)}}{\widehat{A^*(z)}} = \frac{A(z)}{A^*(z)} \frac{\widetilde{\varphi}_z}{\widetilde{\varphi}_z^*}$$

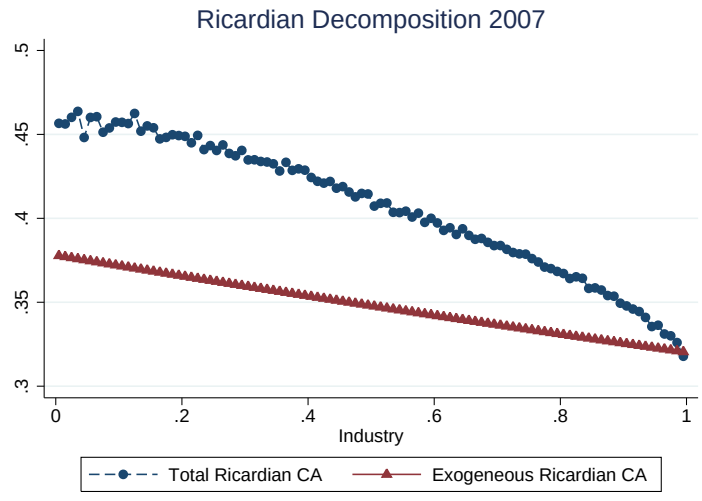
- Given our functional assumptions, we can prove that

$$\frac{\widehat{A(z)}}{\widehat{A^*(z)}} = \underbrace{\lambda A^z}_{exo.} \underbrace{\left(\frac{1+f\chi_z}{1+f\chi_z^*}\right)^{1/a}}_{endo.}$$

Decompose Ricardian Comparative advantage

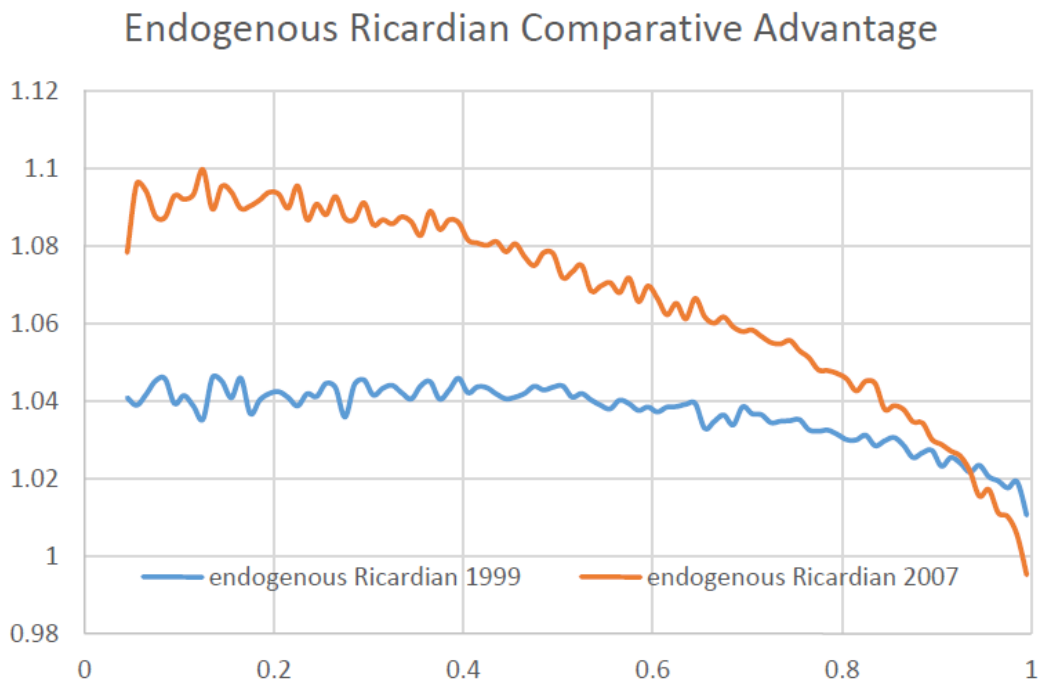


(a)



(b)

