

An Empirical Test of the Efficiency Wage Hypothesis

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Abstract

The efficiency wage hypothesis is a popular explanation of observed labour market realities, however empirical testing has been very inadequate. Measuring effort and calculating productivity has been almost impossible in modern team oriented production processes. Because this study obtains a unique data set with similar production lines making the same product, across multiple geographies, but paying different wage premiums a reasonably controlled test can be conducted on the impact of wage premiums. Despite very good fitting of various production functions no statistical support is found for the idea that premium wages influence output. While these results may be somewhat surprising, given the popularity of the efficiency wage shirking model, there are possible alternative explanations discussed in this paper. As shown in this case study there is not always a connection between wage premium and output, therefore, managers should be careful about using wage premiums to increase effort and employee production.

JEL Classification: J01, J30, D24

1. Introduction

This paper will conduct a direct microeconomic test of the efficiency wage hypothesis. To date empirical testing of this hypothesis has been very inadequate because measuring effort and calculating productivity has been almost impossible in modern team oriented production processes. This study obtains a unique panel study data set for multiple plants within the same company, making essentially the same product but paying different wage premiums across the plants and across time. This data set allows for a reasonably controlled test to be conducted on the impact of wage premiums. Despite very good fitting of various production functions no statistical support is found for the shirking model of the efficiency wage hypothesis. While these results may be somewhat surprising there are possible alternative explanations which are discussed in the conclusions to this paper. As shown in this case there is not always a connection between wage premium and output, therefore, managers should be careful about using wage premiums to increase effort and employee production.

2. Efficiency wage hypothesis

The reality of labour markets undermines the expected results of the neoclassical wage theory and requires an explanation. Wages are widely dispersed, even for the same job in the same location (Guttschalk and Smeeding, 1997). Involuntary unemployment is a reality across the globe and has been studied in detail since the great depression. And finally workers do not move quickly between jobs over small wage differences (Moscarini and Thomsson, 2007).

These empirical realities have spawned a variety of adjustments to neoclassical wage theory. According to Krueger and Summers (1988) these adjustments fit into two groupings. First, firms may not be profit maximisers, but rather act according to the manager or owners' alternative agenda. This is the well understood *agency theory* mechanism. The second type of answer is based on the idea that firms may, for different reasons, find it profitable to pay wages above the market level.

The efficiency wage hypothesis is founded on the idea that it can be profit maximizing for a firm to pay workers a higher wage than the going market rate through reducing a firm's production costs. In its most common model efficiency wages suggests that all other things being equal, effort is a function of wage, and that output is a function of effort. The generally assumed shape for the effort curve is an S shaped curve (Stiglitz, 1976). At the low end of wage, little effort is expended. As wages increase $E' > 0$ and effort increases rapidly in response to premium wages. However, a point is reached where $E'' < 0$. Here either the income effect of the high wage takes over, or the ability of the worker to increase effort diminishes. Eventually effort is either flat or declines. The Output resulting from the effort is assumed to have a monotonic functional relationship and diminishing returns with respect to wage as long as additional effort results in some increased output $\partial O / \partial E > 0$. These relationships are shown in figure 1 and 2.

Figure 1 - Wage-Effort Relationship

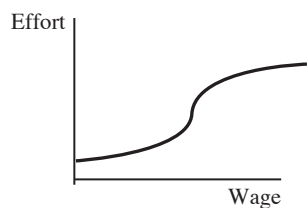
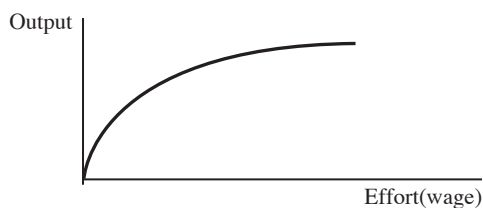


Figure 2 - Effort-Output Relationship



The relationship between wage $\rightarrow$ effort $\rightarrow$ output will form the critical model in the test conducted in this study.

Kinds of models

A proliferation of models occurred in the early 1980s with publications by Stiglitz and Shapiro (1984), Salop (1979), Malcomson (1981) and Akerlof (1982) among others. Under the heading of efficiency wage hypothesis, several model groupings can be created:

1. The premium wage is paid in order to minimize turnover costs. If firms must bear part of the costs of turnover (search and training), and if turnover is a decreasing function of the wages firms pay, there may be an incentive to raise wages in order to minimize turnover cost (Salop, 1979).
2. Increasing wages raises workers' effort level (shirking model). Workers who are paid only the equivalent wages of jobs on the outside have little incentive to perform well, since losing their jobs would not be costly. By raising wages, firms may make the cost of job loss larger and thereby encourage good performance (Stiglitz and Shapiro, 1984).
3. Firms which pay higher wages will find that they attract a higher quality pool of applicants. If worker quality is not directly observable, this will be desirable (Malcomson, 1981).

