Performance Pay and Productivity

By EDWARD P. LAZEAR*

Much of the theory in personnel economics relates to effects of monetary incentives on output, but the theory was untested because appropriate data were unavailable. A new data set for the Safelite Glass Corporation tests the predictions that average productivity will rise, the firm will attract a more able workforce, and variance in output across individuals at the firm will rise when it shifts to piece rates. In Safelite, productivity effects amount to a 44-percent increase in output per worker. This firm apparently had selected a suboptimal compensation system, as profits also increased with the change. (*JEL* J00, J22, J3)

A cornerstone of the theory in personnel economics is that workers respond to incentives. Specifically, it is a given that paying on the basis of output will induce workers to supply more output. Many sophisticated models have been offered, but they have gone largely untested because of a lack of data. Of course, there are some difficulties associated with performance pay schemes that have been pointed out in the literature.[1] There is a literature that examines the choice of payment schemes and its effects on profits and/or earnings.[2] But overall, there have been few attempts to examine the choice of payment scheme and its effect on output.[3] How sensitive is worker behavior to incentives and what specific changes in behavior are elicited? A newly available data set allows these questions to be answered.

The analysis in this paper is based on data from Safelite Glass Corporation, a large auto glass company. During 1994 and 1995, after the introduction of new management, the company gradually changed the compensation method for its workforce, moving them from hourly wages to piece-rate pay. The effects, which are documented by examining the behavior of about 3,000 different workers over a 19-month period, are dramatic and completely in line with economic theory.

In what follows, the theory of piece-rate compensation is sketched with particular emphasis on the predictions that pertain to changes in the compensation method used by Safelite. The theory is backed up by the empirical results, the most important of which are:

1. A switch to piece-rate pay has a significant effect on average levels of output per worker. This is in the range of a 44-percent gain.

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[1] See Lazear (1986) for a detailed discussion of when to pay a piece rate, which is defined to be payment on the basis of output. Also, Eugene F. Fama (1991) discusses other reasons for paying on the basis of some measured time interval. George Baker (1992) discusses the difficulties created by pay-for-performance structures when measurement is a problem. A very early discussion of the incentive effects of piece rates can be found in Sumner Slichter (1928 Ch. 13).

[2] See, for example, Orley Ashenfelter and John H. Pencavel (1976), Eric Seiler (1984), Charles Brown (1992), and Allison Booth and Jeff Frank (1996), who look at compensation method and resulting income. Pencavel (1978), Martin Brown and Peter Philips (1986), Claudia Goldin (1986), Brown (1990), and Robert Drago and John S. Heywood (1995) examine choice of compensation scheme and changes in pay for performance over time.

[3] There are some attempts to examine the effect of incentives on productivity. Sue Fernie and David Metcalf (1996) find that when payment is contingent on performance, jockeys perform better than when payment is unrelated to performance. Also, Harry J. Paarsch and Bruce S. Shearer (1996) find that tree planters in British Columbia produce higher levels of output when paid piece rates, but that they become fatigued more rapidly.

2. The gain can be split into two components. About half of the increase in productivity results from the average worker producing more because of incentive effects. Some of the increase results from an ability to hire the most productive workers and possibly from a reduction in quits among the highest output workers. None reflects the "Hawthorne effect."
3. The firm shares the gains in productivity with its workforce. A given worker receives about a 10-percent increase in pay as a result of the switch to piece rates.
4. Moving to piece-rate pay increases the variance in output. More ambitious workers have less incentive to differentiate themselves when hourly wages are paid than when piece-rate pay is used.

The evidence implies that the choice of compensation method has important incentive effects, not that piece-rate schemes are more profitable. In equilibrium, firms choose a compensation method based on the costs and benefits of the various schemes. Firms that continue to pay hourly wages in equilibrium are those for which the benefits of paying an hourly wage, such as low monitoring costs and perhaps higher quality output, outweigh the costs in the form of lower output.

Some conclusions are unambiguous. Workers respond to prices just as economic theory predicts. Claims by sociologists[4] 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.

The evidence allows somewhat broader interpretation. It is often difficult to obtain actual data on consumers and their reactions to changes in prices. Tests of even the most basic tenets of economic theory are difficult to perform, at least at a micro level. These data are well suited to that purpose. While experiments bear out the basic response of economic agents to prices, the data used in this paper come from the real world rather than a laboratory setting. Compensation, which reflects the most important price that a consumer faces, truly matters to the workers in this setting, and they respond accordingly.

I. Modeling Choice of Pay Scheme: Hourly Wages Versus Piece Rates

The primary motivation behind instituting a piece-rate scheme is to increase worker effort. While it may seem obvious that moving from hourly wages to piece rates would increase effort, it is not. When a firm institutes 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.

This suggests that the term "performance pay" is not very useful. Even if we restrict performance pay to refer to pay based on output (rather than input), a broad set of compensation schemes are included. Hourly wages that are coupled with some minimum standard could be called performance pay because an output-based performance standard must be met to retain employment. In fact, were workers homogeneous, an hourly wage structure with a minimum number of units tolerated per hour could achieve the efficient outcome.[5]

The conditions of the job determine which workers choose to accept employment. If standards are too strict, only the most able will find the job suitable, even at a high wage. A rough sketch of a framework that permits an analysis of the choice of standards and ability is given here.[6]

[4] The hypothesis was first stated by E. L. Deci (1971). Early evidence supporting the claim in the area of child development is presented by Mark R. Lepper et al. (1973).