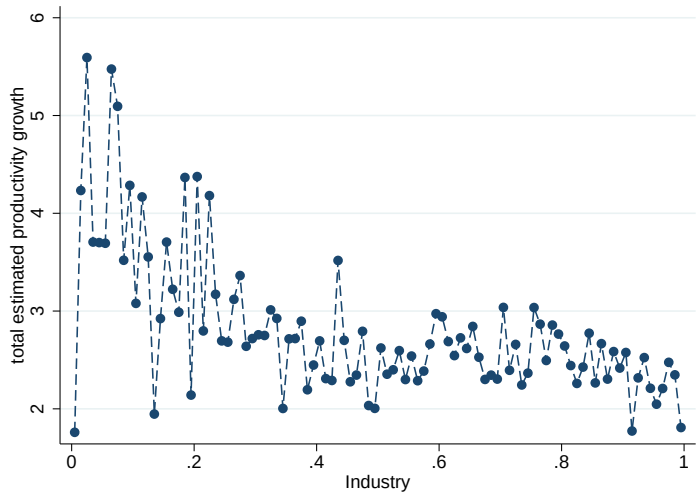
Decompose Ricardian Comparative advantage



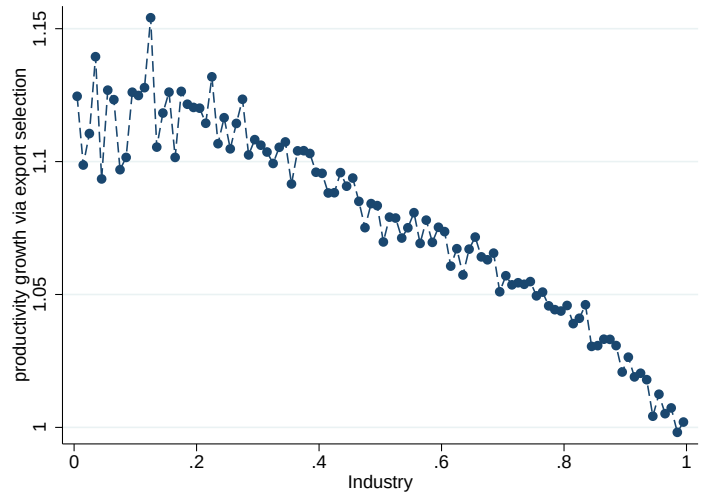
Total Ricardian comparative advantage are amplified by the endogenous firm selection mechanism.

Endogenous Selection Implied Productivity

Total Productivity Growth and Productivity Growth due to Firm Selection



(c)

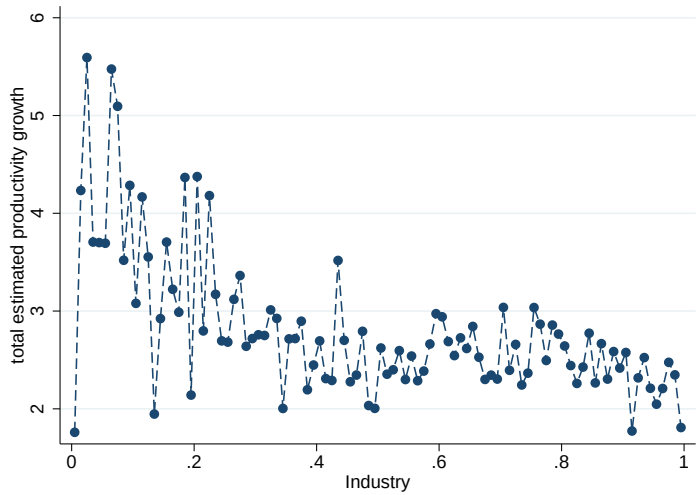


(d)

