Do Firms Pay Efficiency Wages?
Evidence with Data at the
Firm Level

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This study tests the efficiency wage hypothesis by estimating wage and quit equations with data from the Employment Opportunity Pilot Project survey of firms. An efficiency wage model is derived that predicts effects of turnover costs and unemployment on wages as functions of first and second derivatives from the quit equation. The model is tested by examining the relationships between the coefficients in the wage and quit equations; the results are generally favorable to efficiency wage theory. Other important findings are that firm characteristics raising workers' productivity tend to raise wages and that a rise in turnover costs reduces quits.

I. Introduction

In recent years, economists have developed efficiency wage models to explain wage rigidity. If workers' productivity depends positively or firms' costs depend negatively on the wage, firms may find it optimal to pay a wage above the market-clearing level, resulting in involuntary unemployment. At least four models have been developed to explain why productivity or costs can depend on the wage. In Weiss (1980) a more productive pool of applicants applies to the firm as it raises its wage offer. In addition, a

higher wage may induce workers to work harder, either out of gratitude toward the firm as in Akerlof (1982, 1984) or because of the increased cost of losing their jobs as in Shapiro and Stiglitz (1984). Finally, in Stiglitz (1974), Schlicht (1978), and Salop (1979), a firm's turnover costs depend negatively on the wage if fewer workers quit as the wage rises. Since hiring and training new workers is costly, firms may find it profitable to pay a wage above the market-clearing level to reduce turnover.

Testing these hypotheses has been difficult. These models make predictions about the behavior of firms, and little data exist on wages at the firm level. One study that tests the efficiency wage hypothesis with firm-level data is Leonard (1987), which examines the relationship between monitoring intensity and wages with data from 200 plants in the high-technology sector of one state. Other studies such as Dickens and Katz (1987) and Krueger and Summers (1987, 1988) estimate wage equations that include dummy variables for workers' industry affiliation. Since the competitive model of the labor market predicts that workers of identical quality earn the same wage in any industry, the authors interpret the significant coefficients on these dummy variables as evidence for efficiency wage theory.

This study tests the predictions of efficiency wage theory by estimating wage equations and quit equations with data obtained from the Employment Opportunity Pilot Project (EOPP) survey of firms, a survey of over 5,000 firms in 28 geographic sites and 66 two-digit standard industrial classifications (SIC) industries. A firm's behavior in setting wages is modeled under the assumption that the quit rate of its workers (and hence the firm's costs of hiring and training new workers) depends negatively on the wage. The model makes predictions about the size of the derivative of the quit rate with respect to the wage and about the effects of turnover costs and unemployment on wages as functions of first and second derivatives of the quit equation. It also predicts that a rise in turnover costs ought to lower the quit rate. In Appendix A, a more general model is derived in which wages affect productivity as well as turnover. This model shows that firm characteristics raising productivity ought to raise wages in an efficiency wage model. In addition, the more general model demonstrates that the relationships derived in the model ignoring the effect of wages on productivity may not be exact. Instead, the effect of turnover costs and unemployment on wages will be somewhat smaller than predicted by the model that does not account for the effect of wages on productivity. The theoretical model is tested by estimating wage equations and quit equations with data from the EOPP survey, which includes questions about the firm's most recently hired worker.

The results are generally supportive of efficiency wage theory. The effect of turnover costs on wages is positive, as predicted. But its magnitude is smaller than predicted by the model ignoring productivity, possibly because of the additional effect of productivity on wages. That reducing turnover

is an important consideration for firms with high turnover costs is further evidenced by the finding that a rise in turnover costs lowers quits, even when controlling for the wage. The effect of the industry unemployment rate on wages is negative, as predicted, but again its magnitude is smaller than predicted by the model ignoring productivity. It is also found that characteristics of the firm that raise workers' productivity tend to raise wages. However, the effect of the local unemployment rate on wages is insignificant, possibly because higher wages serve as a compensating differential for areas with high unemployment. In addition, the derivative of the quit rate with respect to the wage is smaller than it should be if firms are maximizing short-run profits and if turnover costs are an important part of efficiency wage theory.

This study differs from most previous work in that it concentrates on the labor turnover version of efficiency wage theory, whereas most previous research on efficiency wage theory has centered on models in which workers' effort depends on the wage. The advantage of dealing with the turnover model is that the effect of wages on quits can be estimated, whereas it is nearly impossible to measure the effect of wages on productivity. In addition, even if a positive correlation between a worker's wage and productivity is observed, it is extremely difficult to discern whether the higher productivity results from the higher wage or whether skills that cannot be measured with the available data are responsible for both the higher wage and the higher productivity. Thus, researching the labor turnover model may be a more promising approach than researching models in which productivity depends on the wage. However, the fact that this study examines only the effect of wages on quits means that the model cannot be tested exactly. Thus, while the results support the qualitative predictions of the model, they fall short quantitatively.

II. An Efficiency Wage Model of the Firm

In efficiency wage models, firms pay a wage that exceeds the wage necessary to attract the number of workers they hire. In other words, the amount of labor a firm hires is less than the amount of labor supplied to the firm at the wage it is offering, so that its labor supply constraint is not binding. Thus, the firm chooses both the wage and employment level that maximize profits. In contrast, a firm not paying efficiency wages either pays a wage determined by the market (if it faces a horizontal labor supply curve) or chooses the wage that maximizes profits, subject to the labor supply constraint (if it faces an upward-sloping labor supply curve). This section derives an efficiency wage model in which higher wages reduce turnover, and it compares the predictions of this model with models in which the firm is on its labor supply curve. The effect of wages on productivity is ignored in this section to concentrate on the effect of wages

on turnover costs. As noted above, in Appendix A a more general model is presented in which wages affect both productivity and labor turnover.

Consider a firm that is a price taker at the price P in the product market and that produces output with a Cobb-Douglas production function, $Q = \gamma L^{\alpha} K^{1-\alpha}$. Assume that the firm incurs a cost of $\tau q(w, w^{a}, U)L$ in hiring and training new workers, where τ is the cost of hiring and training each worker and $q(w, w^{a}, U)$ is the quit rate. The quit rate depends on the wage (w), the wage the worker could earn elsewhere (w^{a}), and the unemployment rate (U), where $q_{w} < 0$, $q_{ww} > 0$, and $q_{u} < 0$. In addition, it is likely that quits become less responsive to the wage (i.e., q_{w} becomes less negative) as U increases,[1] so that $q_{wu} > 0$. Under these assumptions, the profit function is

$$\pi = P\gamma L^{\alpha} K^{1-\alpha} - wL - rK - \tau q(w, w^{a}, U)L. \qquad (1)$$

Similar models are found in Stiglitz (1974), Salop (1979), and Flacco and Zeager (1989).[2] If (1) is differentiated with respect to w, L, and K, the first-order conditions are

$$0 = d\pi/dw = -L - \tau q_{u}(w, w^{a}, U)L, \qquad (2a)$$

$$0 = d\pi/dL = \alpha P\gamma L^{\alpha-1} K^{1-\alpha} - w - \tau q(w, w^{a}, U), \qquad (2b)$$

and

$$0 = d\pi/dK = (1 - \alpha)P\gamma L^{\alpha} K^{-\alpha} - r. \qquad (2c)$$

From equation (2a), w can be determined independently of L and K. From this equation, we can derive three conditions that will be met if firms pay efficiency wages. Dividing (2a) by L yields the first condition:[3]

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[1] For example, a change in the wage will probably have a greater effect on the quit rate if the unemployment rate is 6% than if it is 25%. At an unemployment rate of 25%, a change in the wage will have a negligible effect on the quit rate since so few workers quit to begin with.

