Multi-product Firms and Misallocation

Wenya Wang and Ei Yang

School of Finance
Shanghai University of Finance and Economics
Prepared for AEA Meeting, Chicago

Jan 3-5, 2021

Motivation

Multiple-product within firms is an important extensive margin in amplifying

- business cycles in advanced economies [e.g., Bernard, Redding and Schott, 2010, BRS henceforth; Miniti and Turino, 2013], and theoretically the negative effect of distortions [Jaef, 2018]

A comparison between U.S. and China indicates the importance of multi-product (MP) firms

- number share 39% versus 17%; output share 87% versus 42%

Questions:

1. how do distortions affect the number of products at the firm-level empirically?
2. how large is the magnitude of misallocation via the multi-product channel in a general equilibrium model disciplined by data?

This paper: empirical

Uses Chinese National Bureau of Statistics firm-level data 98-07

- definition of products: 5-digit SIC level

Novel stylized facts on multi-product firms in China

1. they are fewer (17% vs 39% in U.S.) and smaller (1/3 of U.S. counterparts)
2. 1 S.D. increase in the Hsieh and Klenow(2009) defined distortion lowers firms' probability of producing multiple products by 1 percentage point

This paper: quantitative

A discrete multi-product choice model with endogenous firm entry and exit:

- given the draws of productivity and product-specific taste shocks, firms decide whether to enter and the number of products
- decision rules are affected by size-dependent distortions

We calibrate the distortion parameters to match the moments in Chinese firm-level data.

Overall 67.43% welfare loss compared to the distortion-free economy

- product intensive margin and firm extensive margin: 29.11% and 36.09%
- product extensive margin least important: 2.23%

Intuition: marginal firms that drop products due to distortions have a medium level of productivities $\Rightarrow$ a small output share change once the granularity of firm size distribution is matched

Literature

- Misallocation: Hsieh and Klenow(2009), Gunner, Ventura and Xu(2008), Restuccia and Rogernson(2008), Brandt, Tombe and Zhu (2013), Tombe and Zhu (2019), David and Venkateswaran (2017), Haltiwanger, Kulick and Syverson (2018), Uras and Wang (2018), Jaef(2018)

- Multi-product: Klette and Kortum (2004), Nocke and Yeaple (2014), Eckel and Neary (2010), Bernard, Redding and Schott (2010), Bilbiie, Ghironi and Melitz (2017), Bernard and Okubo (2016), Argente, Lee and Moreira (2018), Berneard, Redding and Schott (2011), Forslid and Okubo (2018), Manova and Yu (2017)

Data

China's data

Unbalanced panel of NBS Firm-level Data, 98-07

- top 20% manufacturing firms
- more coverage of SME, compared to India's Prowess dx data (top 4%) [e.g., Goldberg et al. 2010]

Product information: variables "Main product 1", "Main Product 2", "Main Product 3" in Chinese characters

- e.g. an office supply maker *Deli* reports *plastic parts* as the unique product in 1998; in 2000, three products: *pencil sharpener, paper cutter* and *file folder*
- close to 5-digit SIC product definition [Bernard, Redding and Schott, 2010]
- underestimated number of products if the true number of product is larger than 3

Fewer & smaller multi-product firms

	CN: AIES 98-07 Pooled			CN: Census	U.S.
	All	Non-SOE	Non-Exporter	2004	BRS(2010)
Number Share	0.27	0.26	0.26	0.17	0.39
Output Share	0.44	0.41	0.36	0.42	0.87
Relative Size	2.08	2.03	1.58	3.50	10.47

Note: The relative size is defined as the ratio of the average output of multi-product firms to that of single-product ones

Two-fold meanings of *smaller*:

1. a smaller average number of products (back-of-envelope): to reach an average 3.5 products per firm as in the U.S., all firms that report 3 products need to produce an extremely large number of 22 products.
2. smaller per product sales: the average sale of U.S. MP firms=2.05* the average sale of single-product (SP) firms. CN, 1.75.

1, 2 and 3 products By industry and age

Fewer & smaller multi-product firms: robustness

1. Industry composition differences? Not likely. 22% MP firms if weighted by the U.S. industry-level shipments
2. Large SP firms in China? Not likely. Less granularity for firms with 500+ workers in China that are disproportionally MP firms
3. Coarser definition of products in China? Not likely. If we use the coarser 4-digit SIC level production definition, the MP firm share in the U.S. is 28%, still larger than 17% in China.

