Dynamic Demand for Capital and Labor: Evidence from Chinese Industrial Firms

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Abstract

This paper employs a structural econometric approach to study the joint dynamic demand for capital and labor in Chinese firms. We recover key structural parameters in a dynamic model of interrelated factor demand subject to joint convex and non-convex costs. The model is able to replicate the stylized facts directly observed from Chinese manufacturing firm-level data over the period 1998-2007. Our estimations reveal that firms exhibit significant convex and fixed costs when adjusting capital or employment stock. Moreover, the adjustments in two factor inputs are inter-related, and adjusting capital and labor simultaneously is more costly than adjusting two inputs sequentially. Our counterfactual analysis suggests that removing the frictions in both capital and labor adjustments will lead to a 1% increase in aggregate total factor productivity (TFP) and a 7% increase in aggregate output.

Motivation

- Existing literature studies dynamics of capital or labor seprately
  - Labor dynamics: Hamermesh et al.(1996), Cooper et al.(2009), Cooper et al.(2018)
  - Investment dynamics: Cooper et al.(2006), Asker et al. (2015), Wu(2018), Tang(2021)
- Chinese firms experienced dramatic changes in capital and labor markets
  - Labor market: reform in household registration system, break "iron-rice bowl" in state sector, labor law revision
  - Capital market: huge inflow of FDI, state firms reform, investment tax
- This paper studies the joint dynamics of capital and labor and their impact on aggregate TFP

Main Takeways

- Recover structural parameters in a dynamic model, so it can replicate the stylized facts directly observable from Chinese firm-level data from 1998 to 2007
  - joint convex and fixed costs are significant $\Rightarrow$ adjustments in capital and labor are inter-related
  - simultaneous adjustment is more costly than sequential adjustment
  - counterfactual: aggregate TFP $\uparrow$ by 1% and aggregate output increases by 7% if all adj. costs are removed

Data and Variables

- Annual Surveys of Industrial Production 1998-2007: all state firms and non-state firms with annual revenue more than $600,000
- Investment rate: $i_{it} = \frac{I_{it}}{K_{it}} = \frac{K_{it+1}-(1-\delta)K_{it}}{K_{it}} \approx \ln K_{it+1} - \ln K_{it} + \delta$
- Employment growth rate: $l_{it} = \frac{L_{it+1}-L_{it}}{L_{it}} \approx \ln L_{it+1} - \ln L_{it}$

Stylized Facts

- Table 1: Moments on investment rate and employment growth rate

Panel a: moments on investment rate i

N20	N1020	N10	Inaction	P10	P1020	P20	*std*	*scorr*
0.048	0.051	0.143	0.055	0.297	0.160	0.245	0.243	0.071
(0.0005)	(0.0005)	(0.0008)	(0.0005)	(0.0010)	(0.0008)	(0.0010)	(0.0006)	(0.0023)

Panel b: moments on employment growth l

N20	N1020	N10	Inaction	P10	P1020	P20	*std*	*scorr*
0.095	0.091	0.215	0.214	0.184	0.093	0.107	0.177	0.018
(0.0007)	(0.0007)	(0.0009)	(0.0009)	(0.0009)	(0.0007)	(0.0007)	(0.0004)	(0.0023)

Panel c: cross correlations between i and l

λ_{i_t,l_t}	$\lambda_{i_t,l_{t-1}}$	$\lambda_{l_t,i_{t-1}}$
0.138	0.089	0.065
(0.0025)	(0.0027)	(0.0026)

A Dynamic Model

- In a stationary equilibrium, the firm's problem is described by the following Bellman equation:

$$V(A,K,L) = \max_{K',L'}[AK^{\alpha_K}L^{\alpha_L} - Lw_0 - I - C(A,K,I,L,L') + \beta EV(A',K',L')]$$

$$K'=(1-\delta)K+I$$

$$\ln A'=u_i+\rho\ln A+\sigma\epsilon',\epsilon\sim N(0,1)$$

- A general functional form for the adjustment costs whenever firms adjust capital, labor, or both, is:

$$C(\cdot) = \begin{cases} C^K=\lambda^K\pi(A,K,L)+\frac{\gamma^K}{2}[\frac{I}{K}]^2K & \text{if } I\neq 0 \\ C^L=\lambda^L\pi(A,K,L)+\frac{\gamma^L}{2}[\frac{L'-L}{L}]^2L & \text{if } (L'-L)\neq 0 \\ C^{KL}=C^K+C^L+\lambda^{KL}\pi(A,K,L)+\frac{\gamma^{KL}}{2}(\frac{I}{K})(\frac{L'-L}{L})\sqrt{KL} & \text{if } I(L'-L)\neq 0 \end{cases}$$