[2] There are differences in the way these authors specify the quit function, however. Stiglitz is concerned with the question of unemployment in less developed countries (LDCs) and models quits as a function of the ratio between urban and rural wages as well as the unemployment rate and the firm's relative wage. Salop expresses the quit rate as $q(w/z)$, where z is a measure of labor market tightness that incorporates the average wage rate and the unemployment rate. In Flacco and Zeager (1989), the quit rate depends only on the firm's wage. Quits also depend negatively on the wage in Schlicht (1978), but in his model a rise in turnover reduces productivity rather than increases costs.

[3] Except for differences in the way that the quit function is expressed, condition A is essentially derived in Stiglitz (1974), Salop (1979), and Flacco and Zeager (1989). In addition, Leonard (1987) basically tests this condition, although he does not explicitly derive it.

$$-\frac{\tau}{w}\frac{\delta\text{Quit}}{\delta\log(w)} = 1. \tag{A}$$

(This can also be expressed as $-\tau q_w(w, w^a, U) = 1$.)

Differentiating condition (A) with respect to w, τ, and U yields two additional conditions that will be met if firms pay efficiency wages:

$$\frac{dw}{d\tau} = -\frac{q_w}{\tau q_{ww}} > 0, \tag{B}$$

and

$$\frac{dw}{dU} = -\frac{q_{wu}}{q_{ww}} < 0. \tag{C}$$

A fourth testable prediction can be derived from the effect of wages on quits and from the fact that condition (B) demonstrates that a rise in turnover costs raises wages:

$$dq/d\tau = (dq/dw)(dw/d\tau) < 0. \tag{D}$$

Condition (D) states that firms with the highest turnover costs will have the lowest quit rates since these firms have the greatest incentive to deter workers from quitting by paying high wages. This condition will obviously be satisfied if a rise in turnover costs raises wages and if a rise in wages decreases quits. A more interesting test would be to examine whether a rise in turnover costs reduces quits even when controlling for the wage. If this is true, it would suggest that firms with high turnover costs consciously try to reduce quits through actions such as offering generous fringe benefits, providing good working conditions, and maintaining good management-worker relationships, in addition to paying high wages.[4]

In Appendix A, a more general efficiency wage model is derived in which workers' effort and quits both depend on the wage. In this model, $e(w, \phi)$ represents the productivity of a worker as a function of the wage and of firm characteristics that raise the productivity of workers (ϕ). In the model in Appendix A, another condition is derived that will be satisfied

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[4] The fact that a rise in turnover costs reduces quits even when controlling for the wage can also be seen by including a parameter (e.g., λ) in the quit equation that represents actions (besides paying high wages) a firm could take to reduce turnover and letting $c(\lambda)$ represent the cost of these actions. Note that λ probably would not be observable to an econometrician. Under reasonable conditions (i.e., if $q_{w\lambda}$ is small), it can be shown that $dq/d\tau = (dq/d\lambda)(d\lambda/d\tau) < 0$.

if firms pay efficiency wages: that firm characteristics that raise the pro-
ductivity of workers will also raise their wages.

In addition, conditions (A), (B), and (C) do not hold exactly in the more
general model. In particular, $-\tau q_w < 1$, $dw/d\tau < -q_w/\tau q_{ww}$, and $|dw/
dU| < |-q_{wu}/q_{ww}|$. However, in Appendix A, it is shown that the left-
hand sides of conditions (B) and (C) should be at least a reasonable fraction
(e.g., at least about 20%) of the right-hand sides. Thus, if wages affect both
productivity and turnover, these conditions will not be exactly satisfied
but will instead provide a general range for the coefficients in the wage
and quit equations.

Another reason why condition A may not be exactly satisfied is that
firms may pay efficiency wages designed to maximize long-run profits. A
firm that is not labor-supply constrained might choose a low wage to
maximize current profits. But if the current wage affects future productivity
and turnover costs, the firm may find it optimal to pay a much higher
wage to maximize the present discounted value of current and future profits.
For example, a firm should pay a higher wage if it expected to survive
indefinitely than if it expected to close down in the near future. Future
productivity or turnover costs could depend on current wages if the quality
of future applicants depends on the current wage because it takes time for
firms to develop a reputation for paying high wages, if workers' gratitude
and loyalty are earned through a history of good wages, or if it takes time
for workers dissatisfied with their current wage to find another job. If
firms pay efficiency wages designed to maximize long-run profits, it is
possible that the values of τq_w estimated in this study will be smaller than
condition A predicts since the total effect of wages on quits may be larger
than the estimated value of q_w.[5]

In contrast to the efficiency wage model, if firms hire in a competitive
and frictionless labor market, labor is supplied elastically at the market
wage. Thus, hiring costs should have no effect on wages, and training costs
should raise wages only to the extent they raise productivity. In addition,
characteristics of a firm would probably have no effect on wages since
labor mobility would ensure that workers of identical ability are paid the
same wage in all firms. The only channel through which characteristics of
the firm could be related to the wage would be if the unmeasured portion
of workers' skills were correlated with characteristics of the firms that
tend to raise productivity (e.g., if firms with high capital-labor ratios tend
to hire workers who are more skilled than predicted by the characteristics
reported in the survey).

Finally, in Appendix B a model is developed in which firms are labor-
supply constrained and face an upward-sloping supply curve for labor

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[5] Even if current wages affects future quits, Campbell (1990) shows that under
reasonable conditions, conditions (B) and (C) will not be affected.

(i.e., they act as monopsonists). In this case the effect of turnover costs and unemployment on wages is ambiguous. A rise in turnover costs encourages firms to pay higher wages to reduce turnover but at the same time reduces labor demand, tending to lower wages. Similarly, a rise in the unemployment rate will reduce turnover, thereby lessening the need to pay high wages. But it also raises the demand for labor since workers are now less likely to quit. Not only are the signs of $dw/d\tau$ and dw/dU ambiguous, but more important, there is no systematic relationship between the derivatives of the quit equation and either $dw/d\tau$ or dw/dU. Thus, if firms do not pay efficiency wages, there is no reason for conditions (B) and (C) to be satisfied or for the right-hand sides and left-hand sides of conditions (B) and (C) to be of even the same order of magnitude.

Recall that conditions (B) and (C) were derived from a model in which firms set both the wage and employment, meaning that they maximize profits by operating at a point above their labor supply curves. In contrast, if firms operate on their labor supply curves, conditions (B) and (C) would not be satisfied except by chance. Finding that these conditions are satisfied would thus be strong evidence for efficiency wage theory.

To the contrary, in a model in which firms are labor-supply constrained and face an upward-sloping labor supply curve, characteristics of the firm that increase productivity will also raise wages. Thus, a finding that firm characteristics that raise productivity also raise wages might be consistent with a model in which firms are on their labor supply curves and thus would not be strong evidence in favor of efficiency wage theory.

III. Data

The data were obtained from interviews conducted as part of the Employer Opportunity Pilot Project survey of employers. This survey was conducted in the spring of 1980 with 5,302 firms in 28 geographical areas in 11 different states. These firms represented 66 two-digit SIC industries and 545 four-digit SIC industries. Included in the survey were a series of questions concerning the personal characteristics, the occupation, the wage, and the number of hours spent hiring and training the most recently hired worker.[6] The data were supplemented with the unemployment rate in the

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[6] Two years later, 3,413 (64%) of the original firms were reinterviewed and were asked a similar series of questions. This study uses data from the first survey because the second survey contains fewer observations, because the second survey was conducted during the deepest recession in the past 50 years, and because the sample of firms in the second survey will not be representative if firms were excluded from this survey in a systematic fashion (e.g., because they went out of business). Regressions run with data from the second EOPP survey generally corroborated the results of the first survey, even though the second survey contained a different set of wage and turnover variables. (See Campbell [1990] for a more in-depth treatment of these results.)

local labor market and with the unemployment rate and capital-labor ratio for the two-digit SIC industry.