Measures of Distortions

- We define $Distortion_{ist}$ following Hsieh and Klenow (2009)

$$\tau_{ist} = 0.5 * log(\frac{ValueAdded}{WageBill})_{ist} + 0.5 * log(\frac{ValueAdded}{CapitalStock})_{ist}$$
$$= 0.5\tau^{l}_{ist} + 0.5\tau^{k}_{ist}$$

- 20% of the variation in firm-level distortions is from reported subsidy rates and interest rates

Distortions and productivities across firm types

		Low τ	High τ
SP Firms	subsidy rate	0.15%	0.12%
	interest rate	2.38%	2.86%
	productivity	0.03	0.21
MP Firms	subsidy rate	0.21%	0.16%
	interest rate	2.32%	2.43%
	productivity	0.06	0.24

Note: Productivity is estimated by the ACF(2015)'s method in the 2004-2007 sample, industry and year demeaned. Low τ means that the firm-level τ is below the average, vice versa for High τ.

- within SP / MP group, firms with a τ higher than the average: less subsidized, higher interest rates
- the group of SP and high-τ firms: tax-like distortions potentially cause these high productivity firms (average 0.21) to produce a single product
- the group of MP and low-τ firms: subsidy-like distortions potentially cause these low productivity firms (average 0.06) to produce multiple products

Distortions & the product extensive margin

Probit model for firm i industry s time t

$$P(Multi_{ist}) = \Phi(\beta_0 + \beta_1 Distortion_{ist} + \beta_2 SOE_{ist} + \beta_3 NonExporter_{ist} + \beta_4 LogAsset_{ist} + \delta_s + \delta_t + \epsilon_{ist})$$

Marginal effects at the means in the baseline probit (column 3):

- 1 S.D. decrease in τ (0.42) increases $P(multi)$ by 1 perc. point
- 1 year increase in firm age increases $P(multi)$ by 0.4 perc. point
- state-owned firms have 1.5 perc. point higher of $P(multi)$ than private-owned ones
- exporter firms have 3 perc. point higher of $P(multi)$ than non-exporter firms

Robust when (1) size is controlled; (2) markup is controlled; (3) distortion measures are replaced by lagged ones; (4) the lagged MP status is controlled.

	(1)	(2)	(3)	(4) 04-07 sub-sample	(5)	(6)	(7)
taul	-0.168***						
	(0.004)						
tauk		-0.002***					
		(0.001)					
tau			-0.088***	-0.074***			
			(0.003)	(0.005)			
markup				-0.048***			
				(0.006)			
L.tau					-0.044***		
					(0.006)		
L.multi					2.894***		
					(0.005)		
L2.tau						-0.040***	
						(0.006)	
L2.multi						2.037***	
						(0.005)	
L3.tau							-0.041***
							(0.006)
L3.multi							1.444***
							(0.005)
age	0.013***	0.013***	0.013***	0.008***	0.004***	0.004***	0.004***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
soe	0.047***	0.047***	0.046***	0.078***	-0.013**	-0.006	-0.009
	(0.003)	(0.003)	(0.003)	(0.007)	(0.007)	(0.007)	(0.007)
nexporter	-0.076***	-0.089***	-0.086***	-0.076***	-0.039***	-0.054***	-0.058***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.005)	(0.005)	(0.006)
logasset	0.134***	0.128***	0.125***	0.106***	0.062***	0.077***	0.089***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
constant	-1.896***	-1.967***	-1.905***	-1.606***	-2.363***	-2.143***	-1.990***
	(0.011)	(0.011)	(0.011)	(0.017)	(0.022)	(0.021)	(0.023)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1,432,808	1,432,808	1,432,808	640,428	831,655	570,379	376,464

Model

Basic settings

A representative household:

- Supplies unskilled labor L & human capital (skilled) H inelastically
- Maximizes her utility from a continuum of goods $\omega \in \Omega$

$$U = \left[\int_{\omega \in \Omega} (\lambda(\omega) q(\omega))^{\rho} \, d\omega \right]^{\frac{1}{\rho}}, \; 0 < \rho < 1 \tag{1}$$

