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

Industry code: 301, nonstandard workers: noe_part+noe_tmp
Motivation: year-to-year % changes

Food & beverage retail industry

Regular workers

Nonstandard workers

Industry code: 570, nonstandard workers: noe_part+ noe_tmp
Economic model

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

**Z**: Stochastic coefficient, shocks to technology and demand

ten-state Markov chain assumed

**\( \psi \)**: Relative productivity of nonstandard workers to regular workers

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

Bellman equation

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

\[ r(Z, l, l') \equiv Z K^Z (l + \psi n)^\gamma - (w_l l + w_n n) - C |l' - l|^{\xi} l_\omega \]
Discretized value function: example

Data id:1,177, firm id:99, year:1995, # of digitizing points:1,536
Nonlinear regression equations

(1) Adjustment rate

\[ y = \frac{\hat{l}'(l, K|\theta) - l}{l} + u \quad E[u(\theta)|l, K] = 0 \]

(2) Euler equation

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

(3) Ratio of nonstandard workers to regular workers

\[ \frac{n}{l} = \frac{n^*(l, K|\theta)}{l} + w \quad E[w(\theta)|l, K] = 0 \]

Moment condition: \( E[m(\theta)] = 0 \quad (10 \text{ moments}) \)

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

(1) System
  FX10 (Fujitsu); Subsystem: Oakleaf-FX
  Operator: University of Tokyo

(2) Hardware
  CPU: SPARC64™ 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 

\[ 6 \times \text{the number of the observation’s} \]

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

\[
V_{m,i+1}(Z, l) = \{r_m(Z,l,l') + \beta EZ V_{m,i}(Z', l')\}. \quad (*)
\]

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

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

Remarks: 99 firms, 1,188 observations, year 1995 to year 2006, 2005 price, million yen  
Source: Basic Survey of Japanese Business Structure and Industry

### Wage rate

\[ w_l = 5.735, \quad w_n = 1.526 \]

Remark: 2005 price  
Source: Monthly Labour Survey
## Estimates of parameters

<table>
<thead>
<tr>
<th></th>
<th>Grid-line search Estimate (a)</th>
<th>Bootstrap Estimate 2 \times (a) !!!!-(b)</th>
<th>SE</th>
<th>Mean (b)</th>
<th>Bias (b) !!!!-!(a)</th>
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</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.3220</td>
<td>0.3137</td>
<td>0.0274</td>
<td>0.3303</td>
<td>0.0083</td>
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<tr>
<td>$\zeta$</td>
<td>0.2097</td>
<td>0.2346</td>
<td>0.0314</td>
<td>0.1848</td>
<td>-0.0249</td>
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<tr>
<td>$\gamma$</td>
<td>0.3500</td>
<td>0.3516</td>
<td>0.0295</td>
<td>0.3484</td>
<td>-0.0016</td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.1574</td>
<td>0.1564</td>
<td>0.0150</td>
<td>0.1584</td>
<td>0.0010</td>
</tr>
<tr>
<td>$C$</td>
<td>1.0350</td>
<td>1.0345</td>
<td>0.0266</td>
<td>1.0355</td>
<td>0.0005</td>
</tr>
<tr>
<td>$\xi$</td>
<td>1.2094</td>
<td>1.2212</td>
<td>0.0112</td>
<td>1.1976</td>
<td>-0.0118</td>
</tr>
<tr>
<td>$\omega$</td>
<td>0.0702</td>
<td>0.0635</td>
<td>0.0263</td>
<td>0.0769</td>
<td>0.0067</td>
</tr>
</tbody>
</table>

Implied Lerner index $(\zeta + \gamma) = 0.5862$, implied demand elasticity = 1.7059

Number of bootstrap repetitions $(N_{bs}) = 75$

Ratio of wage rates: $w_\ell / w_n \approx 0.2661$
Estimated adjustment costs

Industry code: 301