[5] To do this, simply solve for the efficient level of effort per hour, which sets the marginal cost of effort equal to the marginal value of effort. Require that level of effort as the minimum standard for the job. Then, set the hourly wage just high enough to attract workers to the firm.

[6] A more complete version of the model is available in a paper by the same title, National Bureau of Economic Research Working Paper No. 5672 (Lazear, 1996).

Define e to be the output level chosen by a worker, which is a function of underlying ability, A, and of effort choice. Suppose that the firm can observe e.

The firm that pays an hourly wage can specify some minimally acceptable level of output per hour e_0. The firm fires workers whose output falls consistently below e_0. Commensurate with that level of required output is some wage, W, that the firm offers. The worker's utility function is given by

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

where Y is income and X is effort. Naturally, $U_1 > 0$ and $U_2 < 0$.

Let A denote ability. Then output, e, depends on ability and effort according to

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

with $f_1, f_2 > 0$. For any given required level of output e, and ability level, A, there is a unique level of effort X that satisfies (2). Denote by $X_0(A)$ the level of effort necessary to satisfy

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

for the required level of effort e_0. It is clear that given (2),

$$\frac{\partial X}{\partial A} = -\frac{f_2}{f_1},$$

which is negative. Higher-ability individuals need exert less effort to achieve a given level of output.

For any given pair of required output and wage, (e_0, W), there is a group of workers who will accept the job. The minimum-ability individual who will accept a job in lieu of leisure that requires e_0 of output to be produced is A_0 such that

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

where $U(0, 0)$ is interpreted as the utility associated with leisure.

All workers with ability levels that exceed A_0 earn rents from employment because they are required only to produce e_0 of output, and the pain associated with producing it is lower than the pain for individuals with ability A_0, who are just indifferent between working and not. However, because there is competition from other firms, a worker must compare the rents earned at this firm with those offered elsewhere.

Those willing to work at the firm must not have work alternatives that are preferred to those here. The utility that a worker of ability A can get at another firm that does not necessary pay workers of all types the same amount is given by $U(\hat{W}(A), \hat{X}(A))$ where $\hat{W}$, $\hat{X}$ refer to the wage and effort levels on the best alternative job for worker of ability A. Higher-ability workers are likely to find that the straight hourly wage job is not as attractive as an alternative that demands more, but pays more, even if the less able workers would find such a job onerous. Thus, there may exist an upper cutoff, A_h, such that

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

Those who choose to work at the current firm have ability greater than A_0, but less than A_h.[7]

A linear piece rate takes the form $(be - K)$ where K is the implicit charge for the job. The utility that a risk-neutral worker receives can be written

$$\text{Utility under piece rate} = U(bf(X^*(A), A) - K, X^*(A))$$

where $X^*(A)$ is the effort that an individual with ability A chooses when faced with the piece rate b.

[7] Rents are higher on the current job for higher-ability workers in that the more able accomplish the task more easily. But other firms need not constrain all workers to earn the same amount. It is for this reason that some high-ability workers may choose to work elsewhere. If opportunities outside are sufficiently bad, all workers with $A > A_0$ would work at this firm and $A_h = \infty$. It is also possible that there are multiple crossings. These are assumed away for analytic convenience.

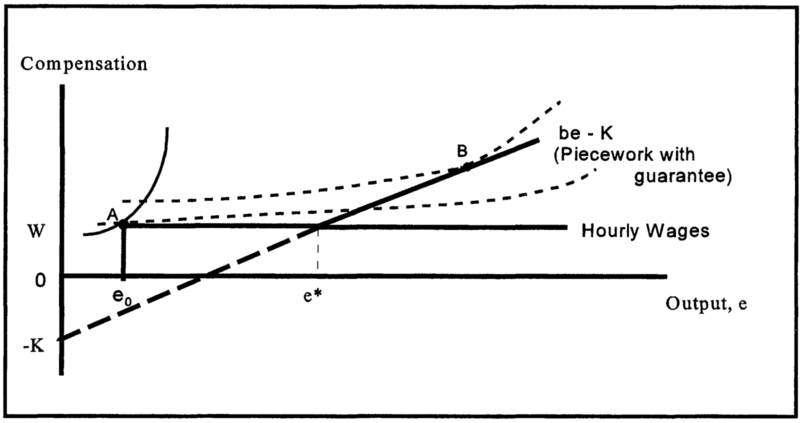

FIGURE 1. COMPENSATION BEFORE AND AFTER AT SAFELITE

In order to fit the Safelite situation analyzed in the empirical section below, it is useful to model the effects of switching from an hourly wage with minimum standard to a piece rate with a minimum guarantee. As part of Safelite's plan, it offered a guarantee at approximately the former wage. The guarantee was coupled, presumably, with the same minimum standard of e_0 as before. Thus, the plan paid W to anyone who would have earned less than W under the piece rate, but paid the piece rate to all of those whose compensation by the piece-rate formula would have exceeded W. The scheme used is

$$\text{Compensation} = \max[W, be - K].$$

The situation is shown in Figure 1.

This scheme is typical of many salespersons' plans. A draw, in this case equal to W, is paid to workers whose output exceeds e_0 up to some level of output, e^*. At output greater than e^*, the worker begins to receive additional compensation for increases in output. As long as the worker produces $e > e^*$, his compensation is given by $be - K$. At most firms, workers who continually dip into their draw by producing $e < e^*$ are likely to find their employment terminated after some period of time.