- Product appeal $\lambda(\omega) \geq 0$ (Hottman, Redding and Weinstein 2016)

Heterogeneous firms:

1. pay entry cost f_e in units of unskilled labor
2. draw (permanent) productivity $\varphi \sim g(\varphi)$, and taste shocks a_1, a_2 *independently* from a Binomial distribution, for two potential product lines. $Prob(a_h) = p$, $Prob(a_l) = 1 - p$, $a_l < a_h$
3. a productivity dependent revenue distortion τ (details later)

Basic settings

Consider a stationary equilibrium, firm's problem if operating

$$\max_{p,l,h} = \{(1-\tau)p_1 q_1 - w_l l_1 - w_h h_1 - w_l f_0 - w_l f_1$$
$$+\mathbb{I}\left((1-\tau)p_2 q_2 - w_l l_2 - w_h h_2 - w_l f_2\right)\}$$

s.t.

$$\text{Inverse demand}: \quad q_i = \frac{Q}{\lambda_i}\left[\frac{p_i}{\lambda_i P}\right]^{-\sigma}, i = 1,2$$
$$\text{Linear production}: \quad l_i = \frac{q_i}{\varphi}, \quad i = 1,2$$
$$\text{Appeal production}: \quad \lambda_1 = a_1 h_1^{\alpha}$$
$$\text{Appeal production}: \quad \lambda_2 = \xi a_2 h_2^{\alpha}$$

- $\xi \in [0,1]$ span of control parameter: limited management capacity for the second product line

Production strategies

Given optimal decisions of l, h, p, firms decide # of products. Assuming $f_0 + f_1 > f_2$,

- when $\xi = 1$, firm with demand shocks (a_h, a_h) produce two products when $\varphi \geq \varphi^*_{hh}$, and quit when $\varphi < \varphi^*_{hh}$.
- when $\xi < 1$, firms with (a_h, a_h) produce at least one product if $\varphi \geq \varphi^*_{hh,1}$, and produce two products if $\varphi \geq \varphi^*_{hh,2}$, where $\varphi^*_{hh,1}$ and $\varphi^*_{hh,2}$ are determined by the zero profit conditions,

$$\kappa(1-\tau)^{\frac{\sigma}{1-\alpha(\sigma-1)}} B \left(a_h \varphi^*_{hh,1}\right)^{\frac{\sigma-1}{1-\alpha(\sigma-1)}} = w_l \left(f_0 + f_1\right)$$

$$\kappa(1-\tau)^{\frac{\sigma}{1-\alpha(\sigma-1)}} B \left(\xi a_h \varphi^*_{hh,2}\right)^{\frac{\sigma-1}{1-\alpha(\sigma-1)}} = w_l f_2.$$

- κ a function of parameters σ, α, B a function of parameters σ, α, wage w_L, w_H and aggregates P, Q, R.

Similar pattern holds for firms with taste shocks (a_l, a_l) and (a_h, a_l).

Productivity dependent distortions

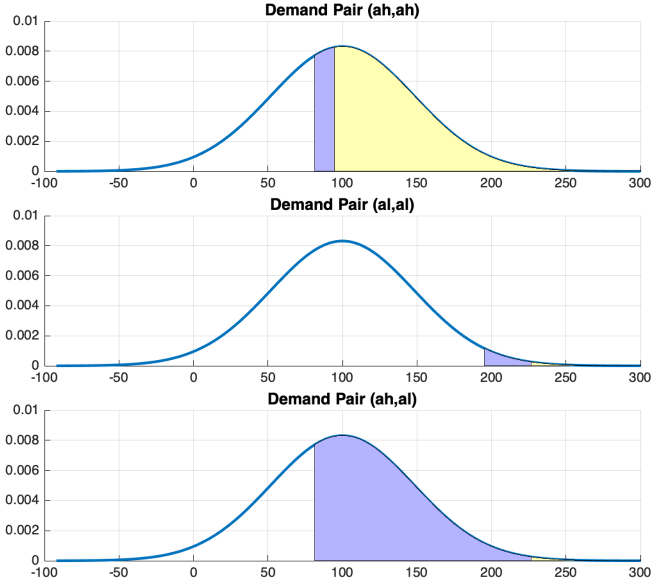
- The total revenue over the wage bills links to distortions

$$\frac{p_1 q_1 + \mathbb{I} p_2 q_2}{w_l l + w_h h} = \frac{1}{(1-\tau)(1-\frac{1}{\sigma})(1+\alpha)}$$

independent with the number of products.