IV. Empirical Results

In order to explore whether the conditions of Section II are satisfied, wage equations and quit equations were estimated with data on the most recently hired worker from the EOPP survey. Table 1 lists the variable names, a brief description of the variables, their means, and their standard deviations. Note that two wage variables are available: the current starting wage (at the time of the survey) and the current top wage of the job for which the worker was hired.[7]

Wage Equation

Table 2 reports the results of regressions with the starting wage as the dependent variable, and table 3 reports the results of regressions with the top wage as the dependent variable. The independent variables include worker characteristics, measures of the time spent hiring and training the worker, the unemployment rate, and firm characteristics.

The worker characteristics are age, sex, experience, and education. Also included are dummy variables for the worker's occupation and geographic region. The costs of recruiting and training are measured by the number of hours spent recruiting, screening, and interviewing for the position (SCREENING) and by the number of hours spent orienting and training the worker in the first month of employment (TRAINING). Condition B predicts that a rise in these costs will raise the wage.

According to condition (C), a rise in the unemployment rate will lower the wage. Both the unemployment rate in the local labor market and in the industry are included in the regressions. Recall that the wage variables are the job's starting wage and top wage at the time of the survey, which occurred in the spring of 1980. Since unemployment tends to affect wages with a slight lag, unemployment rates from 1979 were used in the regressions.

The firm characteristics are the proportion of workers unionized at the firm, the capital-labor ratio for the two-digit SIC industry, the proportions of the firm's work force classified as white-collar and as craft workers, the firm's size, and dummy variables for the one-digit SIC industry.

The expanded model in Appendix A predicts that a rise in firm characteristics that raise the productivity of workers will increase the wage. Firm characteristics that may raise productivity are the capital-labor ratio

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[7] Another variable, the current wage of the most recently hired worker, is also available However, it is not reported in cases where the worker had left the firm before the date of the survey. Wage equations were not estimated with this variable because of possible sample selection bias.

Table 1
Variable Names, Descriptions, Means, and Standard Deviations

		μ	σ
STARTING WAGE	Log of the starting wage	1 344	345
TOP WAGE	Log of the top wage	1 608	409
QUIT	= 1 if worker quit, = 0 otherwise	217	412
AGE	Age of worker when hired	26 80	9.74
1 IF MALE	= 1 if male, = 0 if female	.493	.500
EXPERIENCE	Months of useful job experience	43 37	65 35
EDUCATION	Years of education	12 09	1 63
SCREENING	Hours spent recruiting, screening, and interviewing for the position	5 77	15 04
TRAINING	Hours spent orienting and training the new recruit	33 85	36 81
LOCAL UNEMP RATE*	Unemployment rate in local labor market	0622	0151
LOCAL UNEMP RATE†	Unemployment rate in local labor market	0638	0273
INDUSTRY UNEMP RATE*	Unemployment rate in industry	0606	.0241
INDUSTRY UNEMP RATE†	Unemployment rate in industry	0658	0346
VARIANCE OF IND UNEMP	Variance of industry unemployment rate	1 46	.586
PCT UNION	Proportion of firm's work force unionized	108	.284
CAPITAL EQUIP-LABOR RATIO	Industry ratio of capital equipment to labor (in $ millions of capital per worker)	.0113	0157
CAPITAL-LABOR RATIO	Industry ratio of capital to labor (in $ millions of capital per worker)	0239	.0478
PCT WHITE-COLLAR	Proportion of workers at firm classified as white-collar	361	317
PCT CRAFT	Proportion classified as craft workers	.163	.248
FIRM SIZE	Log of firm's employment	3 00	1 53

* Unemployment rate in 1979 These figures are used in the wage equations
† Average unemployment rate in the period over which the worker was employed These figures are used in the quit equation

and the proportion of workers classified as white-collar or as craft workers. The greater is a firm's capital-labor ratio, the greater is the increase in output resulting from an increase in workers' effort, giving firms with a high capital-labor ratio an incentive to pay higher wages.[8] In addition, a firm with a high capital-labor ratio will experience greater losses if its workers shirk and damage equipment. The potential gain from an increase in workers' effort and the potential loss from their shirking are probably

[8] This relationship between the capital-labor ratio and the wage can also be derived by assuming that the value of α differs between firms. If eqq. (A6) and (A7) are differentiated with respect to α, and α is treated as an exogenous variable, then it can be shown that as long as k is defined to be greater than one, $dw/d\alpha$ and $dk/d\alpha$ will be positively correlated.

more closely related to the stock of capital equipment than to the total capital stock (structures + equipment). Accordingly, the capital equipment/labor ratio appears in five of the six equations.

White-collar and craft workers are generally considered the most highly skilled workers. The proportions of these workers at the firm are included because working with highly skilled coworkers should increase one's own productivity. Also, a worker shirking and wasting the time of highly skilled coworkers imposes a greater cost on the firm. A rise in these proportions should thus raise the wage.

The basic regression appears in column 1 of tables 2 and 3. In column 2 the industry dummy variables are omitted.[9] Because the turnover variables may be correlated with each other, they are entered separately in columns 3 and 4. In column 5 the industry unemployment rate is omitted to concentrate on the local unemployment rate since workers who change jobs are probably more likely to stay in the same area than to stay in the same industry. Finally, in column 6 the total capital-labor ratio replaces the capital equipment/labor ratio.

Quit Equation

Table 4 reports the results of quit equations estimated with data on the last worker hired. The dependent variable is the length of the worker's employment spell. Since this variable is usually censored, the quit function was estimated with a proportional hazard model assuming an exponential distribution.[10] The independent variables are the wage, the wage the worker could earn elsewhere, personal characteristics of the worker, the cost of hiring and training, the unemployment rate, and characteristics of the firm.

If high wages represent economic rent and not just unmeasured differences in ability, the quit rate will depend negatively on the wage. Workers should decide whether to quit on the basis of the wage they expect to earn if they remain with the firm rather than on their starting wage. Thus, the wage variable included in the regressions is the top wage of the job. The quit rate should also depend positively on the worker's alternate wage. Since it is impossible to measure this variable directly, the wage was regressed on characteristics of the worker, and the predicted values of the wage were used as estimates of the alternate wage.[11]

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[9] In col. 2, the variance of the industry unemployment rate is included as an independent variable since industries with more variable unemployment tend to pay higher wages as a compensating differential. This variable becomes insignificant, however, when the industry dummy variables are included.

[10] See Kiefer (1988) for a description of hazard models. I also estimated the equations with a Weibull distribution but could not reject the hypothesis that the spells were distributed exponentially.

[11] Murphy and Topel (1985) demonstrate that the coefficient on the predicted value of a variable obtained from an earlier regression is consistently estimated.

