1 Lecture notes on: "Performance Pay and Productivity," Lazear, 2000, AER

- Lazear (2000, AER) studied reward schemes of the Safelite Glass Corporation
- They changed from hourly wage rates to piece-rates (with minimum requirements)
- Results: on average 44 percent higher output per worker, of which:
  - Half due to incentive effects (workers producing more)
  - Half due to self-selection effects (hiring more productive workers)

Data: 3,000 different workers over 19 month period from 1994-95 from a large auto glass company

> *Hooray economics*: Claims by sociologists and others that monetizing incentives may actually reduce output are unambiguously refuted by the data. Not only do the effects back up economic predictions, but the effects are extremely large and precisely in line with theory.

What you think is obvious is not obvious, but it is true anyway:

> While it may seem obvious that moving from hourly wages to piece rates would increase effort, it is not. When a firm instruments an hourly wage schedule, it usually couples the payment with some minimum level of output that is acceptable. It is possible, therefore, that the minimum acceptable output chosen for hourly wage workers exceeds the level of output that workers voluntarily choose under a piece rate. Further, it may be that the minimum level chosen under hourly wages is so high that only the most able workers can make the cut. When piece rates are instituted, more heterogeneity might be tolerated, resulting in lower average levels of output.
>
> ... Were workers homogenous, an hourly wage structure with a minimum number of units tolerated per hour could achieve the efficient outcome.

2 Model

Note: the notation in the paper is different then that of our lectures and of L&M. Be careful; this can be confusing.

e: output level
A: ability
e_0: Minimum acceptable output
W: wage

Y: income
X: effort

Utility of worker:

$$U(Y, X) \tag{1}$$

$U_1 := \frac{\partial U}{\partial Y} > 0$
$U_2 := \frac{\partial U}{\partial X} < 0$

Output function:

$$e = f(X, A) \tag{2}$$

$f_1 := \frac{\partial f}{\partial X} > 0$, $f_2 := \frac{\partial f}{\partial A} > 0$

$X_0(A)$: The effort required to meet a particular output e_0 given ability A.

$$e_0 = f(X_0(A), A) \tag{3}$$

Total differentiation wrt A: $0 = f_1 \frac{\partial X}{\partial A} + f_2 \implies \frac{\partial X}{\partial A} = -\frac{f_2}{f_1}$
$(\frac{dX}{dA}|e = e_0) = \frac{\partial X_0(A)}{\partial A} = -\frac{f_2}{f_1} < 0$ ... ability and effort are substitutes in production

Imagine a single required output and wage pair (e_0, W). This is a "traditional" wage.

Workers of ability A_0 or higher will prefer this to leisure, i.e., "no work and no pay", where this minimum ability (to be willing to accept the wage contract) is defined by:

$$U(W, X_0(A_0)) = U(0, 0) \tag{4}$$

I.e., this is the participation constraint for workers of ability A_0.
Workers with higher ability would gain a rent from accepting this contract. But other firms compete for this worker.

Let us define the worker's best alternative job as yielding $U(\hat{W}(A), \hat{X}(A))$.

We can imagine that workers of high ability may prefer a job that demands more, and pays more, than the initially-considered firm (firm 0). Let us assume an upper cutoff ability A_h such that:

$$U(W, X_0(A_h)) = U(\hat{W}(A_h), \hat{X}(A_h)). \tag{5}$$

and all workers with ability above A_h prefer to work elsewehere, i.e.,

$$U(W, X_0(A')) \leq U(\hat{W}(A'), \hat{X}(A')) \text{ for } A' \geq A_h$$

So, workers at the "current" firm have $A_0 \leq A < A_h$.

Linear piece rate: $be - K$

Utility under piece rate $= U(b \times f(X^*(A), A) - K,\ X^*(A))$

Where $X^*(A)$ is the worker of ability A's optimal choice effort under piece rate b.

Safelite offered a guaranteed minimum wage approximately at the former wage W, presumably coupled with the former minimum effort standard e_0 (*note: this is why we expected and would expect effort to increase – discuss), i.*e., Compensation $= \max[W, be - K]$. (draw, as in figure 1; note $e^* \neq e_0$).