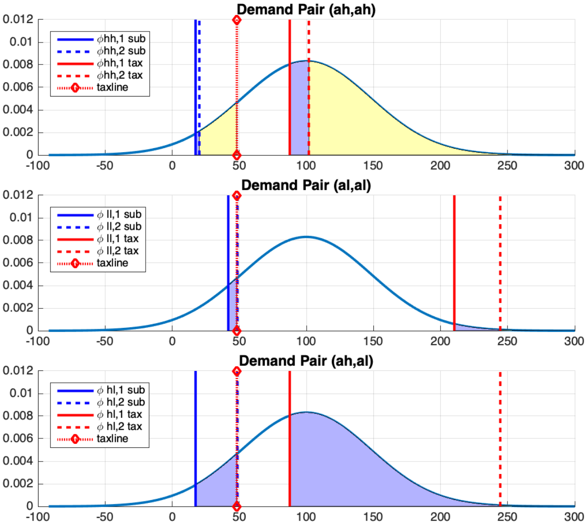
- Data: $E[\tau|\tau > 0] = 0.6$, $E[\tau|\tau < 0] = -0.3$, and $corr(\tau, \varphi) = 0.28$
- Model: For each entering firm, the distortion depends on its productivity draw [Gunner, Ventura and Xu, 2008; Restuccia and Rogerson, 2008]
  - taxed with a common $\tau_t > 0$ if $\varphi > \varphi_{tax}$
  - subsidized with a common $\tau_s < 0$, if $\varphi < \varphi_{sub}$
  - we set $\varphi_{tax} = \varphi_{sub}$
- 12 cutoffs in the economy with this distortion pattern.

Product strategies without distortions ($\xi < 1$)



Product strategies with distortions ($\xi < 1$)

Taxes increase the cutoffs of high productivity firms, while subsidies invite low productivity firms to produce, even up to 2 products. GE conditions



Model predictions in data

Firm-level distortion τ changes the number of products.

In the data, overtime changes in τ shall affect firms' probability of adding & dropping products

Table 1: Marginal Effects of $\Delta\tau$ on Prob. of Product-Add & -Drop

Gap Years	Product Add: All Firms	Product Add: $\Delta\tau < -0.1$	Product Add: $\Delta\tau < -0.3$	Product Drop: All Firms	Product Drop: $\Delta\tau > 0.1$	Product Drop: $\Delta\tau > 0.3$
1	5.71%	+0.44%***	+0.63%***	5.23%	+0.36%***	+0.80%***
2	9.76%	+0.51%***	+0.51%***	8.79%	+0.36%***	+0.88%***
3	13.93%	+0.62%***	+0.68%***	12.29%	+0.53%***	+1.28%***
4	17.95%	+0.40%***	+0.54%***	15.24%	+0.68%***	+1.25%***

Consistent with the model prediction,

- decrease/increase in τ, more likely to add/drop products

Similar results for firms at different ages Add & Drop, Distortions and Age

Quantitative Analysis

Exogenously chosen parameters

α	σ	μ_φ	a_h	f_0	L	$H_{U.S.}$	H_{China}
0.2	4.5	100	1	0.1	10^8	1.1739	0.2346

Human capital share in production function α from Canadian Labor Force Survey 2012

Elasticity of substitution σ implies an undistorted average markup of 1.28 in U.S. [DeLoecker, Eeckhout and Unger, 2019]

Small enough f_0, satisfying $f_0 + f_1 > f_2$.

Standardization: L,a_h.

Let $\varphi \sim N(\mu_\varphi, \sigma_\varphi)$ and $\mu_\varphi = 100$ (a scaling parameter).