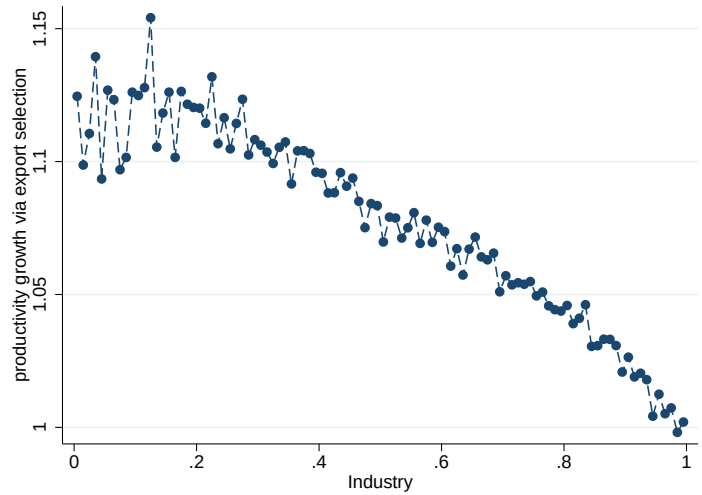
- Firm selection contributes about 11.7% of the total productivity growth.
- TFP growth in China: Hsieh and Klenow (2009), Song et al (2011), Brandt et al (2012), Tombe and Zhu (2015), Chang et al (2016).

Endogenous Selection Implied Productivity

Total Productivity Growth and Productivity Growth due to Firm Selection



(e)



(f)

- Firm selection contributes about 11.7% of the total productivity growth.
- TFP growth in China: Hsieh and Klenow (2009), Song et al (2011), Brandt et al (2012), Tombe and Zhu (2015), Chang et al (2016).

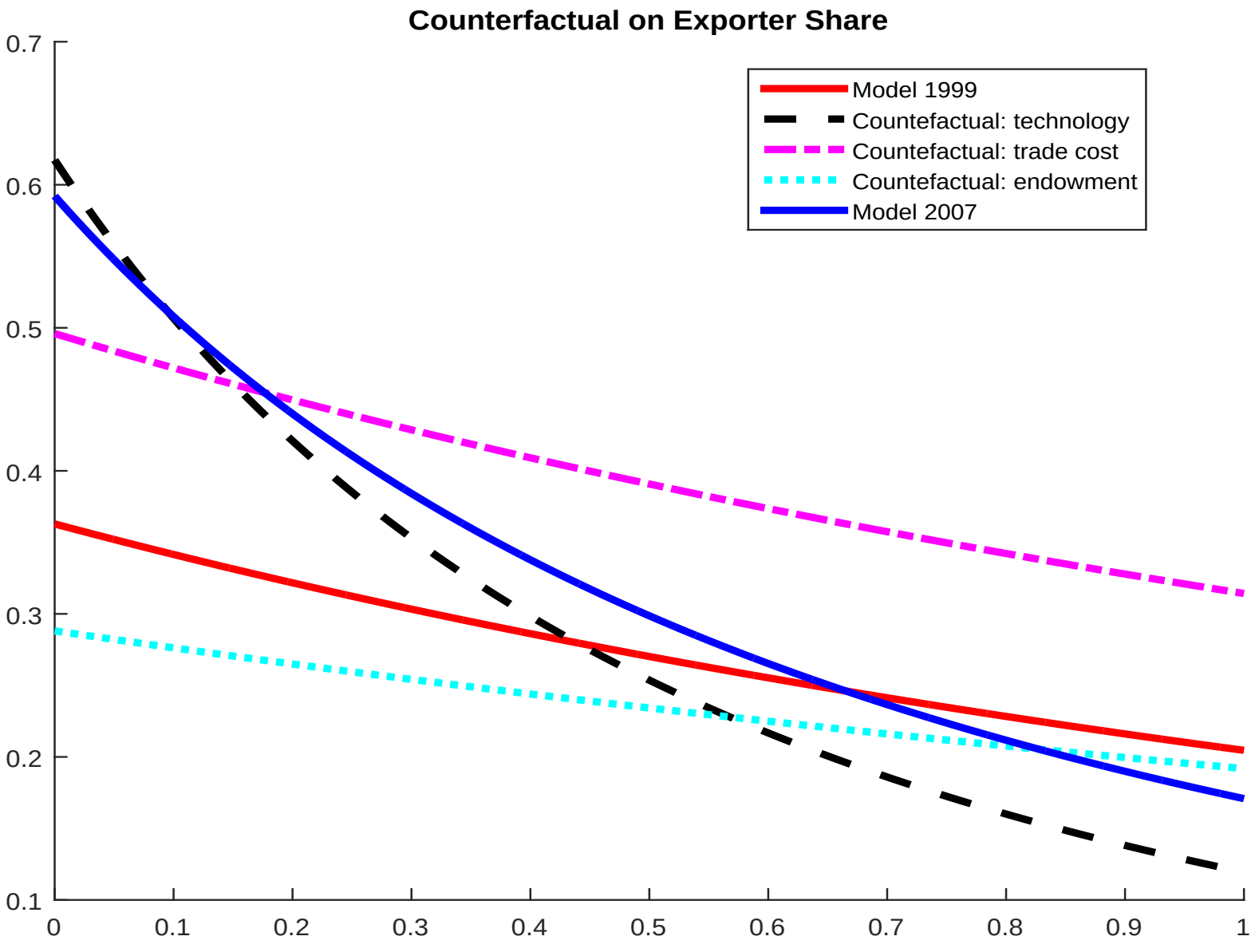
Counterfactual Experiments and Welfare Analysis