  - λ^K (λ^L) represents fixed/non-convex cost, γ^K (γ^L) represents convex cost, when adjusting K (L) alone
  - λ^{KL} is joint fixed cost, γ^{KL} is joint convex cost; extra cost with simultaneous adjustment in K and L
  - $\lambda^{KL} > 0$ and $\gamma^{KL} > 0 \Rightarrow$ simultaneous adjustment is cost-inducing
  - $\lambda^{KL} < 0$ and $\gamma^{KL} < 0 \Rightarrow$ simultaneous adjustment is cost-saving
- The firm's problem is at intensive margin:

$$V(A,K,L) = \max\{V^{no}(A,K,L), V^{KL}(A,K,L), V^K(A,K,L), V^L(A,K,L)\}$$

- The firm's problem is at extensive margin:
  - find (K',L') in $V^{KL}(A,K,L)$, find K' in $V^K(A,K,L)$, and find L' in $V^L(A,K,L)$

Structural Estimations via Simulated Moment Matching

- Table 2: Estimation of structural parameters in the model

Definition of parameters	Parameters	Full (1)	No-joint (2)	Convex (3)	Fixed (4)	Capital (5)	Labor (6)	None (7)
Capital convex cost	γ^K	0.016	0.080	0.143		0.083		
		(1.566e − 06)	(3.468e − 04)	(2.960e − 03)		(6.636e − 04)		
Capital fixed cost	λ^K	0.001	0.047		0.070	0		
		(9.023e − 05)	(6.422e − 05)		(1.288e − 04)	(9.956e − 06)		
Labor convex cost	γ^L	0.006	0.100	0.087			0.083	
		(3.0171e − 04)	(1.031e − 03)	(9.811e − 04)			(6.664e − 04)	
Labor fixed cost	λ^L	0.0005	0.057		0.010		0	
		(4.124e − 05)	(3.969e − 04)		(1.969e − 04)		(1.594e − 05)	
Joint convex cost	γ^{KL}	−0.016		−0.110				
		(8.141e − 04)		(1.770e − 03)				
Joint fixed cost	λ^{KL}	0.080			0.070			
		(6.315e − 04)			(6.172e − 04)			
Serial correlation of shock	ρ	0.750	0.850	0.360	0.750	0.718	0.881	0.742
		(1.175e − 03)	(1.147e − 03)	(5.392e − 04)	(1.012e − 03)	(1.195e − 03)	(9.532e − 04)	(1.070e − 03)
SD of innovation to shock	σ	0.100	0.150	0.450	0.100	0.150	0.171	0.050
		(5.146e − 04)	(8.863e − 04)	(2.032e − 04)	(9.484e − 04)	(2.682e − 04)	(3.471e − 04)	(9.860e − 05)
Objective value in SMM	$\Gamma(\Theta)/100$	1854	8291	6522	8522	2602	2417	3188

- At stationary equilibrium, joint fixed cost > joint qudaratic cost
- Sequential adjustment is preferred over simultaneous adjustment