Human capital ratio: $H_{U.S.}$, H_{China}

- fractions of labor force with some college and above: U.S., 51.62%, China, 19.00% (Population Census 2005)

Calibration: U.S. economy

Treat U.S. economy as distortion free to calibrate six parameters

Table 2: Distortion-Free Economy Calibrated to U.S. Census Data

Parameter	Value	Moment	Data	Model
σ_φ	44	Number Share (Multi)	0.39	0.3829
a_l	0.41	Output Share (Multi)	0.87	0.8591
p	0.53	Top 5% Output Share	0.8633	0.8120
$f_1 = f_2$	4.1×10^4	Top 10% Output Share	0.9219	0.9065
f_e	3.3×10^9	Drop Rate of Entries	0.52	0.4575
δ	0.05	Entry-Existing Firms Ratio	0.09	0.0885

Note: Data moments from BRS (2010) and 2014 Stats of U.S. Business.

In equilibrium, total entry cost amounts to $\frac{M_e f_e}{w_l L} = 7.87\%$ unskilled labor.

Calibration: Chinese economy

Add the distortion and span of control parameters onto the U.S. distortion-free case

Table 3: Calibration with the Chinese NBS Firm-Level Data

Parameter	Value	Moment	Data	Model
ξ	0.865	Number Share (Multi)	0.27	0.2972
τ_t	0.615	Output Share (Multi)	0.44	0.4249
$P(\varphi > \varphi_{tax})$	0.855	Top 5% Output Share	0.61	0.6819
τ_s	-0.225	Subsidized Share	0.16	0.1590

Calibration: counterfactual economies

Table 4: Counterfactual Economies for China

Moments	Data	Benchmark $\tau_{tax} \neq 0$ $\tau_{sub} \neq 0$	$\tau_{tax} = 0$ $\tau_{sub} = 0$	$\xi = 0.865$ $\tau_{tax} \neq 0$ $\tau_{sub} = 0$	$\tau_{tax} = 0$ $\tau_{sub} \neq 0$	$\xi = 1(U.S.)$ $\tau_{tax} = 0$ $\tau_{sub} = 0$
Number Share (Multi)	0.27	0.2972	0.3095	0.3118	0.3095	0.3829
Output Share (Multi)	0.44	0.4249	0.6208	0.6046	0.6208	0.8591
Top 5% Output Share	0.61	0.6819	0.8055	0.7942	0.8055	0.8120
Subsidized Firm Share	0.16	0.1590	0	0	0	0
Top 10% Output Share	0.71	0.8491	0.9033	0.8844	0.9033	0.9065
Drop Rate of Entries	0.31	0.4148	0.4546	0.3755	0.4546	0.4575
Subsidized MP Firm Share	0.05	0.0566	0	0	0	0.088
Measure of Firms	-	0.197	0.270	0.112	0.270	0.269
Aggregate Price	-	0.00054	0.00018	0.00052	0.00018	0.00018
Welfare	-	32.57%	100%	29.82%	100%	102.8%

- Tax distortions depress welfare hugely, dropping to 29.82%
- Subsidy improves welfare to 32.57% by increasing the variety of products and the measure of firms.

Changes in cutoffs with distortions

The single- versus multi-product decisions are distorted

- cutoff percentiles for *hh* (*hl*) type firms to be MP, 45.4 to 51.5 (99.6 to 99.8)
- quantitatively more important margin: subsidized firms into MP, 11% output, into SP, 17%

Table 5: Model Implied Firm Types and Firm Shares

$(a_i, \xi a_i)$	$(a_h, \xi a_h)$	$(a_h, \xi a_h)$	$(a_h, \xi a_l)$	$(a_h, \xi a_l)$	$(a_l, \xi a_l)$	$(a_l, \xi a_l)$
Without Distortions	$\mathbf{M_{hh,1}}$	$\mathbf{M_{hh,2}}$	$\mathbf{M_{hl,1}}$	$\mathbf{M_{hl,2}}$	$\mathbf{M_{ll,1}}$	$\mathbf{M_{ll,2}}$
Cutoff Percentile	34.8%	45.4%	34.8%	99.6%	97.6%	99.5%
With Distortions	$\mathbf{M^t_{hh,1}}$	$\mathbf{M^t_{hh,2}}$	$\mathbf{M^t_{hl,1}}$	$\mathbf{M^t_{hl,2}}$	$\mathbf{M^t_{ll,1}}$	$\mathbf{M^t_{ll,2}}$
Cutoff Percentile	39.8%	51.5%	39.8%	99.8%	98.9%	99.8%
	$\mathbf{M^s_{hh,1}}$	$\mathbf{M^s_{hh,2}}$	$\mathbf{M^s_{hl,1}}$	$\mathbf{M^s_{hl,2}}$	$\mathbf{M^s_{ll,1}}$	$\mathbf{M^s_{ll,2}}$
Cutoff Percentile	4.3%	4.8%	4.8%	14%	11.2%	14%