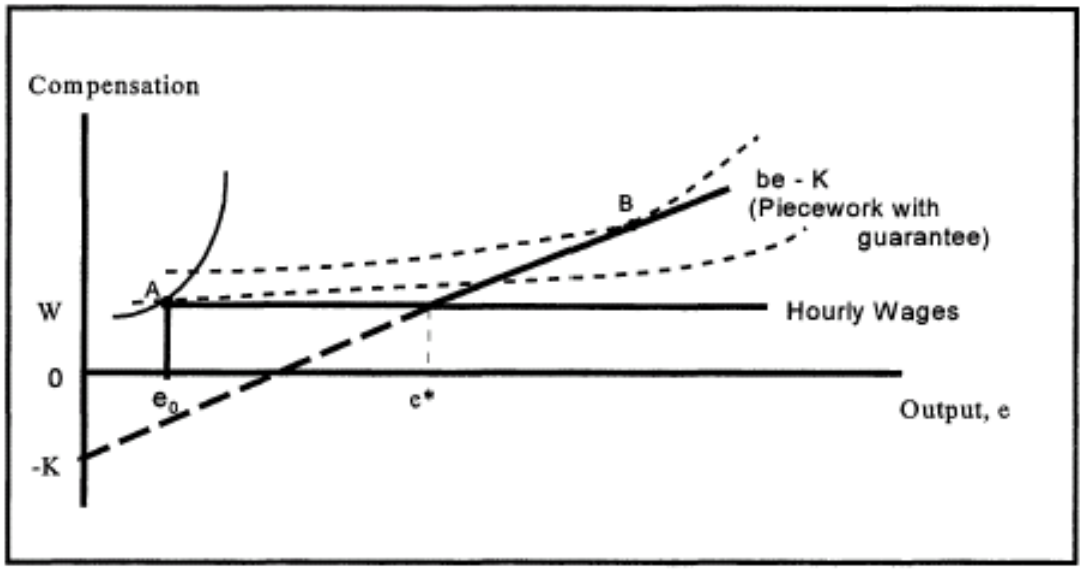

FIGURE 1. COMPENSATION BEFORE AND AFTER AT SAFELITE

Low ability $\Longrightarrow$ steep indifference curves$\Longrightarrow$may optimize at e_0. Note no one will choose $e_0 < e \leq e^*$ (this is a stark rational choice and certainty prediction).

PROPOSITION 1: Effort does not decrease as the firm switches from hourly wages to piece rates *[note: they mean to piece rates with the same minimum effort standard] ...* and it may increase.

Conditions for single crossing/ cut-off points:

I assume they mean conditional on accepting the contract/signing with the firm:

Condition 1: If a worker with ability A chooses $e > e^*$, so does a worker with ability $A' > A$..

Condition 2: If a worker with ability A chooses $e < e^*$ (actually e_0), so does a worker with ability $A'' < A$.

Conditions 1 & 2 $\Longrightarrow$

PROPOSITION 2: If some workers accept the guaranteed wage and some choose to work in the piece rate range, then the average ability of the workforce (at the firm) will not decrease, and will rise, except in a special case.

This seems pretty obvious, and is. The point is they hold on to the original set of workers with $A_0 < A < A_h$ – since these workers could always do as well as before by taking the guaranteed wage. No workers with $A < A_0$ will join the firm; see the conditions above. They also may gain some higher ability workers – if the piece rate is attractive, and thus someone accepts it, $U(bf(X^*(A), A) - K, A) > U(\hat{W}(A), \hat{X}(A))$ may hold for some $A > A_h$; in fact it would be a 'coincidence' they say if it only held for $A \leq A_h$.

[Note: footnote 10 in the paper relates to proposition 2]

PROPOSITION 3: If some workers choose to work in the piece rate range, then the range of worker ability (strictly?) and output will rise.

Trivial from previous proposition.

3 Data

Data: 3,000 different workers over 19 month period from 1994-95 from a large auto glass company in Columbus, Ohio. New CEO and president implemented a "Performance Pay Plan" (PPP), phased in over the 19 months: fees of about \$20 per unit, guarantee of \$11/hour (*unclear whether this was a decline for some, but the paper assumes it was not*).

Unit of observation: Worker in a month. 29,837 'good' observations.