Table 2
Wage Equations with the Log of the Starting Wage as the Dependent Variable

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	447	.182	440	436	290	.443
	(6.57)	(2 79)	(6.57)	(6 44)	(4.51)	(6 49)
Worker characteristics.						
AGE/100	1 94	2.06	2 00	1.93	2.03	1.93
	(6.40)	(6.66)	(6.70)	(6.37)	(6 65)	(6.36)
(AGE/100)^2	−2 45	−2.53	−2.55	−2 44	−2.55	−2 43
	(−5.68)	(−5 72)	(−5 95)	(−5.67)	(−5 86)	(−5.62)
1 IF MALE	153	.156	153	152	.157	157
	(12 89)	(12 90)	(13 08)	(12 81)	(13.17)	(13 25)
EXPERIENCE/100	131	.134	.127	.131	.123	.130
	(6.90)	(6.93)	(6 82)	(6.96)	(6.47)	(6.87)
(EXPERIENCE/100)^2	−.0260	−.0282	−.0246	−.0262	− 0245	−.0260
	(−4 29)	(−4.56)	(−4.12)	(−4 33)	(−4 02)	(−4.28)
EDUCATION	.0257	0265	0255	0261	0260	0259
	(8 23)	(8.30)	(8.29)	(8 39)	(8 26)	(8.26)
Turnover costs.						
SCREENING/100	.0738	0822	0853	.	.0682	0762
	(2 42)	(2 63)	(2.83)		(2.22)	(2 49)
TRAINING/100	0091	0079		0116	.0124	0108
	(71)	(60)		(92)	(.96)	(83)

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Labor market conditions.						
LOCAL UNEMP RATE	0020	.0301	− 0319	0432	.0693	.0811
	(04)	(06)	(−.07)	(09)	(15)	(17)
INDUSTRY UNEMP RATE	−1.73	−1 35	−1 74	−1.67	..	−1.57
	(−6.76)	(−5.65)	(−6.93)	(−6.56)		(−6 19)
VARIANCE OF IND UNEMP		0954	.	..	..	.
		(9.14)				
Firm characteristics.						
PCT UNION	.198	.195	.201	.200	198	201
	(10 78)	(10 42)	(11 17)	(10.88)	(10.69)	(10 86)
CAPITAL EQUIP-LABOR RATIO	1.99	2.51	1 99	1.97	1 56	
	(4 74)	(7.79)	(4.82)	(4 73)	(3 74)	
CAPITAL-LABOR RATIO	.	.	. .	. .	...	214
						(1.67)
PCT WHITE-COLLAR	0564	0537	.0523	.0578	.0720	.0578
	(3.03)	(2.91)	(2.85)	(3.12)	(3 86)	(3 08)
PCT CRAFT	0678	0725	.0762	0731	.0815	0776
	(3 12)	(3.31)	(3.57)	(3.38)	(3.74)	(3 58)
FIRM SIZE	.0203	.0209	0200	0207	0200	0202
	(5 75)	(5 99)	(5 77)	(5 91)	(5 63)	(5.66)
Industry effects included?	yes	no	yes	yes	yes	yes
R^2	498	471	498	.496	.489	.494
N	2,820	2,820	2,928	2,842	2,820	2,820

NOTE —t-statistics are in parentheses To save space, cooefficients on dummy variables representing workers' occupation, geographical region, and industry are not reported but are available from the author on request

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Table 3
Wage Equations with the Log of the Top Wage as the Dependent Variable

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	.594	.319	607	594	415	.594
	(6.25)	(3.47)	(6.40)	(6.27)	(4.61)	(6.24)
Worker characteristics.						
AGE/100	1 78	1.90	1.82	1.76	1.85	1.77
	(4.08)	(4 30)	(4 17)	(4.05)	(4.23)	(4.06)
$(AGE/100)^2$	−2.42	−2.52	−2 49	−2.40	−2.49	−2.40
	(−3 84)	(−3 93)	(−3 93)	(−3 82)	(−3.92)	(−3 80)
1 IF MALE	.185	.191	184	186	.191	188
	(11 28)	(11.46)	(11.26)	(11 31)	(11 56)	(11 47)
EXPERIENCE/100	130	139	116	.133	.121	131
	(4.72)	(4.99)	(4.23)	(4.82)	(4.36)	(4.74)
$(EXPERIENCE/100)^2$	−.0238	−.0269	− 0214	−.0245	−.0219	−.0240
	(−2.59)	(−2.89)	(−2 34)	(−2.67)	(−2.38)	(−2.62)
EDUCATION	0305	.0321	.0324	0305	0311	0306
	(6.94)	(7.20)	(7 42)	(6.99)	(7.04)	(6.96)
Turnover costs·						
SCREENING/100	0292	.0435	.0728	. .	0208	.0291
	(.71)	(1 04)	(1.78)		(.50)	(.70)
TRAINING/100	.124	.125	. .	.127	.129	.125
	(6.80)	(6 74)		(7 03)	(7.03)	(6 85)

Labor market conditions.						
LOCAL UNEMP RATE	− 823	−.721	− 870	−.723	− 740	−.781
	(−1.27)	(−1 10)	(−1 36)	(−1 12)	(−1.14)	(−1 21)
INDUSTRY UNEMP RATE	−2.02	−1.41	−2.16	−2.03		−1.92
	(−5.53)	(−4 19)	(−6 01)	(−5 57)		(−5 32)
VARIANCE OF IND UNEMP		.110	.	. .		. .
		(7 92)				
Firm characteristics:						
PCT UNION	154	.155	148	153	.154	.155
	(6.41)	(6.40)	(6.26)	(6.39)	(6.36)	(6.46)
CAPITAL EQUIP-LABOR RATIO	1 02	1.91	1 11	1 01	49	. .
	(1 72)	(4.18)	(1.87)	(1.70)	(.84)	
CAPITAL-LABOR RATIO	.	. . .		. . .	.	0353
						(19)
PCT WHITE-COLLAR	.0816	.0782	0754	0825	0998	.0810
	(3 09)	(3.04)	(2 89)	(3 15)	(3 79)	(3 05)
PCT CRAFT	.213	.226	.223	212	230	.219
	(7.15)	(7.56)	(7 53)	(7.14)	(7 67)	(7 35)
FIRM SIZE	.0186	.0146	.0190	.0185	.0183	.0183
	(3.88)	(3.13)	(3.99)	(3 89)	(3 79)	(3 80)
Industry effects included?	yes	no	yes	yes	yes	yes
R^2	502	.483	492	504	.494	.501
N	2,057	2,057	2,128	2,069	2,057	2,057

NOTE —t-statistics are in parentheses. To save space, coefficients on dummy variables representing workers' occupation, geographical region, and industry are not reported but are available from the author on request

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Table 4
Quit Equations
(Estimated with Hazard Model Assuming an Exponential Distribution)

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	−2.79	−3 04	−1 42	− 264	−.757	−.707
	(−7.54)	(−3 75)	(− 91)	(− 19)	(−.24)	(−.96)
TOP WAGE	−.962	−.962	−.799	−.795	.	.
	(−4.61)	(−4.30)	(−2.52)	(−2.24)		
ALTERNATE WAGE	263	878	1.582	679	.150	. . .
	(73)	(.50)	(27)	(05)	(01)	
Worker characteristics·						
AGE/100	.	−4.56	−4 74	−2.84	−2.85	−2 53
		(− 81)	(− 34)	(− 09)	(−.12)	(−.61)
(AGE/100)^2		2.96	2 79	0647	.203	− 215
		(.37)	(.15)	(.002)	(.01)	(−.03)
1 IF MALE	. .	.0443	− 162	0195	− 0031	0285
		(12)	(−.13)	(.07)	(−.01)	(22)
EXPERIENCE/100	. .	.0548	−.0951	00000	− 0445	−.0230
		(.18)	(− 11)	(.000)	(−.03)	(−.10)
(EXPERIENCE/100)^2		− 0561	−.0124	− 0379	−.0291	− 0342
		(− 62)	(− 05)	(−.07)	(−.07)	(− 39)
EDUCATION	. . .	.0393	−.00062	.0330	.0363	0417
		(56)	(− 003)	(07)	(10)	(1 25)
Turnover costs.						
SCREENING/100	. .	. . .	−2.16	−1 97	−2 04	−2 04
			(−2.35)	(−2 01)	(−2 19)	(−2.19)