Low-ability workers have steep indifference curves because additional effort must be compensated by large increases in income. The solid indifference curve through A is that of a relatively low-ability worker. The dotted indifference curve through A reflects the preferences of a higher-ability worker since it takes less income to induce him to provide a given amount of effort.[8]

The hourly wage schedule is shown by the step function that starts at zero, becomes vertical at e_0 and then horizontal at point A. The piece-rate schedule with guarantee is the same, except that compensation rises with output above e^*, as shown by the upward-sloping segment. When workers are offered hourly wages, all, even the most able, choose point A. When offered the piece-rate schedule with a guarantee, the less able worker (solid) still chooses A, but the more able worker (dotted) chooses B. This can be stated more formally in three propositions, which are proved in the Appendix.

PROPOSITION 1: *Effort does not decrease when the firm switches from hourly wages to piece rates, and as long as there is some ability type for which output rises, average effort increases.*

Because the guarantee binds for some workers, but not for all, effort does not increase for all workers. Workers whose optimal level of effort lies to the left of e^* in Figure 1 gain nothing by increasing effort. But those whose optimal level of effort is sufficiently high may

[8] "Ability" can be read "ambition" in the interpretation of A. Nothing is changed.

choose to work enough to be on the upward-sloping portion of the compensation function.

Another proposition can be stated, given two conditions:[9]

Condition 1: If a worker with ability A chooses to work at an effort level in the piece-rate range, then any worker with ability greater than A also chooses to work at an effort level in the piece-rate range.

Condition 2: If a worker with ability A chooses to work at an effort level in the wage-guarantee range, then any worker with ability less than A also chooses to work at an effort level in the wage-guarantee range.

Then,

PROPOSITION 2: *A sufficient condition for the average ability of the workforce to be non-decreasing, and more generally, to rise after the switch to piece rates is that some workers accept the guaranteed wage and some workers choose to work enough to be in the piece-rate range.*

Average ability rises because the ability of the lowest-quality worker does not change as a result of the switch in compensation scheme, but the ability of the highest-quality worker rises. Because a piece rate allows the more able to work harder and receive more from the job, and because the hourly wage does not, more able workers prefer piece rates. The least-able worker is indifferent between the two schemes. Switching to piece rates has the effect of changing the pool of applicants to Safelite. Those who prefer to work at high levels of effort favor Safelite over other firms in the industry after the switch.

Finally,

PROPOSITION 3: *A sufficient condition for the range of worker ability and output to rise after the switch to piece rates is that some workers choose to work enough to be in the piece-rate range.*

Even if underlying ability levels did not change, variance in productivity would rise because workers choose the same level of output under an hourly wage, but type-specific levels of output under piece rates. When it is recognized that the maximum ability level increases under a piece rate, the change in output variance becomes even greater.[10]

II. Data

Safelite Glass Corporation is located in Columbus, Ohio, and is the country's largest installer of automobile glass. In 1994, Safelite, under the direction of CEO Garen Staglin and President John Barlow, implemented a new compensation scheme for the auto glass installers. Until January 1994, glass installers were paid an hourly wage rate, which did not vary in any direct way with the number of windows that were installed. During 1994 and 1995, installers were shifted from an hourly wage schedule to performance pay—specifically, to a piece-rate schedule. Rather than being paid for the number of hours that they worked, installers were paid for the number of glass units that they installed. The rates varied somewhat. On average installers were paid about \$20 per unit installed. At the time that the piece rates were instituted, the workers were also given a guarantee of approximately \$11 per hour. If their weekly pay came out to less than the guarantee, they would be paid the guaranteed amount. Many workers ended up in the guarantee range.

Staglin and Barlow changed the compensation scheme because they felt that productivity was below where it should have been. Productivity could have been raised by requiring a higher minimum level of output under a time-rate system. If all workers had identical preferences, this would have worked well. Given differences in work preferences, a uniform in-

[9] Define $X = g(e, A)$ as the inverse of (2). Then it can be shown that Condition 1 and Condition 2 hold as long as $\partial g(e, A)/\partial A < 0$, $\partial g(e, A)/\partial e > 0$, and $\partial U(Y, X)/\partial X^2 > 0$ all hold.

[10] The condition that some workers continue to opt for the guaranteed wage is not superfluous. If all workers opt for the piece rate, then it is possible that even very low ability workers who did not work before now work for the firm. Their addition could actually result in a lowering of average ability.

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.

crease in required output, coupled with a wage increase, would not be received in the same way by all workers. In particular, the lower-output workers would find this more burdensome than the higher-output workers. In order to avoid massive turnover, the firm adopted a piece-rate schedule, which allowed those who wanted to work more to earn more, but also allowed those who would accept lower pay to put forth less effort.

Safelite has a very sophisticated computerized information system, which keeps track of how many units of each kind each installer in the company installs in a given week. Safelite provided monthly data. Since PPP (Performance Pay Plan) was phased in over a 19-month period, many workers were employed under both regimes. Thus, data on individual output are available for most installers both during the hourly wage period and during the PPP period. This before-and-after comparison with person-specific data provides a very clean body of information on which to base an analysis of performance pay incentives.

Some basic characteristics of the sample are reported in Table 1. The data are organized as follows. Each month provides an independent unit of observation. There are 38,764 person-months of data covering a 19-month period. Over the 19-month period, there was a total of 3,707 different individuals who worked for Safelite as installers. The number of "good" observations is 29,837 when partial months and observations with incomplete data are dropped from the data set.

There are a number of possible productivity measures. The one that most Safelite managers look to is units-per-worker-per-day. This is the total number of glass units per eight-hour day that are installed by a given worker. The units-per-worker-per-day number for each individual observation relates to a given worker in a given month. Thus, units-per-worker-per-day is the average number of units per eight-hour period installed by the given worker during the given month.

