Measuring convex adjustment costs of labor employment by intensive computing

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Introduction

Subject: Dynamic labor adjustments with convex adjustment costs
for automobiles manufacturing industry

Economic model: Dynamic optimization for labor employment

- Numerically solving Bellman equation

Econometrics: GMM estimation of 3 nonlinear regression equations

- Grid search, numerically minimizing GMM minimand
- Bootstrap standard errors

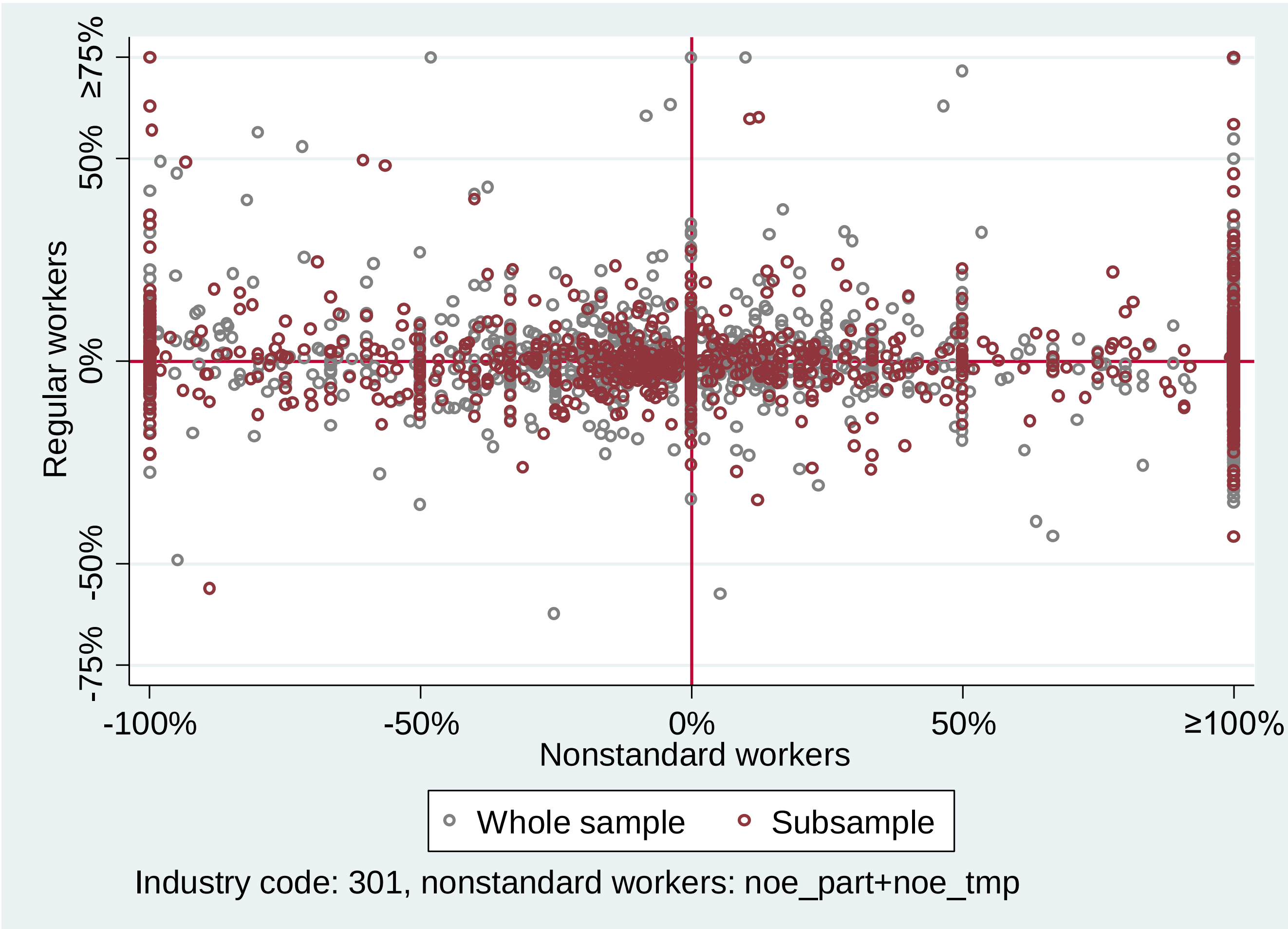
*Covariance and Hessian matrices are near singular.

Computation: Super computer and hybrid parallel computing

Conclusion: Adjustment costs are convex but not quadratic.
Estimated adjustment costs are below 10% of total wage.