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TRAINING/100	..	.	− 499 (−3.02)	−.498 (−2.68)	− 599 (−3.53)	− 600 (−3.60)
Labor market conditions.						
LOCAL UNEMP RATE	.		−23.1 (−4 55)	−18 9 (−3.44)	−18 6 (−3.46)	−18.6 (−3.64)
INDUSTRY UNEMP RATE	.	.	−4 17 (−1 33)	−8.69 (−2 93)	−6 79 (−2.41)	−6 80 (−2.41)
Firm characteristics.						
PCT UNION		...	−.565 (−2 24)	− 389 (−1.19)	−.518 (−1.62)	−.518 (−1.98)
CAPITAL EQUIP-LABOR RATIO	.	.		898 (13)	115 (.02)	.190 (.03)
PCT WHITE-COLLAR	...			− 215 (−1 08)	− 302 (−1.57)	−.303 (−1 58)
PCT CRAFT	.	. .		−.644 (−1 36)	−.749 (−1 79)	−.746 (−2.81)
FIRM SIZE		. .		−.163 (−3.42)	− 173 (−3.93)	−.173 (−4 23)
Industry effects included?	no	no	no	yes	yes	yes
Log likelihood	−1,445.1	−1,425.6	−1,260.6	−1,241.5	−1,250.7	−1,250.7
Hazard rate	0199	.0194	0166	.0157	.0160	.0160
N	2,246	2,246	2,108	2,108	2,108	2,108

NOTE —t-statistics are in parentheses In cols 1–5 the standard errors (and thus the t-statistics) were adjusted with the method discussed in Murphy and Topel (1985) to account for the fact that the alternate wage was obtained from the predicted values from a previous regression To save space, coefficients on dummy variables representing workers' occupation, geographic region, and industry are not reported but are available from the author on request

The cost of screening and training the most recently hired worker is included because firms with higher turnover costs have a greater incentive to deter turnover and, as predicted by condition (D), should thus have the lowest quit rates. The quit rate is also likely to depend on labor market conditions since workers will be less likely to quit if jobs are scarce. Labor market conditions are measured by the average local and industry unemployment rates in the period over which the worker was employed.[12] In addition, the quit rate is likely to depend on the unionization rate. Freeman (1980) argues that unions provide a voice for workers' grievances and thus give dissatisfied workers an alternative to quitting. Independent of the effect of unions on wages and wages on quits, highly unionized firms ought to experience fewer quits.

Column 1 of table 4 includes only the wage and the alternate wage, column 2 adds characteristics of the worker, and column 3 adds the other variables discussed above. In column 4 all the variables appearing in the wage equation are included in the quit equation. Since the wage is actually an endogenous variable that is set at its optimal level by the firm (taking into account its effect on the quit rate), it is omitted in column 5. Finally, the alternate wage is also omitted in column 6 because it is highly correlated with the worker characteristics.

Findings

To determine whether conditions (A), (B), and (C) are satisfied, it is necessary to know the value of τ and the values of the derivatives of the quit function. Unfortunately, the EOPP survey asks only about the time spent training workers in their first month and thus does not take into account training outside the firm, training given after the first month, and exit costs. A more comprehensive estimate of the cost of turnover comes from a study by the M & M Association (1980), which estimated the cost of hiring, training, and exit for different classes of workers.[13] Given the composition of workers in the sample, the average turnover cost is about $3,500 (about 4 month's salary for the average worker in the sample), so this value will be used for τ.

With the proportional hazard model, the quit rate and its derivatives can be expressed as

[12] Note that these unemployment rates differ from the unemployment rates that appear in the wage equation, which are the unemployment rates in 1979.

[13] This 1980 study included in its measure of turnover costs the cost of advertising for the position, travel expenses for the recruiter and/or applicant, administrative costs (e.g., interviewing and reference checks), the cost of medical examinations and induction procedures, the cost of substandard production of new employees, the time spent by current employees in providing on-the-job training, and severance pay. The study estimated the cost of turnover to be $3,611 75 for production workers, $2,291.50 for office and technical workers, and $10,356 16 for salaried employees.

$$q = \exp[\alpha + \beta_1 \ln(w) + \beta_2 \ln(w^a) + \beta_3 U], \tag{3}$$

$$q_w = \frac{\beta_1}{w} e^{(\cdot)}, \tag{3a}$$

$$q_{ww} = \frac{\beta_1^2 - \beta_1}{w^2} e^{(\cdot)}, \tag{3b}$$

and

$$q_{wu} = \frac{\beta_1 \beta_3}{w} e^{(\cdot)}, \tag{3c}$$

where α and the β's are the coefficients and $e^{(\cdot)}$ is the hazard rate reported in table 4. Note that the wage must be expressed in terms of monthly earnings since $q(w, w^a, U)$ is the monthly quit rate.[14] The average wage is $5.45 an hour or about $895 a month.

Condition (A) predicts that $-\tau q_w = 1$. If the average wage and the values of β_1 and the hazard rate from table 4 are substituted into (3a), q_w is calculated to lie between -0.0000139 and -0.0000214. The maximum value for $-\tau q_w$ is 0.0749, which is far less than predicted. Note that q_w rises in absolute value (i.e., becomes more negative) as w falls since $q_{ww} > 0$. Thus, the wage that would satisfy condition A is lower than the wage that firms actually pay. The low value of τq_w is incompatible with an efficiency wage model in which firms maximize short-run profits and in which turnover costs play a significant role. These results, however, may be compatible with an efficiency wage model in which firms pay wages to maximize long-run profits or in which the effect of wages on productivity strongly outweighs the effect of wages on turnover costs.

Condition (B) predicts that $dw/d\tau = -q_w/\tau q_{ww}$. From (3a) and (3b), it can be shown that $-q_w/\tau q_{ww} = -w/[\tau(\beta_1 - 1)]$. If the average wage, the estimated value of τ, and the value of β_1 from table 4 are substituted into this equation, $-q_w/\tau q_{ww}$ is calculated to lie between 0.130 and 0.142. In table 3,[15] the coefficient on TRAINING lies between 0.00124 and 0.00129. This value, however, represents the effect of an additional hour of training on wages, not the effect of an additional dollar of training costs. To convert figures on hours of training into dollar amounts, it will be assumed that individuals in charge of recruiting and training new workers

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[14] While the wage variable appearing in the wage equation is the log of the hourly wage, the units are irrelevant because of the logarithmic specification.

[15] Since the top wage appears in the quit equations, the estimates of $dw/d\tau$ and dw/dU were obtained from the equations for the top wage

earn the same wage as the recruit's top wage and that fringe benefits add 27% to the cost of an employee.[16] With these assumptions, it is calculated that $d \ln(w)/d\text{TRAINING\$}$ averages 0.000105.[17] At the average monthly wage of \$895, $dw/d\text{TRAINING\$} = 0.0940$ (recall that $d \ln(w) = dw/w$), a value 66%–72% the size of $-q_w/\tau q_{ww}$.