The average number of glass units installed per day over the entire period is 2.98, with a

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.

standard deviation of 1.53. The average actual pay was $2,254, which is above the amount that would be paid had the worker received exactly the amount to which he was entitled based on a straight piece rate. The difference reflects vacation, holiday, and sick pay, as well as two other factors. First, not all workers are on PPP during the period. When on hourly wages, some received higher compensation than they would have had they been on PPP, given the number of units installed. Of course, when a given worker switches to PPP, incentives change and his output may go up enough to cover the deficit. Second, even when workers are on PPP, a substantial fraction of person-weeks calculated on the basis of the PPP formula comes in below the guaranteed weekly compensation. The guarantee binds for those worker weeks, and actual pay then exceeds PPP pay. In all months after the introduction of PPP, at least some workers received the guaranteed pay and some earned more than the guarantee. Thus, the sufficient conditions for Propositions 2 and 3 are met throughout the period.

Means for actual and PPP pay reveal almost nothing about the effects of PPP on performance and sorting. A more direct approach is needed. Table 2 presents some means of the key variables and breaks them down by the PPP dummy, which is set equal to one if the worker in question is on PPP during the given month.[11]

The story that will be told in more detail below shows up in the simple means. The average level of units-per-worker-per-day is about 0.54 units, or 20 percent higher in the piece-rate regime than in the hourly wage regime. Also, the variance in output goes up when switching from hourly wages to piece rates, as can be seen by comparing the standard deviations of 1.59 to 1.42.[12]

Thus, Propositions 1, 2, and 3, which state that both mean and variance in output rise when switching from hourly wages to piece rates, are borne out by the simple statistics. Further, note that there is good indication that profitability went up significantly with the switch. The cost per unit is considerably lower in the piece-rate regime than it is with hourly wages.[13]

The simple statistics do not take other factors into account. In particular, auto glass demand is closely related to miles driven, which varies with weather. Major storms, especially hail, also cause glass damage. Month effects and year effects matter. Perhaps more important, the management change that took place before PPP was instituted had other direct effects on the company that may have changed output during the sample period, irrespective of the switch to PPP. To deal with these factors, month and year dummies are included. The simplest specification in the first row of Table 3 yields a coefficient on the PPP dummy of 0.368. Evaluated at

[11] Only observations where workers were on one pay regime or the other for the full month are used. Partial month observations are deleted.

[12] This number includes within-worker components as well as between-worker components. The latter is of interest and is investigated in more detail below.

[13] The fact that actual pay has only risen slightly after the switch to PPP than before reflects the phase-in pattern of the PPP program. Lower-wage areas were brought into the program first, which means that the PPP = 1 data are dominated by lower-wage markets. This pattern also affects the differences between piece-rate and hourly wage output if early switchers to PPP have different average output levels than late switchers to PPP.

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 included
2	0.197 (0.009)				0.73	Dummies for month and year; worker-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 included
4	0.202 (0.009)	0.224 (0.058)	0.273 (0.018)		0.76	Dummies for month and year; worker-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 included

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

the mean of the log of units-per-worker-per-day, this coefficient implies that there is a 44-percent gain in productivity with a move to PPP.

There are three possible interpretations of this extremely large and statistically precise effect. First, the gain in productivity may result from incentive effects associated with the program. Second, the gain may result from sorting. A different group of workers may be present after the switch to piece rates. Third, the pattern of implementation may cause a spurious positive effect. Suppose that Safelite picked its best workers to put on piece rates first. The PPP dummy coefficient would pick up an ability effect because high-ability workers would have more PPP months than low-ability workers. Unless ability is correlated with region in a particular way, the third explanation can be ruled out because Safelite switched its stores to PPP on a regional basis, starting with Columbus, Ohio, where the headquarters is located, and moving out. The other two effects can all be identified by using the data in a variety of ways.

When worker dummies are included in the regression, the coefficient drops to 0.197 from 0.368. The 0.197 is the pure incentive effect that results from switching from hourly wages to piece rates. Evaluated at the means, it implies that a given worker installs 22 percent more units after the switch to PPP than he did before the switch to PPP. This estimate controls for month and year effects. Individual ability is held constant as is shop location by including the person dummies. Approximately half of the 44-percent difference in productivity attributed to the PPP program reflects an incentive effect.

Nor does this gain appear to be a Hawthorne effect.[14] This can be seen by examining regression 3 in Table 3. The regression includes a variable for tenure and also one for time that the worker has been on the PPP program. It is zero for all months before the individual is on piece rates. It is the number of years that the individual has been on piece rates in the current person-month observation. For example, a worker who started 1994 on hourly wages and was switched to PPP on July 1, 1994 would have time since PPP equal to zero for the June 1994 observation, to 0.5 for the January 1995 observation, and to 1.0 for the June 1995 observation.

Consider the estimates with fixed effects in regression 4. The coefficient of 0.273 on time since tenure coupled with a PPP dummy coefficient of 0.202, means that the initial effect of switching from hourly wage to piece rate is to increase log productivity by 0.202. After one year

[14] The Hawthorne effect, named after the Hawthorne Western Electric Plant in Illinois, alleges that any change is likely to bring about short-term gains in productivity.

on the program, the increase in log productivity has grown to 0.475. The Hawthorne effect would imply a negative coefficient on time since PPP. If the Hawthorne effect held, then the longer the worker were on the program, the smaller would be the effect of piece rates on productivity. The reverse happens here. After workers are switched to piece rates, they seem to learn ways to work faster or harder as time progresses.