- Counterfactual experiments to change one channel of structural adjustment
  - Technology
  - Trade cost
  - Endowment
- Welfare analysis

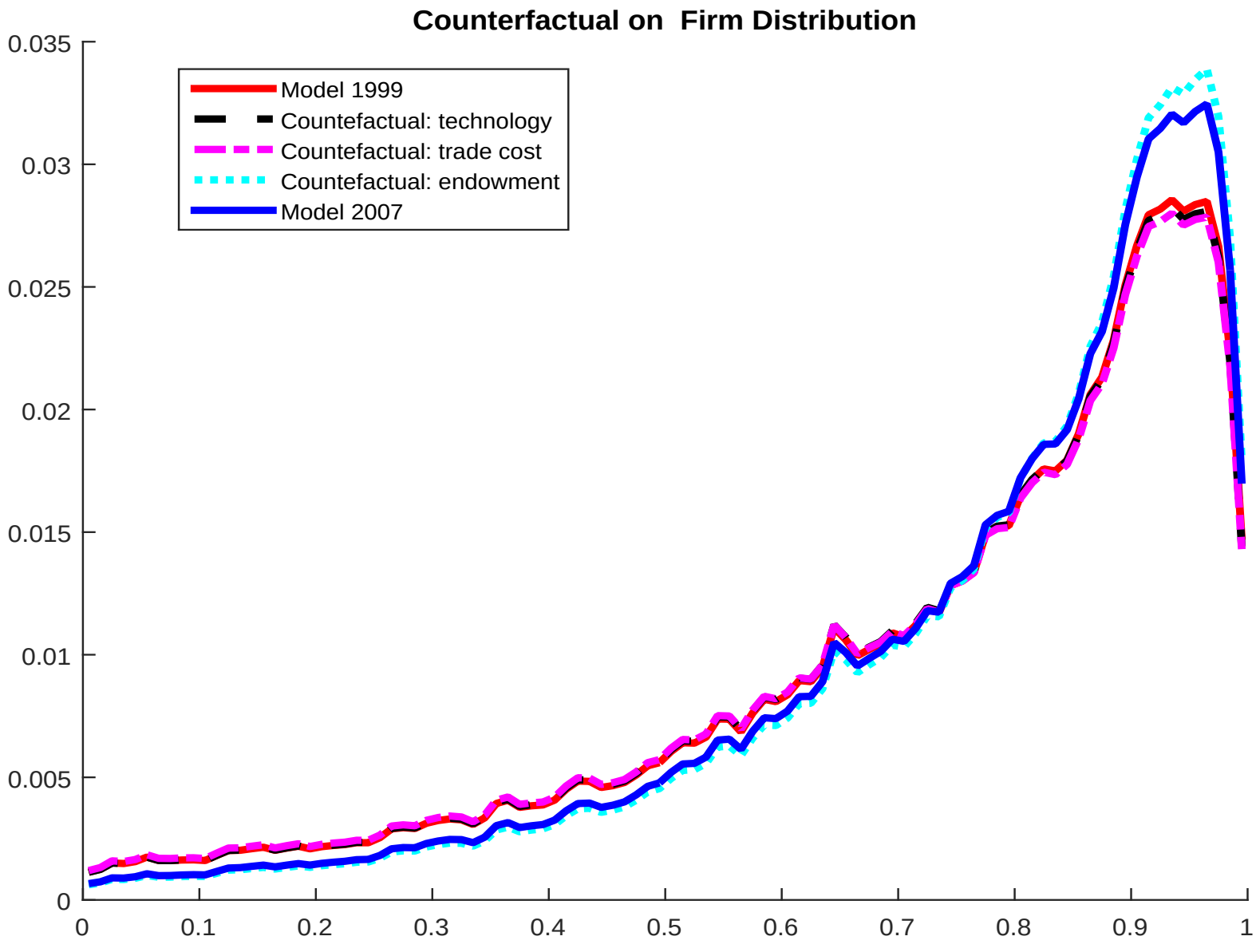
Structural Adjustment under Counterfactuals