Because SCREENING and TRAINING are correlated, SCREENING is insignificant in the regressions in which TRAINING also appears. Thus, the best estimate of the coefficient on SCREENING is probably found in column 3, in which TRAINING is omitted. With this value of the coefficient on SCREENING, calculations similar to those above show that $dw/d\text{SCREENING\$} = 0.0944$, which is 66%–73% the size of $-q_w/\tau q_{ww}$. These values are consistent with the model in which firms pay efficiency wages and in which wages affect both turnover and productivity.[18]

These findings do not, though, conclusively prove that firms with higher training costs pay higher wages to deter turnover. It could be argued that the positive effect of training costs on wages results only from the fact that training makes workers more productive, rather than from firms' desire to reduce turnover. The coefficient on TRAINING, however, seems too large to account for the effect of training on productivity. When the coefficient on EDUCATION is adjusted to account for the fact that EDUCATION is measured in years while TRAINING is measured in hours, the coefficient on TRAINING is 40–50 times larger than the coefficient on EDUCATION. It seems implausible that training by one's firm increases an individual's productivity that much more than schooling. While it may be argued that an individual is acquiring more practical skills from on-the-job training than from schooling, regressions with data from the second EOPP survey indicate that the effect of vocational training (which represents practical training) on wages is half the size as the effect of schooling. Thus, while the coefficient on TRAINING seems much too large to account

[16] This figure was obtained from Munnell (1988) for 1980. It represents spending on nonwage compensation and wages for time not worked as a percentage of wages for time worked. Thus, the cost of an additional hour of training is the trainer's wage (estimated as the average top wage for workers in the sample, which is \$5 45) plus the recruit's starting wage (which averages \$4.10), all times 1.27 The cost of an additional hour of screening is the screener's wage (again estimated at \$5.45) times 1.27 Thus, to calculate how much a \$1 increase in turnover costs raises wages, the coefficient on TRAINING must be divided by 12.1, and the coefficient on SCREENING must be divided by 6.9.

[17] TRAINING\$ represents the cost of training in dollar terms, while TRAINING represents the number of hours spent training. The same notation is used for SCREENING.

[18] The fact that TRAINING and SCREENING do not represent the full cost of turnover should not affect these results since the issue is not the magnitude of turnover costs but the effect on wages of a \$1 increase in turnover costs.

for the effect of training on productivity, its size is consistent with the efficiency wage model.

Condition (C) predicts that a rise in the unemployment rate lowers the wage and, in particular, that $dw/dU = -q_{wu}/q_{ww}$. From (3b) and (3c), it can be shown that $-q_{wu}/q_{ww} = \beta_3 w/(1 - \beta_1)$. Two unemployment rates were considered in this study: the unemployment rate in the local labor market and the industry unemployment rate. The coefficient on the local unemployment rate is always insignificant and, in fact, is sometimes positive in the equations for the starting wage. If the average wage and the values for β_1 and β_3 (for the local unemployment rate) from table 4 are substituted into the expression for $-q_{wu}/q_{ww}$, it is calculated to lie between $-9,420$ and $-11,490$. In table 3, $d \ln(w)/dU$ lies between -0.72 and -0.87 for the local unemployment rate, so that dw/dU lies between -644 and -779, which is 5%–9% the size of $-q_{wu}/q_{ww}$. This is much smaller than the efficiency wage model predicts.

A possible explanation why the coefficients on the local unemployment rate are insignificant and much smaller than predicted is that previous researchers (e.g., Hall 1972; Reza 1978; Adams 1985; and Marston 1985) have found that wages tend to be higher in areas with high unemployment and have generally considered the higher wages to be a compensating differential for the higher probability of unemployment. It is possible that the two effects of local unemployment on wages (i.e., the fact that high unemployment lessens the need for firms to pay high wages to reduce turnover and the fact that higher wages serve as a compensating differential for areas with high unemployment) nearly cancel out, so that the net effect is small.

Better results were obtained with the industry unemployment rate, which is always negative and significant at the 1% level. Note that some of the regressions include dummy variables for the one-digit SIC industry, while others do not. Since the industry unemployment rates are highly correlated with the industry dummies, it is important to compare coefficients from wage equations and quit equations that either both omit the industry dummies or both include the industry dummies. Consider first wage and quit equations both omitting the industry dummies. Column 3 of table 4 includes the industry unemployment rate but does not include the industry dummies. From the coefficients in this column, $-q_{wu}/q_{ww}$ is calculated to equal $-2,070$. Column 2 of table 3 also includes the industry unemployment rate but does not include the industry dummies. In this column, $d \ln(w)/dU = -1.41$, meaning that $dw/dU = -1,260$, which is 61% the size of $-q_{wu}/q_{ww}$.

Now consider wage and quit equations including the industry dummies. The industry unemployment rate, the industry dummies, and the wage all appear in column 4 of table 4. With the coefficients in this column, $-q_{wu}/q_{ww} = -4,330$. The industry unemployment rates and the industry dummies

appear in columns 1, 3, 4, and 6 of table 3. From these coefficients, dw/dU is calculated to lie between $-1,720$ and $-1,930$, which is 40%–45% the size of $-q_{wu}/q_{ww}$.

While $dw/d\tau$, dw/dU, $-q_w/\tau q_{ww}$, and $-q_{wu}/q_{ww}$ were calculated at the average monthly wage for all workers in the sample, the relationships between $dw/d\tau$ and $-q_w/\tau q_{ww}$, and between dw/dU and $-q_{wu}/q_{ww}$ are independent of the wage since these expressions are all linear functions of the wage. Thus, the same relationships between these expressions would be found for workers paid any wage, not just for workers paid the average wage.

Condition (D), which predicts a negative correlation between a firm's turnover cost and its quit rate, is satisfied. In the quit equations reported in table 4, the coefficient on SCREENING is negative and significant at the 5% level, and the coefficient on TRAINING is negative and significant at the 1% level, suggesting that firms with high turnover costs actively try to discourage quits through actions besides paying good wages. (Recall that the wage is included as an explanatory variable in half of these regressions.) This is an important result, as it indicates that reducing quits is an important consideration for firms with high turnover costs. It strengthens the argument that reducing turnover is the reason why firms with high turnover costs pay higher wages.

The results also support the hypothesis that a positive relationship exists between the wage and firm characteristics raising workers' productivity. The coefficient on the capital equipment/labor ratio is always positive; in the 10 columns of tables 2 and 3 in which it appears, it is significant at the 5% level in nine equations and significant at the 1% level in six equations. As expected, this coefficient is much larger and more significant than the coefficient on the total capital-labor ratio.[19]

In addition, the coefficients on PCT WHITE-COLLAR and PCT CRAFT are always positive and significant at the 1% level, meaning that workers who work with a high proportion of skilled coworkers receive higher wages on average. If workers of different occupations are complements in the production process, it makes intuitive sense that firms employing many highly skilled workers find it optimal to pay good wages to all their workers. First, working with skilled coworkers increases the resources at one's disposal and thus raises the potential gain from an increase in effort. Second, the productivity of one's coworkers may depend on how

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[19] While other economists have shown that the capital-labor ratio has a positive effect on wages (see Dickens and Katz [1987] for a review of these studies), this is the first time to my knowledge that it has been shown that the capital equipment/labor ratio has a much greater impact on wages than does the total capital-labor ratio.

hard one works.[20] These results may help explain Dickens and Katz's (1987) and Krueger and Summers's (1987) findings that certain industries pay higher wages to workers of all occupations.

If firms differ in turnover costs and in characteristics affecting productivity, the wage that maximizes profits will vary across firms (even if they hire identical workers), possibly explaining why studies have found significant effects of industry dummy variables on wages.

V. Conclusion

In the *Journal of Economic Perspectives,* Richard Thaler (1989, p. 190) writes, "Are the firms that pay high wages those who would gain the most from an increase in worker effort? . . . Are the industries that pay high wages those with the highest turnover costs? Who knows?" This study answers these questions in the affirmative. It not only shows that firms with the highest turnover costs pay the highest wages but also shows that efficiency wage theory does a reasonably good job of predicting the degree to which turnover costs raise wages.