Motivation: year-to-year % changes

Automobiles manufacturing industry



Motivation: year-to-year % changes

Food & beverage retail industry

Economic model

$$V\left[Z_t, l_t\right] = \max_{\{l_{s+1}, n_s\}_{s=t}^{\infty}} E_t \left\{ \sum_{s=t}^{\infty} \beta^{s-t} \left[Z_s K_s^{\zeta} \left(l_s + \psi n_s\right)^{\gamma} - \left(w_l l_s + w_n n_s\right) - C \left| l_{s+1} - l_s \right|^{\xi} l_s^{\omega} \right] \right\}$$

Z: Stochastic coefficient, shocks to technology and demand

ten-state Markov chain assumed

ψ: Relative productivity of nonstandard workers to regular workers

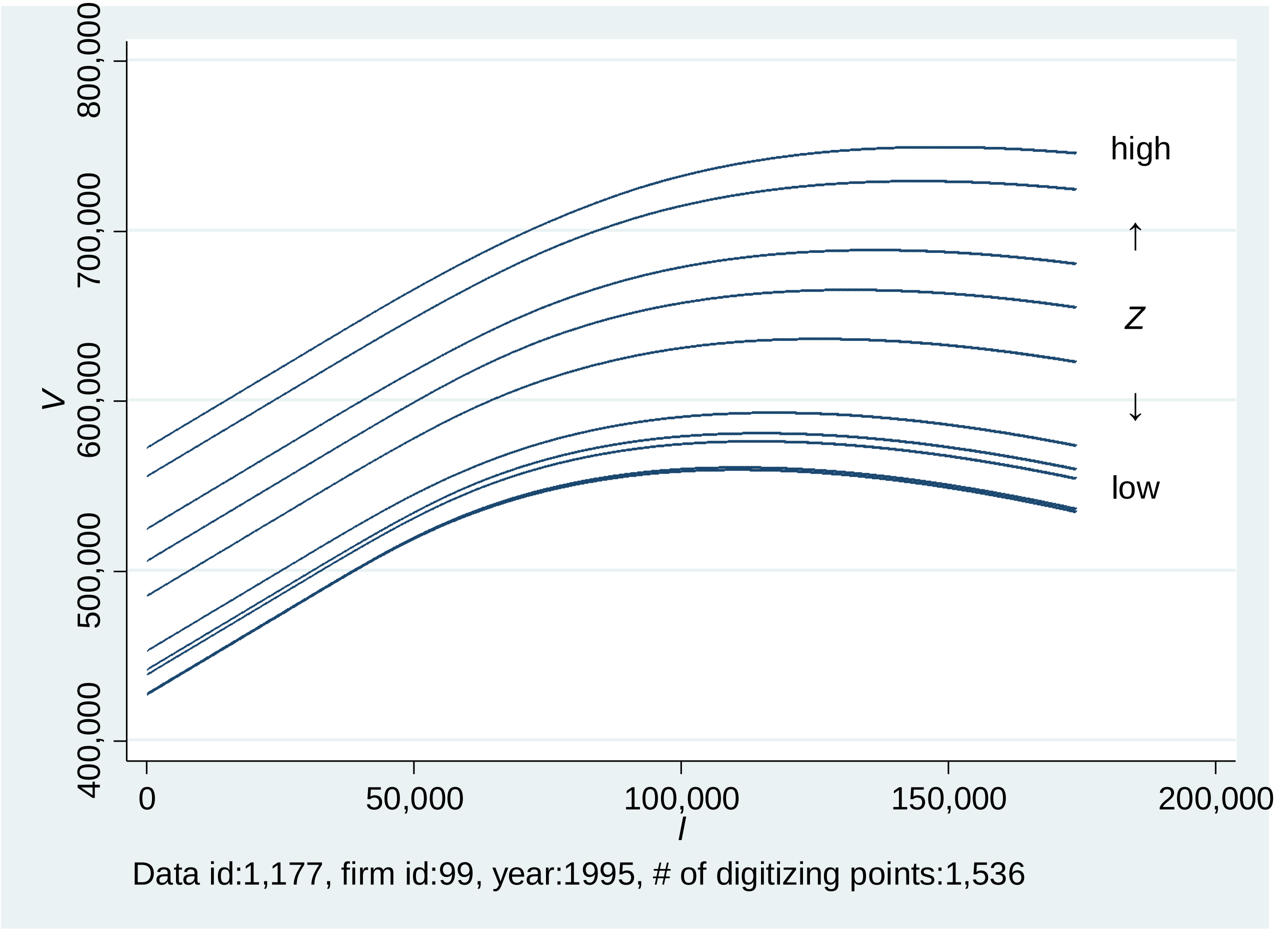
$\theta \equiv (\beta, \zeta, \gamma, \psi, C, \xi, \omega)$: 7 unknown parameters