III. Sorting

Tenure effects are large and significant. Using regression 3 of Table 3, it is estimated that one year of tenure raises log productivity by about 0.34. As is true of all tenure estimates, there are two interpretations. The first is learning. Turnover rates are over 4 ½ percent per month, and the mean level of tenure is only about two-thirds of a year. It would not be surprising to see a worker increase his windshield installation rate dramatically during the first few months on the job. The second interpretation is one of sorting. Those who are not making it get fired or quit early. Regression 4 of the table assists in interpretation.

Regression 4 reports the estimates of the regression in regression 3, including fixed effects for individuals. Thus, the tenure coefficient reflects the effect of tenure for a given worker, averaged across individuals. The estimate of 0.20 on log productivity can be interpreted as the average effect of learning within the sample.[15] Thus, the effect of learning appears substantial.

The theory stated in Propositions 2 and 3 suggests that the optimal piece rate is implemented such that both mean and range of worker ability should rise after the switch to piece rates. The theory implies specifically that there should be no change in the number of low-ability workers who are willing to work with the firm, but that piece rates would allow high-ability workers to use their talents more lucratively. Thus, the top tail of the distribution should thicken.

Underlying ability is difficult to measure, but actual output can be observed. The fifth regression of Table 3 provides evidence on this point. "New regime" is a dummy set equal to one if the individual was hired after January 1, 1995, by which point almost the entire firm had switched to piecework. The theory predicts that workers hired under the new regime should produce more output than the previously hired employees.[16] Indeed, workers hired under the new regime have log productivity that is 0.24 greater than those hired under the old regime, given tenure.

Separations can also be examined. Suppose that workers must try the job for a while to discover their ability levels. Workers who find the job unsuitable leave. Then, looking at the relation of ability to separation rates (quits plus layoffs) before and after the switch to piece rates will provide evidence on the validity of Propositions 2 and 3.

A separation is defined as an observation in which the worker in question did not work during the subsequent month. Thus, a dummy is set equal to one in the last month of employment. Those workers who work through July 1995 (the last month for which data are available) have this dummy set equal to zero for every month in which they worked. A worker who was employed, say from January 1994 through February 1995, would have the dummy equal to zero in every month of employment, except for February 1995, when it would equal one.

Table 4 reports a breakdown of separation rates by PPP regime and by worker output deciles where output is defined as units-per-worker-per-day during the previous month.[17]

First note that simple effect of a move to PPP increases turnover from 3.3 percent per month to 3.6 percent per month, but the difference is not statistically significant.[18] The direction of

[15] The term "average" is used cautiously. The sample contains different numbers of observations at each tenure level so that the average picks up not only nonlinearities, but different tenure effects for different types of individuals that may be more or less heavily weighted in the sample.

[16] Taken literally, the theory implies that none of the low-output incumbents should leave since the guarantee makes them no worse off than before, but some higher-quality workers are now willing to take the job.

[17] This is done so that no mechanical connection between low output per week and separation would exist as a result of leaving in the middle of a week.

[18] Note that the turnover rates in Table 4 are lower than the one reported in Table 1. This is because in order to be

TABLE 4—SEPARATION RATES BY REGIME AND DECILE

	Hourly regime			PPP regime			Difference between PPP and hourly separation rates	
Decile	Separation rate	Number of observations	Standard error	Separation rate	Number of observations	Standard error	Difference	Standard error
Lowest								
0	0.041	1,641	0.005	0.039	1,285	0.005	−0.002	0.007
1	0.043	1,465	0.005	0.038	1,491	0.005	−0.006	0.007
2	0.042	1,358	0.005	0.037	1,625	0.005	−0.005	0.007
3	0.039	1,245	0.005	0.037	1,691	0.005	−0.002	0.007
4	0.037	1,282	0.005	0.034	1,693	0.004	−0.003	0.007
5	0.038	1,279	0.005	0.04	1,792	0.005	0.002	0.007
6	0.025	1,223	0.004	0.03	1,777	0.004	0.005	0.006
7	0.029	1,135	0.005	0.03	1,879	0.004	0.001	0.006
8	0.03	880	0.006	0.022	2,169	0.003	−0.008	0.007
9	0.033	2,437	0.004	0.027	339	0.009	−0.007	0.009
Highest								
Overall	0.033	13,945	0.002	0.036	15,741	0.002	0.003	0.002

the change is not surprising since a major change in the pay system may make some of the incumbents unhappy enough to leave or may signal that the firm has become less tolerant of low productivity.

Second, theory predicts that those at the higher end of the ability spectrum should see turnover rates that decline. Although the highest output deciles are the ones that experience the largest declines in separation rates, the differences are not statistically significant.

IV. Fixed Effects

Some of the theoretical predictions can be tested by estimating person-specific fixed effects. Since the data set consists of multiple observations on a given individual over time and under different regimes, person-specific effects can be estimated. Fixed effects are estimated from a regression of the log of output-per-worker-per-day on tenure and time dummies. Should this be done using data from both regimes combined or from one or the other? Some workers were employed in both hourly wage and piece-rate regimes whereas some worked in only one regime. The theory implies that incentives are muted during the hourly wage period, so it is not clear that fixed effects based on output during the hourly wage period are good proxies for ability. This might suggest using the fixed effects estimated during the piece-rate regime for those who worked in both regimes. But then separation behavior over the two regimes cannot be examined since no one who worked in both hourly wage and piece-rate regimes left the firm during the hourly wage regime.