The effects of distortions in MP firm framework

Table 6: Decomposition of Misallocation into Three Margins

	Benchmark	PF-FF	PF	No Dist.
Measure of Firms	0.197	0.197	0.234	0.270
Aggregate Price	0.000537	0.000190	0.000187	0.000178
Welfare	32.57%	61.68%	97.77%	100%

Note: Benchmark: Calibrated Chinese economy with distortions. PF-FF: Distortions are removed while both the product cutoffs and the firm measure are fixed as in the Benchmark. PF: Distortions are removed while the product cutoffs are fixed. And the firm measure is adjusted.

The product extensive margin is the least important among the three margins:

1. product intensive margin: 61.68% – 32.57%
2. firm extensive margin: 97.77% – 61.68%
3. product extensive margin: 100% – 97.77%.

Why the product extensive margin is not quantitatively important?

Two reasons:

1. The fat tail of firm-level output distribution. With distortions,
   - the most productive firms keep producing two products;
   - the marginal firms that (1) drop the second product have a medium level of productivities; (2) add the second product have a low level of productivities;
2. The span of control parameter $\xi = 0.865$ is small
   - If we shut down the second line of all firms in the distortion-free economies, while keeping the aggregate price and firm measure fixed, the welfare levels drop to 94.76% for $\xi = 0.865$ and 76.81% for $\xi = 1$.

Conclusions

Stylized facts

- multi-product firms are fewer and smaller in China
- product extensive margin: distortions distort firms' decision of being multi-product firms

A discrete multi-product choice model with endogenous firm entry and exit calibrated to China

- the model theoretically shows the product extensive margin of distortions
- but quantitatively the welfare loss is much smaller through this margin, compared to the product intensive and firm extensive margins.

Thank you!

Appendix

Multi-Product Firms in Top $x\%$

Top $x\%$ firms	2%	5%	10%	25%	50%	All
Frac. of Multi-	38.89%	33.43%	30.05%	24.87%	17.44%	16.95%

Note: top $x\%$ in sales distribution. Data from China 2004 economic census.

Firm Size Distribution: China vs U.S.

Does trade affect lack of large firms observation?

- exporting firms: labor intensive + low end of global value chain, more likely to be small
- only firms for domestic production, robust lack of large firms

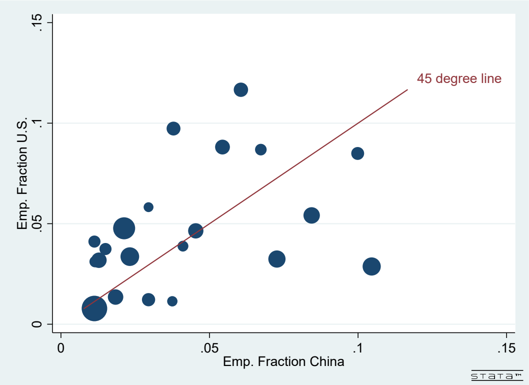
Table 7: Frac. of Output by Top x% Firms

	U.S.				China	
	2012	2007	2002	1997	2004 All	2004 Domestic
Top 2% *	83.29%	81.02%	79.46%	77.38%	65.99%	65.93%
Top 5%	89.23%	88.08%	85.42%	82.58%	77.54%	77.57%
Top 10%	93.38%	92.50%	91.63%	91.24%	85.38%	85.53%

*From the sales distribution

China More Employment in Labor Intensive Industries?

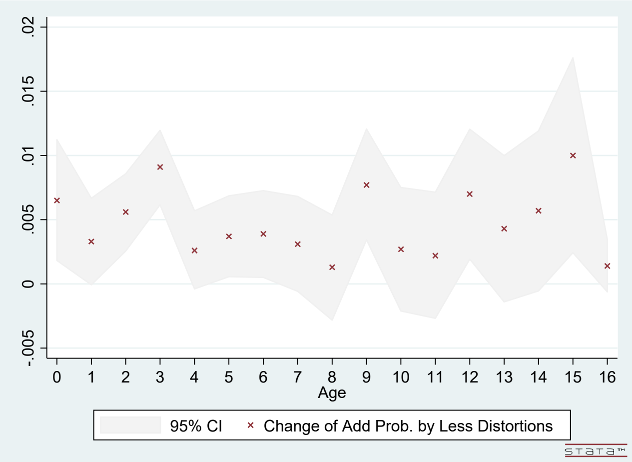
No clear sign that capital-output ratio are lower in industries that China employs more workers.