Bellman equation

$$V\left[Z, l\right] = \max_{\{l'\}} \left\{ r\left(Z, l, l'\right) + \beta E_Z V\left[Z', l'\right] \right\}$$

$$r\left(Z, l, l'\right) \equiv Z K^{\zeta} \left(l + \psi n\right)^{\gamma} - \left(w_l l + w_n n\right) - C \left| l' - l \right|^{\xi} l^{\omega}$$

Discretized value function: example



Nonlinear regression equations

(1) Adjustment rate

$$y = \frac{\hat{l}'\left(l, K \middle| \theta\right) - l}{l} + u \qquad E\left[u(\theta) \middle| l, K\right] = 0$$

(2) Euler equation

$$v\left(l, l', l'', Z, Z'; \theta\right) \equiv \frac{\partial r\left(l, l', Z; \theta\right)}{\partial l'} + \beta E_Z\left[\frac{\partial r\left(l', l'', Z'; \theta\right)}{\partial l'}\right] \qquad E\left[v\left(l, l', l'', Z, Z'; \theta\right) \middle| l, K\right] = 0$$

(3) Ratio of nonstandard workers to regular workers

$$\frac{n}{l} = \frac{n^*\left(l, K \middle| \theta\right)}{l} + w \qquad E\left[w(\theta) \middle| l, K\right] = 0$$

Moment condition: $E\left[m(\theta)\right] = 0$ (10 moments)

$$m(\theta) \equiv \left(u,\ lu,\ Ku,\ v,\ lv,\ Kv,\ w,\ lw,\ Kw,\ \Delta y_{(2)} \middle| \theta\right)^T \qquad \Delta y_{(2)} \equiv \left(\hat{y} - E[\hat{y}]\right)^2 - \left(y - E[y]\right)^2$$

Computations

(1) System

FX10 (Fujitsu); Subsystem: Oakleaf-FX

Operator: University of Tokyo

(2) Hardware

CPU: SPARC64^{TM} IXfx (1.848 GHz)

System configuration of Oakleaf-FX

Whole system: 1.135 PFLOPS, 4,800 nodes, memory:150 TByte

For analysis: (max) 22.7 TFLOPS, 98 nodes, 16 threads / node, 32 Gbyte / node

(3) Software

Fortran 77/90/95, MPI, Open MP, LAPACK

Algorithm (part)

⋮

[Value function iteration (discrete model)]

3-1. Allocate at most 1,536 digitizing points to 6 × the number of the observation's regular workers for each of the spaces of l and l'.

3-2. Initiate $V_{m,i=0}(Z, l)$ by 0; calculate $r_m(Z,l,l')$; and set $i = 0$.

3-3. For each Z and l, compute $V_{m,i+1}(Z, l)$ and $l'_{i+1}(Z, l)$ by

$$V_{m,i+1}(Z, l) = \{r_m(Z,l,l') + \beta E_Z V_{m,i}(Z', l')\}. \qquad (*)$$

3-4. If the update of the value function is small, go to step 3-5. Otherwise, increment i by 1; and return to step 3-3.

[Refinement of policy function]

3-5. Apply the cubic spline interpolation to the right-hand side of equation (*); and compute l'.

⋮

Descriptive statistics of data

	Mean	SD	Minimum	Maximum
Revenue	96,112	381,368	666	3,745,849
Value added (VA)	33,118	137,733	87	1,553,513
Regular workers (l)	1,359	3,934	30	30,242
Nonstandard workers (n)	57	286	0	4,918
Capital stock (K)	21,670	74,371	99	661,475
Adjustment rates (y)	1.00%	17.74%	-56.12%	303.87%
Ratio of workers (n / l)	7.08%	19.04%	0.00%	202.56%

Remarks: 99 firms, 1,188 observations, year 1995 to year2006, 2005 price, million yen
Source: Basic Survey of Japanese Business Structure and Industry

Wage rate: $w_l = 5.735$, $w_n = 1.526$
Remark: 2005 price
Source: Monthly Labour Survey

Estimates of parameters

	Grid-line search	Bootstrap			
	Estimate (a)	Estimate $2 \times (a) - (b)$	SE	Mean (b)	Bias (b) − (a)
β	0.3220	0.3137	0.0274	0.3303	0.0083
ζ	0.2097	0.2346	0.0314	0.1848	-0.0249
γ	0.3500	0.3516	0.0295	0.3484	-0.0016
ψ	0.1574	0.1564	0.0150	0.1584	0.0010
C	1.0350	1.0345	0.0266	1.0355	0.0005
ξ	1.2094	1.2212	0.0112	1.1976	-0.0118
ω	0.0702	0.0635	0.0263	0.0769	0.0067

Implied Lerner index ($\zeta + \gamma$) = 0.5862, implied demand elasticity = 1.7059
Number of bootstrap repetitions (N_{bs}) = 75
Ratio of wage rates: $w_l / w_n \approx 0.2661$

Estimated adjustment costs