An alternative is to use the hourly wage regime estimated fixed effects, based on the argument that fixed effects are highly correlated across periods. Indeed, there is evidence of strong correlation. Figure 2 shows the scatterplot, which reveals the pattern. The correlation between the fixed effect from the hourly wage period and that from the piece-rate period is 0.72 with 1,519 observations. This correlation is high, but not perfect. There are some workers who performed relatively better under the hourly wage system than under the piece-rate system and vice versa. A regression of the fixed effect from the piece-rate regime on the same individual's fixed effect from the hourly wage regime yields a coefficient of 0.700 with a standard error of 0.017. The constant term is −0.04 with a standard error of 0.01. The effect of

in the sample for Table 4, the worker must have been with the firm during the previous month as well. Thus, those who leave during their first month are included in Table 1 but not in Table 4.

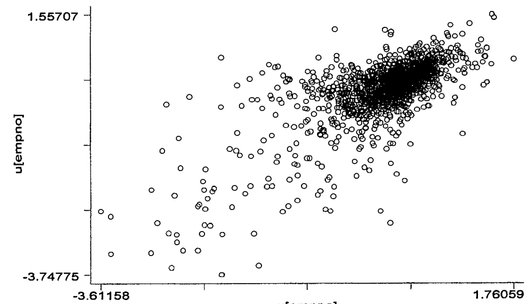

FIGURE 2. SCATTERPLOT OF FIXED EFFECTS FROM THE TWO REGIMES

ability on effort is attenuated during the hourly wage period because there is less incentive to put forth effort. If the fixed effect of output in the piece-rate period measures true ability, whereas the fixed effect during the hourly wage period measures ability only imperfectly, then the coefficient in the regression of piece-rate fixed effects on hourly wage fixed effects is biased toward zero.[19] The fact that it equals 0.700 suggests that workers do reveal their abilities to a large extent even during the hourly wage period.[20]

This evidence provides a rationale for using the hourly wage-period fixed effects to examine turnover. The median level of fixed effect for those who leave no later than two months after the start of the piece-rate system (the leavers) is 0.15 with an upper bound of the 95-percent confidence interval of 0.19. The median level of fixed effect for those who stay beyond the initial two months (the stayers) is 0.22 with a standard error of lower bound of the 95-percent confidence interval at 0.21. The medians are significantly different, with the more able, as measured by pre-period fixed effects, being more likely to stay.[21]

TABLE 5—VARIATION IN FIXED EFFECTS

Regime	Number of individuals	Standard deviation in fixed effects	Difference between 90th and 10th percentile in fixed effects
Hourly wage	1,519	0.65	1.28
Piece rate	1,519	0.64	1.12

There is no evidence that the stayers have higher variance in ability than the leavers. The standard deviation of the fixed effects for the stayers is 0.68 and that for the leavers is 0.89, with number of observations equaling 1,511 and 659, respectively. More evidence on this point is presented in Table 5, where fixed effects estimated on hourly wage-regime data are computed for those individuals who worked in both regimes.

Again, the results of Table 5 suggest that the prediction about variance in ability finds no support in the fixed effects results.[22] The standard deviation in fixed effects among piece-rate workers is virtually identical during the piece-rate and hourly wage regime. The 90-10 percentile is higher during the hourly wage regime. Although Table 2 reveals an increase in the variance in output when the firm switches from hourly wages to piecework, the increase in variance does not reflect an obvious change in the dispersion of underlying ability.

Summarizing, it is clear that person-specific effects are important. They play a significant role in the interpretation of the results of Table 3, and their pattern is consistent with the theory in that their mean levels tend to rise as the firm goes from time rates to piece rates. They provide no support for the hypothesis that variance in underlying ability increases when the firm switches from time rates to piece rates. Ability

[19] The bias is caused by the standard errors-in-variables problem, where the observed independent variable is not the true effect, but instead the true effect plus measurement error.

[20] The relation of ability to output need not be monotonic, especially during the hourly wage period. Since the lowest- and highest-ability workers, A_0 and A_h, earn no rents, they should be least concerned about losing their jobs. Middle-ability workers earn rents and may therefore put forth additional effort to reduce the likelihood of a termination.

[21] Part of this difference may reflect pure selection that would occur even in the absence of a regime change. Presumably, the tenure variable included in the output regression controls for most of the regime-independent sorting.

[22] The difference between this sample and the previous one is that the former sample included those who left before piece-rate-based fixed effects could be estimated.

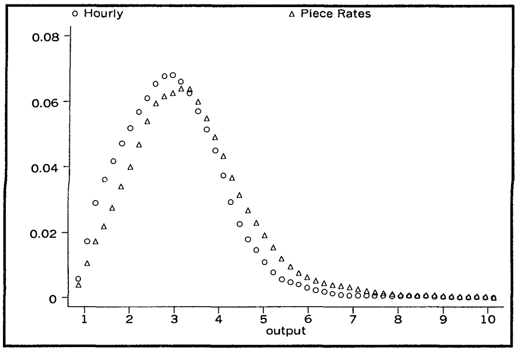

FIGURE 3. KERNEL DENSITIES IN THE TWO REGIMES

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.

is higher among those who work at the end of the sample period than among workers present at the beginning of the sample period. Most of the increase in ability is a result of selection through the hiring process that occurs after piece rates are adopted.

The effect of differential changes in turnover rates, hiring policy, and incentives can be summarized by the kernel densities of output shown in Figure 3. The two distributions look rather similar, but it is clear that the piece-rate distribution lies to the right of the hourly wage distribution. Further, the peak value of the density function during the piecework regime is lower than that of the hourly wage regime. There is less concentration of output around the modal value under piece rates than there is under hourly wages.[23]

V. Pay and Profitability

The effect of the program on pay can be traced also. Table 6 reports the effects of the switch to the PPP regime.