- Table 3: Compare model with data

Moments	Data	Full (1)	No-joint (2)	Convex (3)	Fixed (4)	Capital (5)	Labor (6)	None (7)
Moments on investment rate i								
N20	0.048	0.070	0.011	0.044	0	0.031	0.065	0.056
N1020	0.051	0.015	0.008	0.128	0	0.069	0.089	0.071
N10	0.143	0.017	0.026	0.124	0.001	0.130	0.117	0.125
Inaction	0.055	0.149	0.339	0	0.412	0.038	0.031	0.042
P10	0.297	0.309	0.263	0	0.205	0.217	0.185	0.072
P1020	0.160	0.298	0.212	0.386	0.288	0.248	0.222	0.383
P20	0.245	0.143	0.142	0.318	0.094	0.266	0.290	0.525
std	0.243	0.210	0.188	0.190	0.189	0.155	0.197	0.174
scorr	0.071	−0.066	0.073	−0.006	−0.071	0.282	0.297	−0.128
Moments on employment growth l								
N20	0.095	0.092	0.035	0.261	0.049	0.129	0.113	0.127
N1020	0.091	0.092	0.064	0.010	0.072	0.157	0.148	0.146
N10	0.215	0.126	0.076	0	0.089	0.193	0.200	0.092
Inaction	0.214	0.378	0.747	0.426	0.596	0.043	0.070	0.265
P10	0.184	0.129	0.024	0	0.120	0.183	0.197	0.094
P1020	0.093	0.099	0.008	0.035	0.039	0.166	0.166	0.150
P20	0.107	0.084	0.046	0.368	0.035	0.130	0.107	0.125
std	0.177	0.172	0.163	0.282	0.152	0.177	0.167	0.173
scorr	0.018	0.017	0.109	−0.079	0.102	0.393	0.332	−0.128
Cross correlations between i and l								
λ_{i_t,l_t}	0.138	0.228	0.781	0.945	0.720	0.416	0.304	0.999
$\lambda_{i_t,l_{t-1}}$	0.089	0.202	0.100	0.017	−0.002	0.986	0.047	−0.128
$\lambda_{l_t,i_{t-1}}$	0.065	0.510	0.161	−0.093	0.126	0.022	0.993	−0.128

- The "Full" mode successfully replicates most data moments

Robustness Check

- Table 4: Estimation of structural parameters in various sub-samples

		By Ownership		By Industry		By Regions	
Definition of parameters	Parameters	State	Private	Machinery	Auto-parts	Coastal	Interior
Capital convex cost	γ^K	0.016	0.020	0.016	0.015	0.013	0.016
		(2.824e − 06)	(9.932e − 05)	(5.498e − 06)	(8.678e − 03)	(2.058e − 04)	(2.586e − 06)
Capital fixed cost	λ^K	0.001	0.0025	0.001	0	0	0.001
		(1.689e − 04)	(1.632e − 04)	(3.221e − 04)	(5.461e − 04)	(9.456e − 04)	(1.521e − 04)
Labor convex cost	γ^L	0.006	0.010	0.006	0.005	0.006	0.006
		(5.752e − 04)	(1.108e − 04)	(1.149e − 03)	(5.237e − 04)	(9.080e − 05)	(5.285e − 04)
Labor fixed cost	λ^L	0.0005	0	0.0005	0	0	0.0005
		(7.561e − 05)	(4.784e − 05)	(1.477e − 04)	(1.946e − 04)	(2.090e − 04)	(6.926e − 05)
Joint convex cost	γ^{KL}	−0.016	−0.02	−0.016	−0.015	−0.016	−0.016
		(1.476e − 03)	(8.571e − 05)	(2.950e − 03)	(7.274e − 04)	(1.605e − 04)	(1.356e − 03)
Joint fixed cost	λ^{KL}	0.080	0.075	0.08	0.055	0.080	0.080
		(1.182e − 03)	(3.541e − 04)	(2.299e − 03)	(5.913e − 04)	(1.071e − 03)	(1.069e − 03
Serial correlation of shock	ρ	0.750	0.800	0.750	0.750	0.750	0.750
		(2.245e − 03)	(6.642e − 04)	(4.283e − 03)	(7.858e − 03)	(1.994e − 03)	(1.992e − 03)
SD of innovation to shock	σ	0.100	0.100	0.100	0.100	0.100	0.100
		(9.766e − 04)	(5.183e − 04)	(1.868e − 03)	(2.030e − 03)	(5.659e − 03)	(8.727e − 04)
Objective value in SMM	$\Gamma(\Theta)/100$	599	1010	152	102	1313	590

- At stationary equilibrium, joint fixed cost > joint qudaratic cost $\Rightarrow$ sequential adjustment $\succ$ simultaneous adjustment

Counterfactual

- Table 5: Impact on aggregate variables

Removing all adjustment costs	All	State	Private	Machinery	Auto-parts	Coastal	Interior
Δ% in aggregate TFP	1.134	1.134	1.461	1.134	1.070	1.121	1.134
Δ% in output Y	7.285	7.285	4.708	7.285	6.250	6.745	7.285
Δ% in capital K	8.034	8.034	4.136	8.034	7.052	7.472	8.034
Δ% in employment L	7.757	7.757	4.387	7.757	5.735	6.742	7.757