Employer Learning, Productivity and the Earnings Distribution: Evidence from Performance Measures

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Pay distributions fan out with experience. Why?

1. Employers learn about worker productivity.
2. Workers’ productivity evolve heterogeneously.

This paper: estimation of a specification nesting both!

Quantification of learning vs dynamic evolution of productivity.

Important: employer learning can lower HC return w.r.t. social return!
Intuition for Identification

- Data are wages + **performance measures** in one firm.

- EL: wages correlate with performance measures, past $>$ future.

- EL: at some point, firms have learned: correlations equalize.

- DPH: wages correlate with performance measures, past $\simeq$ future.

- DPH + EL: firms have never learned, correlations do not equalize.

- Covariance structure between wages and performance gives information on this!
Both employer learning (EL) and dynamic productivity heterogeneity (DPH) are important!

Dispersion of pay increases primarily because of DPH.

Learning very important for young, keeps being important later
→ employers try to hit a *moving target*.

Learning lowers significantly HC return
→ especially for *older* workers.
Farber and Gibbons 1996; Altonji and Pierret 2001; Lange 2007 exploit AFQT to argue that learning is important;

Baker, Gibbs and Holmstrom 1994 analyze (and provided to authors) data on managerial employees used here.

The Nested Model

- Labor markets are spot markets.
- Information is symmetric across employers.
- Firms known economy structure, update expectations Bayesianly.
- Worker productivity:
  \[ \tilde{Q}_{i,t} = Q(x_i, t)Q_i, t \]
  where \( Q(x_i, t) = \mathbb{E}[\tilde{Q}_{i,t} | x_i, t] \)
- Denote \( \tilde{q}_{i,t} = \log(\tilde{Q}_{i,t}) = \chi_{i,t} + q_{i,t} \)
- \( q_{i,t} \) evolves according to:
  \[ q_{i,t} = q_{i,t-1} + \underbrace{\kappa_{i}}_{i-specific\ trend} + \underbrace{\epsilon_{i,t}}_{\text{Innovation}} \]
  where \( \kappa_{i} \sim \mathcal{N}(0, \sigma_{\kappa}^2) \) and \( \epsilon_{i,t} \sim \mathcal{N}(0, \sigma_{r}^2) \)
Information Structure

- Three different signals:
  1. $z_{i,0}$ at the start, unobservable TDE.
  2. $\{z_{i,t}\}_{t=1}^{T}$, production, unobservable TDE.
  3. $\{p_{i,t}\}_{t=1}^{T}$, performance measure, (partially) observable TDE.

- Signal structure:

  $$p_{i,t} = q_{i,t} + \epsilon_{i,t}^P$$
  $$z_{i,0} = q_{i,0} + \epsilon_{i,0}$$
  $$z_{i,t} = q_{i,t} + \epsilon_{i,t}^Z$$

- All errors are independently distributed, mean zero, normal r.v.

- $\rightarrow$ standard Kalman filtering can be used, no l.o.g.
Pure Employer Learning Model

- Restrictions: $\sigma^2_\kappa = \sigma^2_r = 0$

- Log wages are given by

$$w_{i,t} = \mathbb{E}[q_i|l^t] = \chi_t + (1 - K_{t-1})\mathbb{E}[q_i|z_{i,0}] + K_{t-1} \frac{1}{t-1} \sum_{j=1}^{t-1} \phi_{i,j}$$

where, given a weight $\phi$ depending on the variance of signals,

$$\phi_{i,t} = (1 - \phi)p_{i,t} + \phi z_{i,t}$$

$$K_t = \frac{t \sigma^2_q}{t \sigma^2_q + \sigma^2_\phi}$$

- Thus:

$$\text{COV}(w_{i,t}, p_{i,t}) = \begin{cases} K_{t-1}(\sigma^2_q + \frac{1-\phi}{t-1} \sigma^2_p) & \tau < t \\ K_{t-1}\sigma^2_q & \tau \geq t \end{cases}$$
Implications of pure EL

1. Wage changes are serially uncorrelated;

2. The variance in pay increases with experience at a decreasing rate.

3. $\text{COV}(\text{wage, past performance}) > \text{COV}(\text{wage, future performance})$ with a discontinuity at $t = \tau$.