Productivity measure: units/worker/day Mean=2.98, std. dev. = 1.53

Summary stats:

TABLE 1—DATA DESCRIPTION

Variable	Definition	Mean	Standard deviation
PPP dummy	A dummy variable equal to 1 if the worker is on PPP during that month	0.53	
Base pay	Hourly wage	$11.48	$2.94
Units-per-worker-per-day	Average number of units of glass installed by the given worker during the month in question	2.98	1.53
Regular hours	Regular hours worked during the given month	153	41
Overtime hours	Overtime hours worked that month	19	19
Pay	Pay actually received in a given month	$2,254	$882
Pay-per-day	Actual pay per eight hours worked; this differs from PPP pay in that the wage guarantee and other payments are included in the total	$107	$36
Cost-per-unit	Actual pay for a given worker, divided by the number of units installed by that worker in a given month	$40	$62
Log of pay-per-day	Log of actual pay per eight hours worked	4.62	0.29
Separation dummy	A dummy equal to 1 if the employee quit during this month	0.047	

Notes: There were 2,755 individuals who worked as installers over the 19-month period covered by the data. The unit of analysis is a person-month. There are 29,837 person-months of good data. Pay-per-day is calculated only for workers whose total hours in a month exceeded 10 and cost-per-unit only for workers whose monthly units installed exceeded 3.

Note: in all months after PPP, at least some workers received the guaranteed pay and some recieved more, satisfying the conditions for prop. 2 & 3.

4 Results

Simple breakdown:

TABLE 2—MEAN AND STANDARD DEVIATIONS OF KEY VARIABLES BY PAY STRUCTURE

	Hourly wages		Piece rates	
Number of observations	13,106		15,246	
Variable	Mean	Standard deviation	Mean	Hourly wages
Units-per-worker-per-day	2.70	1.42	3.24	1.59
Actual pay	$2,228	$794	$2,283	$950
PPP pay	$1,587	$823	$1,852	$997
Cost-per-unit	$44.43	$75.55	$35.24	$49.00

Note: 1,485 observations were dropped because the individual spent part of the month on PPP and part on hourly wages.

Note: final column should read "standard deviation." Note, PPP pay is "what it would have been" for left column.

Is this the whole story? Problems of such simple analysis (discuss):

- PPP introduced selectively: The PPP dummy may not be exogenous/orthogonal
  - In fact, lower-wage areas brought in first
- The months it was introduced may differ because of a company-wide shock; seasonal effects; no "controls"
- Employee attrition/ new employees; cannot differentiate worker's productivity increases from change in composition of workforce
- Doesn't differentiate effect by type of worker, location, etc.

OLS regression

TABLE 3—REGRESSION RESULTS

Regression number	Dummy for PPP person-month observation	Tenure	Time since PPP	New regime	R^2	Description
1	0.368 (0.013)				0.04	Dummies for month and year include
2	0.197 (0.009)				0.73	Dummies for month and year; worke specific dummies included (2,755 individual workers)
3	0.313 (0.014)	0.343 (0.017)	0.107 (0.024)		0.05	Dummies for month and year include
4	0.202 (0.009)	0.224 (0.058)	0.273 (0.018)		0.76	Dummies for month and year; worke specific dummies included (2,755 individual workers)
5	0.309 (0.014)	0.424 (0.019)	0.130 (0.024)	0.243 (0.025)	0.06	Dummies for month and year include

Notes: Standard errors are reported in parentheses below the coefficients.
Dependent variable: ln output-per-worker-per-day.
Number of observations: 29.837.

Notes: Horizontal display is non-typical; also, no stars for significance. "Boring" coefficients not displayed. Rows 2 & 4 are like "fixed-effects" models; note high R^2 if these dummies count, very low R^2 otherwise. Dependent variable may not be relevant one depending on goal.

Dependent variable: should read "in logs" (?)

Interpretation of results:

1. Simplest regression, large and significant 0.368 coefficient on impact of PPP on log(output/worker/day); implies a 44% gain in productivity at mean of dependent variable.

Note on derived calculation:
$\frac{\partial \log(Y)}{\partial X} = \beta = .368 = \frac{1}{Y}\frac{\partial Y}{\partial X} \implies \frac{\partial Y}{\partial X} = \beta Y$
$\log(Y) = \beta X + c$
$exp(\log(Y)) = Y = \exp(\beta X + c) = \exp(c)\exp(X\beta)$
at $X = 1$: $Y = \exp(c)\exp(\beta)$
at $X = 0$: $Y = \exp(c)$
$\frac{\Delta Y}{\Delta X} = \exp(c)(\exp(\beta) - 1)$
$\frac{\Delta Y}{\Delta X}/Y(0) = \exp(c)(\exp(\beta) - 1)/(\exp(c)) = e^{\beta} - 1 = \exp(.368) - 1 = 0.444...$

2. Including individual dummies $\implies$ smaller but positive significant coefficient 0.197 $\implies$ 22% gain in productivity for the typical worker. This is claimed

as "the incentive effect." The remaining effect (regression 1) could be "sorting,' or a spurious effect from the selection of high-quality workers for PPP first.