The log of pay-per-worker went up by 0.068, implying about a 7-percent increase in compensation. Recall that the increase in productivity for the firm as a whole was 44 percent. Regression 2 of Table 6 implies that the log of pay for a given worker rose by 0.099, implying a 10.6-percent gain in earnings. This is just under half the increase in per-worker productivity. Thus, the firm passes along some of the benefits of the gain in productivity to its existing workforce. The effect without worker dummies is smaller than that with worker dummies because the newer workers are paid less than the more senior workers whom they replace. Further, 92 percent of workers experienced a pay increase, with a quarter of the workers receiving increases at least as large as 28 percent.

Did profits rise? This depends on the increase in productivity relative to the increase in labor and other costs. Given the numbers (44-percent increase in productivity, 7-percent increase in wages), it is unlikely that other variable costs of production ate up the margin still given to the firm. The piece-rate plan seems to have been implemented in a way that likely made both capital and labor better off.[24]

There is one cost that has been ignored throughout. Piecework requires measurement of output. In Safelite's case, the measurement comes about through a very sophisticated information system. But the system involves people and machines that are costly. Indeed, in equilibrium, firms that pay hourly wages or monthly salaries are probably those for whom

[23] The model in Figure 1, taken literally, implies that there should be holes in the data, which are not found. There are a number of possible explanations. First, workers may try to get into the piece-rate range and fail. Second, since the unit of measurement is a month, there may be some weeks during which the worker hits the piece-rate range and others where he does not, averaging out to some amount between 2.5 and 5 units. Third, the worker may not guess e_0 perfectly, and this creates variance around e_0. Finally, there may be other reasons to exceed the minimum level of output.

[24] The firm's earnings are up substantially since the switch to piece rates, but this could reflect other factors as well.

measurement costs exceed the benefits from switching to output-based pay.

In this case, the gains in productivity were very large. Further, the information systems were initially put in place for reasons other than monitoring worker productivity, having to do with inventory control and reduced installation lags. The economies of scope in information technology, coupled with the labor productivity gains, are probably large enough to cover whatever additional cost of monitoring was involved.[25]

VI. Quality

One defect of paying piece rates is that quality may suffer.[26] In the Safelite case, most quality problems show up rather quickly in the form of broken windshields. Since the guilty installer can be easily identified, there is an efficient solution to the quality problem: The installer is required to reinstall the windshield on his own time and must pay the company for the replacement glass before any paying jobs are assigned to him. This induces the installer to take the appropriate amount of care when installing the glass in the first place.[27]

Initially, Safelite used another system that relied on peer pressure.[28] When a customer reported a defect, the job was randomly assigned to a some worker in the shop that was responsible for the problem.[29] The worker assigned to do the re-do was not necessarily the worker who did the original installation and the worker was not paid for doing the repair work. But workers knew the identity of the initial installer. If one installer caused his peers to engage in too many re-dos, his coworkers pressured him to improve or resign. More recently, the system was changed to assign re-do work to the worker who did the initial installation. Workers are not paid for the re-do, but they are not charged for the wasted glass or for other costs associated with the re-do, as a fully efficient system would require. The outcome has been that quality has gone up after the switch to PPP, rather than down. The firm surveys its customers on their satisfaction with the job. The customer satisfaction index rose from slightly under 90 percent at the beginning of the sample period to around 94 percent by the end of the sample period. Because re-dos are costly to the worker, he is motivated to get it right the first time around.

VII. Piecework Is Not Always Profitable

It is interesting that the productivity gains are so large for this particular firm. Of course, this is only one data point and it is one where the case for piece rates seems especially strong. Output is easily measured, quality problems are readily detected, and blame is assignable.

Managerial and professional jobs may not be as well suited to piecework. The fact that the productivity gains are so large in this case is worthy of attention, but these results do not imply that all firms should switch to piece-rate pay.

Piece-rate pay, defined narrowly, is used sparingly in the United States. Although it is difficult to obtain data on the distribution of piece-rate work, one national survey, the National Longitudinal Survey of Youth,[30] asked whether a worker was on piece rates up through 1990. Results from this survey are shown in Table 7.

In a subsample of 7,438 workers, 3.3 percent reported being on piece rates. The number varies significantly by occupation. As expected, managers, whose output is difficult to measure,

[25] This was not always so. Whenever a firm switches from one pay system to another, it is almost certain that one system does not maximize profit.

[26] See Lazear (1986) and Baker (1992).

[27] Beth J. Asch (1990) examines the effects of compensation schemes on military recruiter performance with a focus on quality dimensions. As recruiters receive incentive pay for signing up recruits, there is a tendency to take lower-quality applicants.

[28] See Eugene Kandel and Lazear (1992) for a discussion of the effects of peer pressure and norms in an organization.

[29] There are two advantages of assigning the re-work to the shop rather than the individual. First, the customer gets faster service since it is unnecessary to wait for the availability of the original installer. Second, some workers will have already separated from the firm before the defect is noticed. Assigning the work to the shop deals with this problem. Neither argument provides a rationale for forcing the re-work to be done by others without pay.

[30] The NLSY is a nationally representative sample of 12,686 young men and young women who were 14 to 22 years of age when they were first surveyed in 1979.