4. The size of the step in 3) declines with experience.

Figure 1: Simulated Covariances bw Pay and Performance

Panel A: Employer Learning Model

Panel B: Pure Productivity Model

ashed Lines=older workers, Solid lines=younger workers
Pure Dynamic Productivity Model

- Restrictions: $\sigma_0^2 = \sigma_z^2 = 0$

- Log wages are given by

  $$w_{i,t} = q_{i,t}$$
  $$p_{i,t} = q_{i,t} + \epsilon_{i,t}^p$$

- Thus

  $$\text{COV}(w_{i,t}, p_{i,\tau}) = \text{COV}(q_{i,t}, q_{i,\tau})$$

- Implications:

  1. Wage changes are serially correlated (HC accumulation).
  2. Variance in pay increases in experience at **Increasing** rate.
  3. $\text{COV}(w_{i,t}, p_{i,\tau})$ is increasing in experience $t$ and in $\tau$.
  4. There is no discontinuity in $\text{COV}(w_{i,t}, p_{i,\tau})$ at $t = \tau$.  

The Data

- Data come from the study of the internal organization of the firm by Baker, Gibbs and Holmstrom.

- Personnel record for all managerial employees.


- Attention restricted to 9,626 employees with non-missing education, with
  
  1. Non-missing education.
  
  2. At least one wage or performance measure between ages 25 and 54
  
  3. At least one more wage or performance measure
The Data

<table>
<thead>
<tr>
<th>% Male</th>
<th>76.4%</th>
<th>Salary^2 ($1,000s)</th>
<th>$54.003</th>
</tr>
</thead>
<tbody>
<tr>
<td>% White</td>
<td>89.6%</td>
<td>(25.562)</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>39.57</td>
<td>3.13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(9.47)</td>
<td>(0.71)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Education</th>
<th>Performance Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>% HS</td>
<td>17.9%</td>
</tr>
<tr>
<td>% Some College</td>
<td>19.8%</td>
</tr>
<tr>
<td>% College</td>
<td>36.1%</td>
</tr>
<tr>
<td>% Advanced</td>
<td>26.3%</td>
</tr>
</tbody>
</table>

Notes: Parentheses contain standard deviations.

- Discrete performance is adjusted by constructing a latent performance variable.
- Authors add measurement error in wages.
- Performance is persistent: thus authors assume noise in performance is persistent.
Performance and Age

Figure 2: Log Wages and Performance, by Age

Controlling for education, race, gender, and year effects
Empirical Moments 1

Figure 3a: Moments with 95% CI

Panel A: Variance of Log Pay

Panel B: Performance Auto-Correlations

Panel C: Pay Auto-Correlations

Panel D: Cor of Pay Changes

In panels B-D: solid-navy=young (exp 1-15), hollow-maroon=older (exp 16-30)
Dashed lines = 95% confidence interval
Figure 3b: Moments with 95% CI
Cor of Pay and Perf

solid-navy=young (exp 1-15), hollow-maroon=older (exp 16-30)
Dashed lines = 95% confidence interval
## Parameter Estimates

<table>
<thead>
<tr>
<th></th>
<th>Employer Learning</th>
<th>Productivity</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>productivity parameters:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma_q^2$</td>
<td>0.118</td>
<td>0.025</td>
<td>0.037</td>
</tr>
<tr>
<td>(initial productivity)</td>
<td>(0.0057)</td>
<td>(0.0051)</td>
<td>(0.0072)</td>
</tr>
<tr>
<td>$\sigma_r^2$</td>
<td>-</td>
<td>0.0040</td>
<td>0.00049</td>
</tr>
<tr>
<td>(random productivity innovations)</td>
<td></td>
<td>(0.00032)</td>
<td>(0.00040)</td>
</tr>
<tr>
<td>$\sigma_k^2$</td>
<td>-</td>
<td>0.0000825</td>
<td>0.00015</td>
</tr>
<tr>
<td>(heterogeneous growth)</td>
<td></td>
<td>(0.0000023)</td>
<td>(0.000016)</td>
</tr>
<tr>
<td><strong>information parameters:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma_0^2$</td>
<td>0.383</td>
<td>-</td>
<td>0.114</td>
</tr>
<tr>
<td>(noise on initial, private signal)</td>
<td>(0.061)</td>
<td></td>
<td>(0.071)</td>
</tr>
<tr>
<td>$\sigma_u^2$</td>
<td>0.650</td>
<td>0.405</td>
<td>0.488</td>
</tr>
<tr>
<td>(noise on performance measure)</td>
<td></td>
<td>(0.031)</td>
<td>(0.051)</td>
</tr>
<tr>
<td>$\sigma_z^2$</td>
<td>0.506</td>
<td>-</td>
<td>0.206</td>
</tr>
<tr>
<td>(noise on repeat, private signals)</td>
<td></td>
<td></td>
<td>(0.075)</td>
</tr>
<tr>
<td><strong>measurement parameters:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma_w^2$</td>
<td>0.0049</td>
<td>0.00030</td>
<td>2.83e-12</td>
</tr>
<tr>
<td>(measurement error in wages)</td>
<td>(0.00021)</td>
<td>(0.00048)</td>
<td>(4.95e-12)</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.645</td>
<td>0.634</td>
<td>0.640</td>
</tr>
<tr>
<td>(auto-correlation in performance)</td>
<td></td>
<td>(0.0084)</td>
<td>(0.0084)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.009)</td>
</tr>
</tbody>
</table>