Condition (B) expresses the effect of turnover costs on wages as a function of the first and second derivatives from the quit function. The effect on wages of a $1 rise in turnover costs is smaller than predicted by the model ignoring the effect of wages on productivity, but is reasonable if allowance is made for the fact that wages affect productivity as well as turnover. In contrast, these results are not consistent with a perfectly competitive labor market in which workers of identical ability earn the same wage at any firm since the effect of turnover costs on wages appears much too large to be explained by the effect of training on workers' productivity. These results are also probably not consistent with a model in which firms are labor-supply constrained and face an upward-sloping supply curve for labor since in that case the relationship between turnover costs and wages would likely be much different from that predicted by condition (B). Note that the wage equations and quit equations were estimated separately. Since there would be no reason for the coefficients from these equations to be related in the way predicted by condition (B) if the efficiency wage model did not explain wage behavior, these findings are quite remarkable.[21]

[20] For example, if a firm employs many highly skilled workers and if their productivity or their propensity to quit depends on the cleanliness of the firm, it will make sense for the firm to pay its janitors well to induce greater effort on their part.

[21] While slightly different results could be obtained if different assumptions were made (e.g , about the magnitude of turnover costs or about how we convert figures on hours of training into dollar terms), we would have no reason to expect the coefficients to be of even the right order of magnitude if the efficiency wage model were not valid.

Furthermore, the finding that firms with higher turnover costs experience fewer quits even when controlling for the wage provides further evidence that reducing quits is an important consideration for firms with high turnover costs.

When unemployment is measured by the industry unemployment rate, the effect of unemployment on wages is somewhat smaller than predicted by condition (C) but again is reasonable if wages affect productivity as well as quits. Again, it is unlikely that the coefficients from the wage and quit equations would be related in this way if efficiency wage theory were not valid. However, the effect of the local unemployment rate on wages is much smaller than predicted by condition (C), although this result may be explained by the findings of previous researchers that higher wages serve as a compensating differential for areas with high unemployment.

As predicted by the general efficiency wage model in which wages affect both productivity and turnover, the wage depends positively on firm characteristics that raise workers' productivity such as the capital-labor ratio and the percentage of workers classified as white-collar or craft workers. However, a model in which firms pay equilibrium wages and face an upward-sloping supply curve for labor predicts the same result. These findings could also be consistent with a model in which firms hire in a perfectly competitive labor market if firm characteristics that raise productivity are positively correlated with the portion of workers' abilities that is unmeasured. Thus, these results are not conclusive evidence for efficiency wage theory. What is interesting about these results is the finding that the capital equipment/labor ratio far outperforms the total capital-labor ratio in predicting wages. In addition, the finding that workers who work with a large proportion of highly skilled coworkers earn higher wages might help explain why certain industries pay higher wages to workers of all occupations.

Finally, while τq_w is lower than predicted by condition (A), its value may be consistent with an efficiency wage model in which wages have a much greater effect on productivity than on turnover costs or in which firms pay wages to maximize long-run profits. Promising topics for future research might be to explore the dynamics through which wages could affect future productivity and turnover costs and to try to estimate the relative strengths of the effects of wages on productivity and turnover costs.

Appendix A

An Efficiency Wage Model with Wages Affecting Productivity and Turnover

Now suppose that workers' productivity depends on their wage so that the production function can be written as

$$Q = \gamma e(w, \phi)L^{\alpha}K^{1-\alpha}, \qquad (A1)$$

where $e(w, \phi)$ represents the efficiency of each unit of labor.[22] The efficiency of each worker depends on the wage (w) and on a vector of firm characteristics affecting productivity (ϕ), where $e_w > 0$, $e_{\phi} > 0$, and $e_{w\phi} > 0$. It is assumed that $e_{w\phi} > 0$ since a rise in a firm characteristic that raises workers' productivity (e.g., the capital-labor ratio) means that a given increase in the wage and hence in workers' effort results in a greater increase in output.[23]

Under these assumptions, the profit function becomes

$$\pi = P\gamma e(w, \phi)L^{\alpha}K^{1-\alpha} - wL - rK - \tau q(w, w^a, U)L. \qquad (A2)$$

If (A2) is differentiated with respect to w, L, and K, the first-order conditions are

$$0 = d\pi/dw = P\gamma e_w(w, \phi)L^{\alpha}K^{1-\alpha} - L - \tau q_w(w, w^a, U)L, \qquad (A3)$$

$$0 = d\pi/dL = \alpha P\gamma e(w, \phi)L^{\alpha-1}K^{1-\alpha} - w - \tau q(w, w^a, U), \qquad (A4)$$

and

$$0 = d\pi/dK = (1 - \alpha)P\gamma e(w, \phi)L^{\alpha}K^{-\alpha} - r. \qquad (A5)$$

If equation (A3) is divided by L and the capital-labor ratio (K/L) is represented by k, this equation can be expressed as

$$0 = P\gamma e_w(w, \phi)k^{1-\alpha} - 1 - \tau q_w(w, w^a, U). \qquad (A6)$$

Note that (A6) implies that $-\tau q_w < 1$ in a model in which wages affect both productivity and turnover.

Dividing equation (A4) by (A5) yields the equation

$$0 = w + \tau q(w, w^a, U) - \frac{\alpha}{1 - \alpha}rk. \qquad (A7)$$

[22] This specification assumes that output is homogeneous of degree one with respect to the efficiency of each worker but not with respect to the number of workers. It implies that if the efficiency of each worker doubles, output will also double. But if the number of workers doubles, output will rise less than proportionately Akerlof and Yellen (1986) defend this specification on the grounds that shirking misuses other inputs as well as labor. In addition, an increase in workers' effort should result in other inputs being used more efficiently.

[23] For example, if a wage increase causes workers to increase their effort by 10%, output will rise more at a firm with a high capital-labor ratio than at a firm with a low capital-labor ratio.

If (A6) and (A7) are totally differentiated and put into matrix notation, the system of equations can be expressed as

$$
\begin{bmatrix} P\gamma e_{ww}k^{1-\alpha} - \tau q_{ww} & (1-\alpha)P\gamma e_w k^{-\alpha} \\ 1 + \tau q_w & -[\alpha/(1-\alpha)]r \end{bmatrix} \begin{bmatrix} dw \\ dk \end{bmatrix}
$$

$$
= \begin{bmatrix} -P\gamma e_{w\phi}k^{1-\alpha} & q_w & \tau q_{wu} \\ 0 & -q & -\tau q_u \end{bmatrix} \begin{bmatrix} d\phi \\ d\tau \\ dU \end{bmatrix}.
$$

The determinant is

$$
\det = -[\alpha/(1-\alpha)]rP\gamma e_{ww}k^{1-\alpha} + [\alpha/(1-\alpha)]r\tau q_{wu}
$$

$$
- (1-\alpha)P\gamma e_w k^{-\alpha} - (1-\alpha)\tau q_w P\gamma e_w k^{-\alpha}.
$$

From (A7), $w + \tau q$ can be substituted for the quantity $[\alpha/(1-\alpha)]rk$ in the first term to obtain

$$
\overset{+}{} \qquad\qquad\qquad \overset{+}{}
$$

$$
\det = [\alpha/(1-\alpha)]r\tau q_{ww} - (1-\alpha)\tau q_w P\gamma e_w k^{-\alpha}
$$

$$
\overset{+}{} \qquad\qquad \overset{+}{} \qquad\qquad \overset{-}{}
$$

$$
- P\gamma e_{ww}k^{-\alpha}\tau q + P\gamma k^{-\alpha}[-e_{ww}w - (1-\alpha)e_w].
$$

The sign of this determinant can be shown to be positive if the efficiency of labor can be expressed by the Cobb-Douglas function $e(w, \phi) = cw^\rho \phi^\varepsilon$, and if $\alpha > \rho$. The second condition will be satisfied if the elasticity of output with respect to the number of workers exceeds the elasticity of output with respect to the wage (i.e., if a 10% increase in the number of workers raises output more than a 10% increase in the wage).