TABLE 7—PIECE-RATE PROPORTIONS IN THE NATIONAL LONGITUDINAL SURVEY OF YOUTH

Occupation	Number in occupation in NLSY	Percent piece rate
Professional/technical	1,848	1.4
Managers/officials/proprietors	468	0.9
Sales	477	1.3
Clerical	1,522	1.3
Craftsmen	2,278	3.6
Operatives	296	9.8
Nonfarm labor	543	13.8
Farm labor	6	16.7
TOTAL	7,438	3.3

are least likely to be on piece rates. At the other extreme, about 14 percent of laborers are paid piece rates. The use of incentive pay, broadly defined, is more widespread. Pencavel (1978 p. 228, Table 2) reports a peak of 30 percent of workers in manufacturing who received incentive pay in the United States in 1945–1946, with a downward trend afterward.

The relative paucity of piece-rate pay in the United States is not particularly disturbing for this study. For one thing, piece rates remain more prevalent in other countries. For example, using a data set on manufacturing in Sweden (which accounts for 20 percent of the workforce), it is found that 22 percent of workers received piece-rate pay as late as 1990. But even were this not the case, the experiment would be relevant. As far as the workers are concerned, the effect of a change in compensation was exogenous, and the data consist of about 3,000 independent worker responses to that common change. The implication of the study is not that firms should switch to piecework, but rather that when workers faced a new compensation scheme, they responded by altering effort, turnover, and labor-supply behavior in the way predicted by theory.

VIII. Summary and Conclusion

The results imply that productivity effects associated with the switch from hourly wages to piece rates are quite large. The theory implies that a switch should bring about an increase in average levels of output and in its variance. These predictions are borne out. The theory does not imply that profits must rise. Market equilibrium is characterized by firms that choose a variety of compensation methods. Firms choose the compensation scheme by comparing the costs and benefits of each scheme. The benefit is a productivity gain. Costs may be associated with measurement difficulties, undesirable risk transfers, or quality declines.

The theory above implies that average output per worker and average worker ability should rise when a firm switches from hourly wages to piece rates. The minimum level of ability does not change, but more able workers, who shunned the firm under hourly wages, are attracted by piece rates. As a result of incentive effects, average output per worker rises. Thus, average ability and output, as well as variance in output and range of ability, should rise when a firm switches from hourly wages to piece rates.

The effects of changing the compensation method were estimated using worker-level monthly output data from Safelite Glass Company. The primary predictions of the theory are borne out. Moving to a piece-rate regime is associated with a 44-percent increase in productivity for the company as a whole. Part of the gain reflects sorting, part reflects incentives, and some may reflect the pattern in which the scheme was implemented. The incentive effect of the piece-rate scheme accounts for an increase in productivity of about 22 percent. The rest of the 44-percent increase in productivity is a result of sorting toward more able workers or possibly some other factors. Sorting occurs primarily through the hiring process, where a disproportionate share of new hires come from higher ability groups after the switch to piece rates. There is no strong evidence that the change to piece rates increases separations relatively more among lower-output workers. Nor is there evidence of an increase in range or variance in underlying ability after the switch to piecework.

Since the data measure actual productivity, tenure effects on productivity (rather than wages) can be estimated. Tenure effects on productivity are found to be large. Part reflects learning on the job, but a significant fraction reflects sorting that induces the least productive workers to leave first. Also, time since the introduction of the piecework scheme is positively associated with productivity.

Workers captured some of the return from moving to piece rates. The average incumbent worker's wages rose by just over 10 percent as a result of the switch. Over 90 percent of the workers had higher pay during the piece-rate period than they did during the hourly wage period.

APPENDIX

PROOF OF PROPOSITION 1:

Output cannot fall below e_0 because of the firm-imposed constraint at e_0. But output may exceed e_0 if for some A, $A_0 \leq A \leq A_h$,

$$U(W, X_0(A)) < U(bf(X^*(A), A) - K, X^*(A)) \tag{A1}$$

where $X^*(A)$ is the effort level chosen by worker of type A given piece rate b. As long as there is some type A for whom output rises, average output must rise.

PROOF OF PROPOSITION 2:

If any choose to work in the piece-rate range, then surely the worker with the highest ability chooses to work in this range. But the highest-ability worker cannot, except in the rarest coincidence, be A_h. If A_h chooses to work in the piece-rate range, then A_h, who was indifferent to working under hourly wages, is at worst indifferent to working under piece rates, but more generally, strictly prefers the piece rate. If A_h earns rents under the new plan, then A_h is no longer the marginal worker. There exists an A_h^* with $A_h^* > A_h$ who would now be the marginal worker, i.e., the worker for whom

$$U(bf(X^*(A_h^*), A_h^*) - K, A_h^*) = U(\hat{W}(A), \hat{X}(A))$$

where $X^*(A_h^*)$ is defined as the effort for type A_h^* under piece rates b and where $\hat{W}$, $\hat{X}$ are the wage and effort on the alternative job.

Also, if any accept the wage guarantee, then surely A_0 accepts the guarantee. We know that A_0 is willing to work for W at effort e_0 because A_0 worked under these terms before. Furthermore, since the guarantee has not been made any more attractive, no one with $A < A_0$ is willing to work for the guaranteed wage. Since the lower bound on ability remains the same and the upper bound does not fall and generally rises, average ability does not decrease and generally increases after the switch to piecework.

PROOF OF PROPOSITION 3:

From the Proof to Proposition 2, $A_h^* \geq A_h$. But A_0 cannot rise because the wage guarantee is still available so A_0 remains willing to work. This is sufficient to imply that range or variance in ability rises. Also, since all workers choose to produce e_0 under the hourly wage, but some produce in the piece-rate range with the new scheme, positive variance in A implies positive variance in e under piece rates.

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