Reported are the parameter values for the pure employer learning model, the pure productivity model and combined model. The pure employer learning model and the pure productivity model are estimated imposing zero restrictions on the relevant parameters.
Correlations

Figure 4: Results - Correlations of Pay and Performance

Panel A: Empirical Moments

Panel B: Pure Learning Model

Panel C: Pure Productivity Model

Panel D: Combined Model

Dots=data, Lines=moments implied by model estimates, Standard Error Bars generated from 500 bootstraps. solid-navy=young (exp 1-15), hollow-maroon=older (exp 16-30)
Figure 5: Results - Pure Learning Model

Panel A: Variance of Log Pay

Panel B: Performance Auto-Correlations

Panel C: Pay Auto-Correlations

Panel D: Cor of Pay Changes

Dots=data, Lines=moments implied by model estimates, standard error bars generated from 500 bootstraps. solid-navy=young (exp 1-15), hollow-maroon=older (exp 16-30)
Results: Pure DPH Model

Figure 6: Results - Pure Productivity Model

Panel A: Variance of Log Pay
- Graph showing variance of log pay against experience.

Panel B: Performance Auto-Correlation
- Graph showing performance auto-correlation against lags.

Panel C: Pay Auto-Correlations
- Graph showing pay auto-correlations against lags.

Panel D: Cor of Pay Changes
- Graph showing correlation of pay changes against lags.

ots=data, Lines=moments implied by model estimates, standard error bars generated from 500 bootstraps.
olid-navy=young (exp 1-15), hollow-maroon=older (exp 16-30)
Results: Full Model

**Figure 7: Results - Combined Model**

Panel A: Variance of Log Pay

Panel B: Performance Auto-Correlation

Panel C: Pay Auto-Correlations

Panel D: Cor of Pay Changes

Dots=data, Lines=moments implied by model estimates, standard error bars generated from 500 bootstraps.

solid-navy=young (exp 1-15), hollow-maroon=older (exp 16-30)
Figure 8: Productivity, Wage, and Error Variances

Full Model

- **Productivity**
- **Wage**
- **Firm Expectation Error**
### Table 5 The Share of Returns to Investments Going to Individuals

<table>
<thead>
<tr>
<th>Experience</th>
<th>Discount Factor R</th>
<th>0.9</th>
<th>0.92</th>
<th>0.95</th>
<th>0.97</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>0.67</td>
<td>0.71</td>
<td>0.78</td>
<td>0.84</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.60</td>
<td>0.66</td>
<td>0.75</td>
<td>0.82</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.61</td>
<td>0.67</td>
<td>0.75</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>0.60</td>
<td>0.64</td>
<td>0.71</td>
<td>0.76</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0.56</td>
<td>0.60</td>
<td>0.64</td>
<td>0.68</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>0.49</td>
<td>0.51</td>
<td>0.55</td>
<td>0.57</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>0.39</td>
<td>0.40</td>
<td>0.42</td>
<td>0.43</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>0.25</td>
<td>0.25</td>
<td>0.26</td>
<td>0.26</td>
<td></td>
</tr>
</tbody>
</table>

The table displays the increase in the present discount value of life-time wages as a fraction of the increase in the present discounted value of remaining life-time production associated with a unit increase in worker productivity at experience level t. These ratios are shown for different experience levels and for the specified gross discount factors. The calculations are based on the parameter estimates for the combined model presented in Table 4. We assume that individuals careers last for 40 years.
Conclusions

- New evidence on EL vs DPH as sources of wage heterogeneity.
- New estimation approach based on performance measures.
- Learning is not the primary driver of wage dynamics...
- ...however, expectation errors are always large...
- ...affecting importantly incentives to accumulate experience, especially later.
- Caveat: results restricted to managers within one firm → the market probably already learned a lot about them.