year	model 1999	A and λ 2007	f and τ 2007	endm't 2007
R^*/R	16.74	9.17	16.09	13.98
exporter share: $z \leq 0.5$	0.314	0.402	0.440	0.261
exporter share: $z \geq 0.5$	0.236	0.177	0.350	0.212
capital intensity for all firms	0.659	0.658	0.655	0.694
capital intensity for exporters	0.631	0.567	0.633	0.678
aggregate exporter share	0.240	0.193	0.355	0.211
aggregate export intensity	0.189	0.147	0.379	0.173

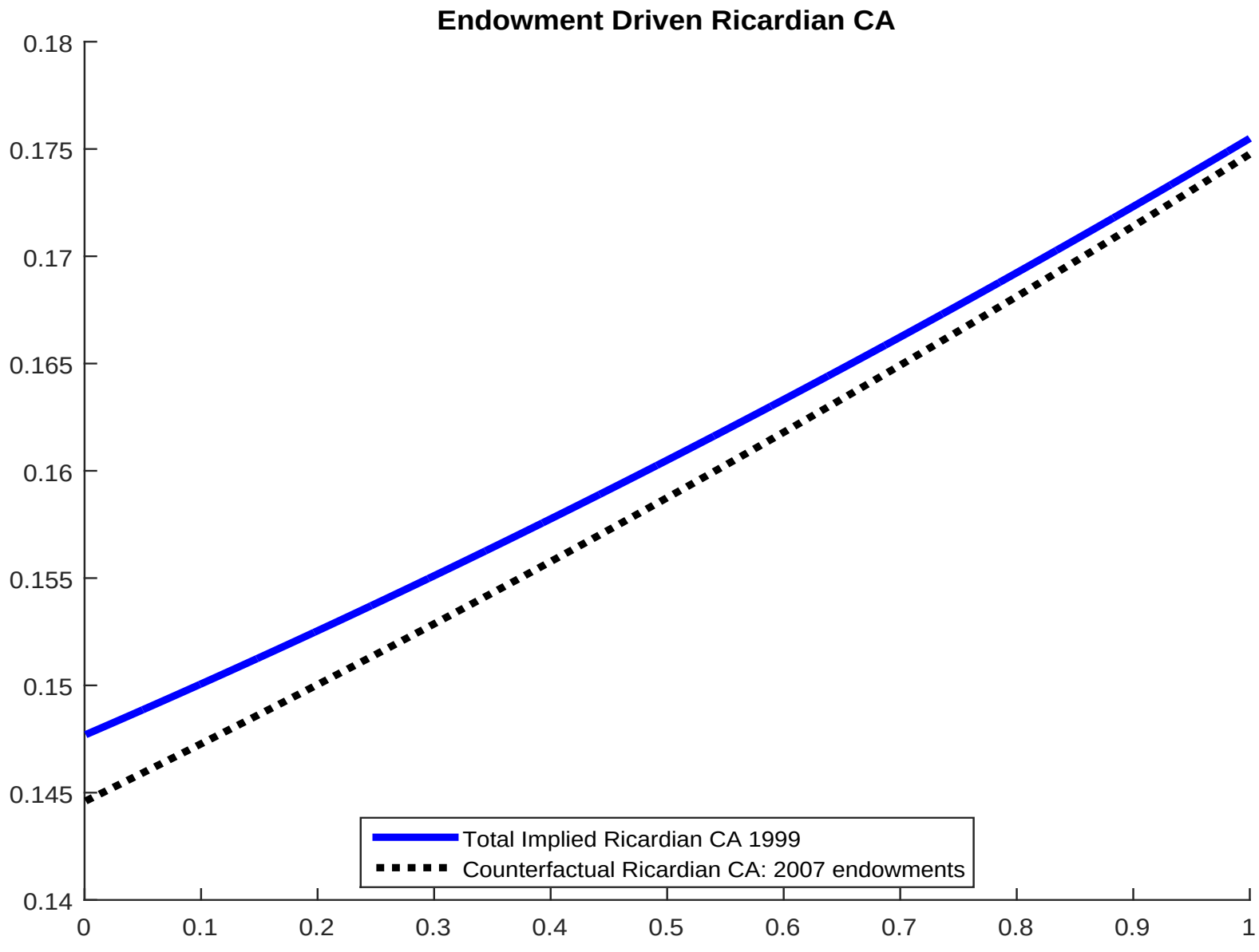
Structural Adjustment under Counterfactuals