3. Similar results, no "Hawthorne" effect; productivity *improves* as time passes since PPP, even controlling for tenure

4. Similar to 3, but with individual dummies; even *greater* improvements, controlling for tenure .

Note: there might have been other systemic changes.

Discuss: how are tenure and time-since-PPP separately identifiable here?

4.1 Sorting

OLS tenure estimates combine learning and sorting; those who are not making it quit or are fired; OLS-FE estimates measure only learning; both effects appear substantial.

5. (row 5, table 3) Hired under "New regime" dummy. The workers hired under the new regime are more productive, controlling for tenure, etc.

No significant results for separation rates.

4.2 "Fixed Effects"

Note: Lazear is not using the term "fixed effects" in its most typical sense, as in "fixed-effects regressions" which control for individual- fixed effects but generally do not actually report these. Lazear actually wants to estimate these individual dummies and see how they relate to hires and quits (Discuss)

Lazear can estimate

$$Y_{it} = \boldsymbol{\beta}'\mathbf{X}_{it} + \sum_{i-1..n} c_i D_i + \varepsilon_{it}$$

where Y_{it} is the output variable (log output/worker/day) for individual i at time t, $\mathbf{X}_{it}$ is a matrix of variables for individual i at time t, including month and year dummies, tenure, and time since PPP. D_i is the dummy for individual i – the c_i terms are estimable where we have multiple observations on the same individual. For data after the PPP, these can be seen as proxies for ability and motivation; although it is unclear what they would represent before the PPP; perhaps intrinsic motivation or desire to please, win promotion, etc. *But if he wants to compare the FE of those who quit both before and after PPP, or compare the FE of those who quit near the beginning of PPP versus stayers, he cannot use FE's estimated after PPP (discuss).*

Since he has multiple observations on workers around before and after PPP, Lazear can estimate

$$Y_{it} = \boldsymbol{\beta}'\mathbf{X}_{it} + \sum_{i-1..n}(1 - PPP_{it})c_{i0}D_i + \sum_{i-1..n} PPP_{it}c_{i1}D_i + \varepsilon_{it}$$

where $PPP_{it} = 1$ if the observation is after PPP introduced in worker i's factory, and $PPP_{it} = 0$ otherwise.

For workers with multiple months before and after PPP, Lazear can estimate both c_{i0} and c_{i1} – the worker's individual-fixed effect both before and after the new policy. He plots these in figure 2:

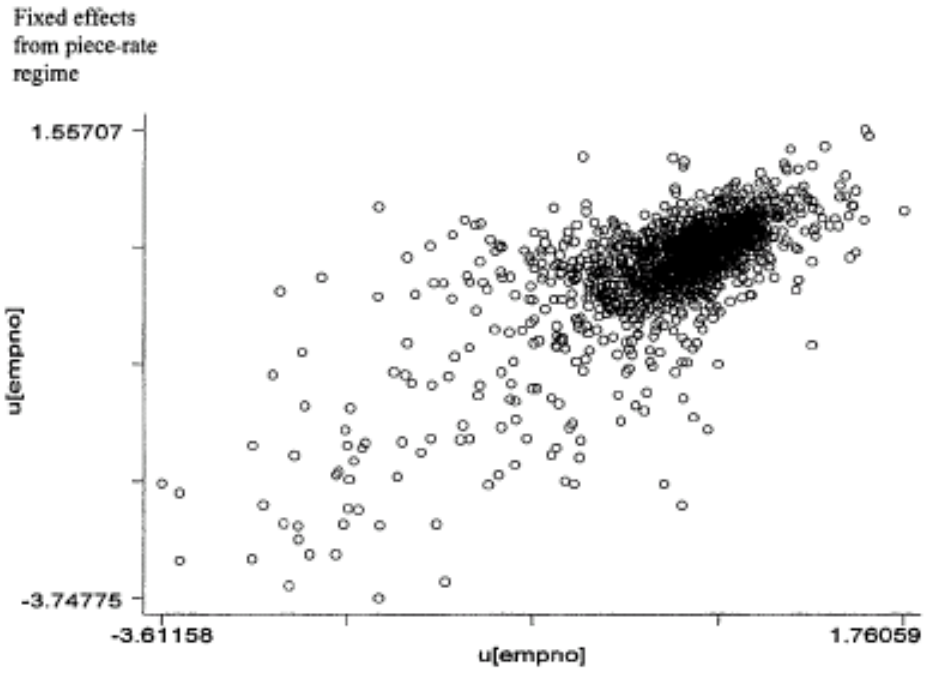

FIGURE 2. SCATTERPLOT OF FIXED EFFECTS FROM THE TWO REGIMES

He regresses one on the other, and finds and computes a 0.700 coefficient, which is highly significant; the "fixed effects" are highly correlated.

This may suggest intrinsic motivation (discuss).

The high correlation is taken as a rationale for using the hourly wage-period individual effects to examine turnover.

Median fixed effect (from wage regime data) for those who leave before two months into PPP regine is 0.15 (95% upper bound 0.19); versus 0.22 for the stayers (lower bound 0.21).

Note: this should occur anyway, as more able people typically stay. Authors claim "presumably" the tenure variable controls for this; I am not sure. They should justify this and/or give comparable figures before PPP.

No evidence that stayers have a higher variance. Not clear what this means for their model.

...

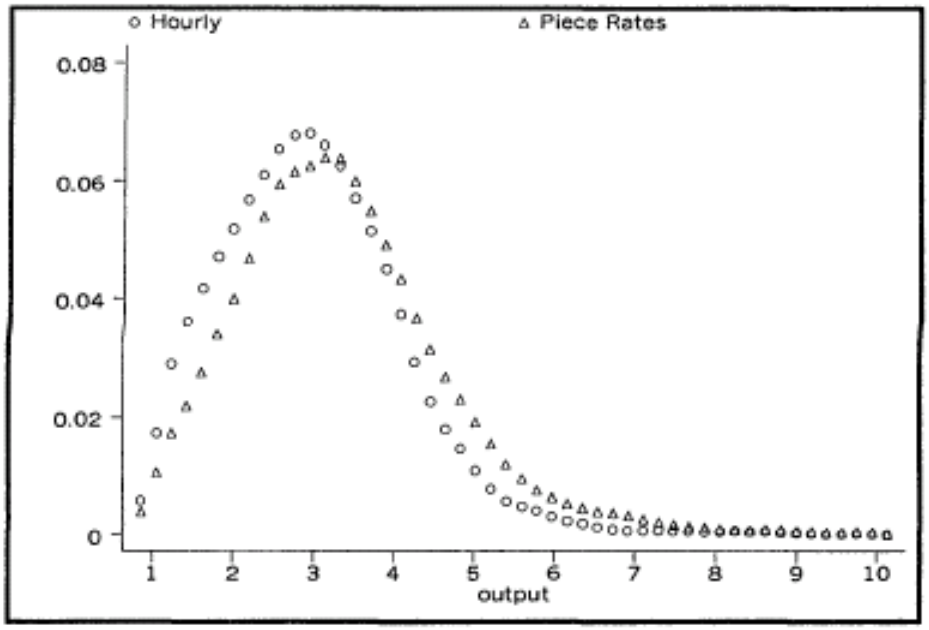

FIGURE 3. KERNEL DENSITIES IN THE TWO REGIMES

Note piece rate distribution is to the right, less concentrated around the peak.

TABLE 6—REGRESSION RESULTS

Regression number	PPP dummy	R^2	Description
1	0.068 (0.005)	0.06	Dummies for month and year included
2	0.099 (0.004)	0.76	Dummies for month and year; worker-specific dummies included (2,755 individual workers)

Notes: Standard errors are reported in parentheses below the coefficients.
Dependent variable: ln pay-per-day.
Number of observations: 29,837.

5 Pay and profitability

Compensation up by about 7-10%, productivity rose by around 44%

But measurement may be costly.

6 Quality

Quality may suffer (if it is not also easily monitored).
This relates to the problem of motivating multiple tasks.

7 Piecework not always profitable

NLSY shows only 3.3% of workers in US on piece rates, mostly among laborers.
More common in Sweden.