Note: 3-digit NAICS level. Size of circle = capital-output ratio for each industry from NBER-CES productivity database.

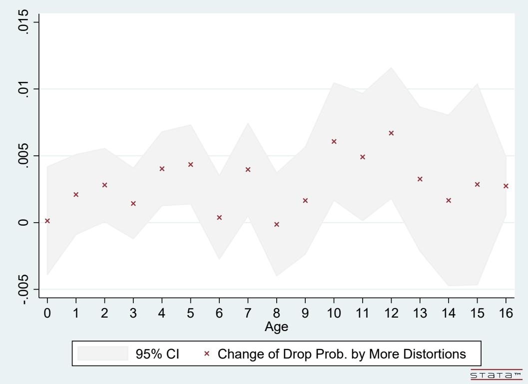
Age, Change of Distortions and Product-Add

Figure 1: Marginal Increase in Prob(Product-Add) when $\Delta\tau < -0.1$ and its 95 Confidence Interval, from t to $t+1$, across ages



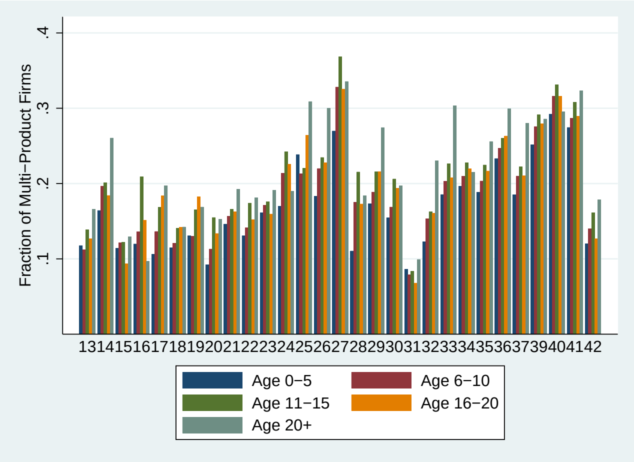
Age, Change of Distortions and Product-Drop

Figure 2: Marginal Increase in Prob(Product-Drop) when $\Delta\tau > 0.1$ and its 95 Confidence Interval, from t to $t+1$, across ages



Back

Industry and Age



Product Scope Distribution by Year

Firm and Output Shares by Number of Products

	Number Share			Output Share		
	1	2	3	1	2	3
1998	0.69	0.16	0.14	0.53	0.18	0.28
1999	0.69	0.16	0.13	0.53	0.17	0.27
2000	0.71	0.15	0.12	0.52	0.18	0.28
2001	0.72	0.15	0.11	0.54	0.18	0.26
2002	0.73	0.15	0.11	0.55	0.18	0.25
2003	0.75	0.15	0.10	0.56	0.19	0.25
2004	0.72	0.16	0.11	0.57	0.19	0.24
2005	0.73	0.16	0.11	0.56	0.19	0.24
2006	0.73	0.16	0.11	0.57	0.19	0.24
2007	0.74	0.16	0.11	0.57	0.19	0.23

Note: Firms without any product information are excluded.

Back

General Equilibrium Conditions

- As in Melitz (2003), the general equilibrium are determined by

1. An aggregate relationship between the average profit $\bar{\pi}$ and the cutoff $\varphi^*_{hh,1}$:

$$\bar{\pi} = F(\varphi^*_{hh,1}, \Gamma) \tag{2}$$

   where Γ denotes the systematic distortion pattern.

2. The free entry condition which implicitly links the average profit and the cutoff:

$$G(\varphi^*_{hh,1}, \Gamma)\bar{\pi} = \delta w_L f_e \tag{3}$$

   where $G(\varphi^*_{hh,1}, \Gamma)$ is the expected surviving probability.

- Other variables can be derived from optimal condition and market clear conditions.