Structural Adjustment under Counterfactuals



Structural Adjustment under Counterfactuals



Welfare Analysis

- Compute welfare for China and RoW using the estimated $A(z)$ and $A(z)^*$
- Welfare depends on Ricardian comparative advantage, H-O comparative advantage, Krugman love of varieties, and Melitz endogenous productivity.
- Estimate the welfare change overtime in baseline model

$$\begin{aligned} \frac{\exp(U_{2007})}{\exp(U_{1999})} &= 4.78 \\ \frac{\exp(U^*_{2007})}{\exp(U^*_{1999})} &= 1.98 \end{aligned}$$

  - Implied real consumption grows at 19.3% for China and 1.13% for RoW.
  - In the data real GDP per capita grows at 12.5% for China and 4.9% for RoW.
  - Costinot et. al (2015) and Levchenko and Zhang (2016) study the welfare implication of evolving comparative advantages.

Welfare Analysis

- Compute welfare for China and RoW using the estimated $A(z)$ and $A(z)^*$
- Welfare depends on Ricardian comparative advantage, H-O comparative advantage, Krugman love of varieties, and Melitz endogenous productivity.
- Estimate the welfare change overtime in baseline model

$$\begin{aligned} \frac{\exp(U_{2007})}{\exp(U_{1999})} &= 4.78 \\ \frac{\exp(U^*_{2007})}{\exp(U^*_{1999})} &= 1.98 \end{aligned}$$

  - Implied real consumption grows at 19.3% for China and 1.13% for RoW.
  - In the data real GDP per capita grows at 12.5% for China and 4.9% for RoW.
  - Costinot et. al (2015) and Levchenko and Zhang (2016) study the welfare implication of evolving comparative advantages.

Welfare Analysis

- Compute welfare for China and RoW using the estimated $A(z)$ and $A(z)^*$
- Welfare depends on Ricardian comparative advantage, H-O comparative advantage, Krugman love of varieties, and Melitz endogenous productivity.
- Estimate the welfare change overtime in baseline model

$$\begin{aligned} \frac{\exp(U_{2007})}{\exp(U_{1999})} &= 4.78 \\ \frac{\exp(U^*_{2007})}{\exp(U^*_{1999})} &= 1.98 \end{aligned}$$

  - Implied real consumption grows at 19.3% for China and 1.13% for RoW.
  - In the data real GDP per capita grows at 12.5% for China and 4.9% for RoW.
  - Costinot et. al (2015) and Levchenko and Zhang (2016) study the welfare implication of evolving comparative advantages.

Welfare Analysis: Counterfactuals

- Calculate the welfare changes from the baseline case for 1999 and the counterfactuals. Compute $\frac{\exp(U_{1999}^{CF})}{\exp(U_{1999})}$ for China and RoW.

	A and λ	f and τ	endm't
China	2.29	1.026	2.386
RoW	1.119	1.008	2.156

Conclusion

- Document puzzling structural adjustments of Chinese production and export
- Provide a unifying framework of international trade that generate a rich set of predictions
- No single driving force behind the observed adjustments
- Endogenous firm selection contributes 12 percent of total productivity growth and affects Ricardian comparative advantage.
- China and RoW benefit from China's structural adjustment.