From Cramer's Rule, the derivatives of the wage with respect to ϕ, τ, and U are

$$
\overset{+}{}
$$

$$
\frac{dw}{d\phi} = \frac{[\alpha/(1-\alpha)]rP\gamma e_{w\phi}k^{1-\alpha}}{\det} > 0,
$$

$$
\overset{+}{} \qquad\qquad \overset{+}{}
$$

$$
\frac{dw}{d\tau} = \frac{-[\alpha/(1-\alpha)]rq_w + q(1-\alpha)P\gamma e_w k^{-\alpha}}{\det} > 0,
$$

and

$$
\overset{-}{} \qquad\qquad\qquad \overset{-}{}
$$

$$
\frac{dw}{dU} = \frac{-[\alpha/(1-\alpha)]r\tau q_{wu} + \tau q_u(1-\alpha)P\gamma e_w k^{-\alpha}}{\det} < 0.
$$

Note that when wages affect both productivity and turnover, $dw/d\tau$ and dw/dU are smaller (in absolute value) than the expressions calculated in Section II, which include only the effect of wages on turnover. To get a general idea of how much smaller these expressions are when the productivity effect is present, let θ represent the ratio of $dw/d\tau$ calculated when the productivity effect is present to the value of $dw/d\tau$ when it is not present. Thus,

$$\theta = \frac{\dfrac{-[\alpha/(1-\alpha)]rq_w + q(1-\alpha)P\gamma e_w k^{-\alpha}}{\{[\alpha/(1-\alpha)]r\tau q_{ww} - (1-\alpha)\tau q_w P\gamma e_w k^{-\alpha} \\ - P\gamma e_{ww}k^{-\alpha}\tau q + P\gamma k^{-\alpha}[-e_{ww}w - (1-\alpha)e_w]\}}}{\dfrac{-q_w}{\tau q_{ww}}}$$

$$= \frac{[\alpha/(1-\alpha)]rq_w\tau q_{ww} - (1-\alpha)qP\gamma e_w k^{-\alpha}\tau q_{ww}}{\{[\alpha/(1-\alpha)]r\tau q_{ww}q_w - (1-\alpha)\tau q_w P\gamma e_w k^{-\alpha}q_w \\ - P\gamma e_{ww}k^{-\alpha}\tau q q_w - P\gamma k^{-\alpha}e_{ww}wq_w - (1-\alpha)P\gamma k^{-\alpha}e_w q_w\}}.$$

Note that from (A6) we can substitute $(1 + \tau q_w)k^{-1}$ for $P\gamma e_w k^{-\alpha}$, and from (A7) we can substitute $(w + \tau q)k^{-1}$ for $[\alpha/(1-\alpha)]r$. Furthermore, if it is assumed that $e(w, \phi) = cw^\rho\phi^\varepsilon$, it can be shown that $e_{ww} = -(1-\rho)w^{-1}e_w$, so that $P\gamma e_{ww}k^{-\alpha} = -(1-\rho)(1 + \tau q_w)k^{-1}w^{-1}$. Making these substitutions and dividing the numerator and denominator by k^{-1} and q_w yields

$$\theta = \frac{(w + \tau q)\tau q_{ww} - (1-\alpha)q(1 + \tau q_w)\tau q_{ww}(q_w)^{-1}}{\{(w + \tau q)\tau q_{ww} - (1-\alpha)\tau q_w(1 + \tau q_w) + (1-\rho)(1 + \tau q_w)w^{-1}\tau q \\ + (1-\rho)(1 + \tau q_w) - (1-\alpha)(1 + \tau q_w)\}}.$$

It is possible to obtain rough estimates of θ by substituting into the above equation the parameters from the study and a range of values for α and ρ. To derive estimates of θ, we will use (as in Sec. IV) the values of $\tau = 3,500$ and $w = 895$. Equation (3) shows that $q = e^{(\cdot)}$, $q_w = (\beta_1/w)e^{(\cdot)}$, and $q_{ww} = [(\beta_1^2 - \beta_1)/w^2]e^{(\cdot)}$, where $e^{(\cdot)}$ is the hazard rate. The values of β_1 and the hazard rate from table 4 were substituted into the equations for q, q_w, and q_{ww}. Values of 0.5 and 0.7 were used for α, and values of 0.1 and 0.4 were used for ρ (where ρ is the elasticity of output with respect to the wage). With these values, θ ranged between 0.17 and 0.70. Thus, if wages affect both productivity and turnover, $dw/d\tau$ should lie between about 17%–70% of $-q_w/\tau q_{ww}$. By a similar analysis, it can also be shown that dw/dU should lie between about 17%–70% of $-q_{wu}/q_{ww}$ if wages affect both productivity and turnover.

It is interesting to note that with the values of β_1 from table 4, $-\tau q_w$ is much less than one (its highest value is 0.075), so that the left-hand side of condition A is much less than the right-hand side. However, these calculations show that it is possible for the left-hand sides of conditions

(B) and (C) to be a relatively large fraction of the right-hand sides, even if the left-hand side of condition (A) is a relatively small fraction of the right-hand side.

Appendix B

A Model with a Labor-Supply Constrained Firm

Suppose now that the firm is labor-supply constrained and faces an upward-sloping supply curve for labor. If $L(w)$ represents the amount of labor supplied at the wage w (with $L' > 0$ and $L'' < 0$), the firm's profits can be written as

$$\pi = P\gamma L(w)^{\alpha} K^{1-\alpha} - wL(w) - rK - \tau q(w, w^{a}, U)L(w). \quad (B1)$$

Differentiating (B1) with respect to w and K yields

$$d\pi/dw = 0 = \alpha P\gamma L(w)^{\alpha-1} K^{1-\alpha} L'(w) - wL'(w) - L(w)$$
$$- \tau q(w, w^{a}, U)L'(w) - \tau q_{w}(w, w^{a}, U)L(w) \quad (B2)$$

and

$$d\pi/dK = 0 = (1 - \alpha)P\gamma L(w)^{\alpha} K^{-\alpha} - r. \quad (B3)$$

If (B3) is solved for K and substituted into (B2), the following equation is obtained:

$$0 = \alpha(1 - \alpha)^{[(1-\alpha)/\alpha]} P^{(1/\alpha)} \gamma^{(1/\alpha)} r^{[-(1-\alpha)/\alpha]} L'(w) - wL'(w)$$
$$- L(w) - \tau q(w, w^{a}, U)L'(w) - \tau q_{w}(w, w^{a}, U)L(w). \quad (B4)$$

Totally differentiating (B4) with respect to w, τ, and U yields the following results:

$$\frac{dw}{d\tau} = \frac{qL' + q_{w}L}{\{\alpha(1 - \alpha)^{[(1-\alpha)/\alpha]} P^{(1/\alpha)} \gamma^{(1/\alpha)} r^{[-(1-\alpha)/\alpha]} L''}{} - wL'' - 2L' - \tau qL'' - 2\tau q_{w}L' - \tau q_{ww}L\}} ,$$

$$\frac{dw}{dU} = \frac{\tau q_{u}L' + \tau q_{wu}L}{\{\alpha(1 - \alpha)^{[(1-\alpha)/\alpha]} P^{(1/\alpha)} \gamma^{(1/\alpha)} r^{[-(1-\alpha)/\alpha]} L''}{} - wL'' - 2L' - \tau qL'' - 2\tau q_{w}L' - \tau q_{ww}L\}} .$$

Note that the signs of the numerators in both the above expressions are ambiguous (although the denominators must be negative for profit maximization). Thus, in a model in which firms are labor-supply constrained, the effect of turnover costs and unemployment on wages is ambiguous.

Finally, if productivity is a function of the wage and firm characteristics raising productivity (i.e., productivity equals $e(w, \phi)$ as in App. A), it can be shown that $dw/d\phi$ is positive, meaning that firm characteristics raising productivity would be likely to raise wages even if firms operate on their labor supply curves.

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