While the search and training model may not be directly observable in production output both the shirking model and quality employee model should result in higher output for higher wage premiums. For a review of efficiency wage literature see Sorensen 1994, and Akerloff and Yellen, 1986.

Empirical testing

An important early test on efficiency wage is that of Raff and Summers (1987) relative to Henry Ford's wage. Raff and Summers conduct a case study on Henry Ford's introduction of the 'five dollar day' in 1914. Their conclusion is that the Ford experience supports efficiency wage interpretations. 'Ford's decision to increase wages so dramatically (doubling for most workers) is most plausibly portrayed as the consequence of efficiency wage considerations.... Ford's new wage put him in the position of rationing jobs, and increased wages did yield substantial productivity benefits and profits' (Raff and Summers, 1987, p.83). However, this was not a quantitative data test as the study was only an interpretive study with Raff and Summers reading the history and providing their interpretation of its meaning.

Cappelli and Chauvin (1991, p.784) point out that 'efficiency wage arguments rely on a largely untested relationship between wage premiums and worker productivity'.

In developed countries testing the connection between wage and productivity has proven more difficult. Effort is not directly observable, especially in team efforts and coordinated production processes. The ability to measure effort has been the missing link in previous studies. Unable to directly observe labour effort in common modern team oriented production processes, previous studies have relied on indirect measures like the level of supervision (Abowd *et al.*, 1999) or on management surveys (Campbell and Kamlani, 1997) or discipline (Cappelli and Chauvin, 1991). This is clearly a weak approach because the level of supervision and discipline could be influenced by a large number of causal factors not related to labour effort. Included in this group of factors could be cost cutting, supervisory capability and effort, union rules and protections and non-remuneration related loyalty programs.

There have been efforts to try and measure effort in motivational and behavioural economics. Strobl and Walsh (2007) use data from Ghana which asks workers 'how tired are you at the end of the day'. From this measure they construct

a measure of effort. Goldsmith *et al.* (2000) also seek to measure effort by using a psychological classification called 'locus of control' which is based on the motivational theory called 'expectancy theory' made popular by Vroom (1964). While both of these studies use a subjective assessment they are able to find relationships with wage and supervision, but not directly with output. Several additional attempts have been made which support efficiency wage impacts (Wadhvani and Wall, 1991; Levine, 1992) but these have been indirect studies measuring sales levels or using industry on industry wages ratios.

Two more recent studies have tried to directly test the efficiency wage model using production function models. These are industry level studies and have conflicting results. Liu and Sakamoto (2005) develop an aggregate model on Taiwanese industry. They use a Cobb-Douglas production function with an inverse measure of wage deprivation substituting for above market wages. Their data is limited to yearly totals by industry for six years but they do find results that are inconsistent with efficiency wage expectations.

Huang *et al.* (1996) use a translog production function at a two digit industry level for U.S. firms and try to break wage down into a human capital component and a wage premium. They find that the wage premium behaves consistent with efficiency wage theory, however, they note, 'the wage premium could still be unmeasured human capital' (p.126).

This paper is able to add to the literature by avoiding the difficulties of measuring effort through looking directly at output as the result of effort, when controlled for other variables. It is able to directly measure wage premium by comparing the wage for specific job classifications with local market averages for the same job rather than using industry or firm ratios such as Levine (1992) or Cappelli and Chauvin (1991). It also adds evidence at the level of the decision maker through a micro, single firm study rather than the aggregated industry studies of Huang and Lui reference above. Of course being a micro study the results in this paper serves only as a single point of data and so cannot establish a universal maxim, however, the results can support or challenge established views.

3. Data

In addition to the problems of directly observing labour effort in a team environment, plant level non-currency data for measuring labour productivity is hard to come by. Most firms track and maintain historical information only for required accounting systems while productivity data requires collection from multiple tracking systems (hours worked, inputs, outputs etc.). Sometimes these data are created in short-term operational systems, but rarely are they summarized and saved in historical systems comparable across plants. That is why the data for this particular study are unique and valuable. The data comes from four U.S. plants of an international confectionary manufacturing company. The same product used in this study, with flavour/pack size variants, is made across the plants in this study. Labour is the largest production cost factor in the financial profile of these products.

Manufacturing plants and production process

The manufacturing plants used in this study have been selected from four cities and are referred to by the state within which they are located (Georgia, Illinois, Texas and Tennessee). None of the plants are unionized, thus eliminating union rules and protection on performance measurements. The plants are large with hundreds of employees each, but each location has a sufficient manufacturing base and civilian labour force to provide a competitive labour environment so the firm itself (representing only a small per cent of the market) will not overly impact the local labour market.

The basic production technologies have been in place for many years across each plant. Minor new technologies are added onto the lines to improve quality, safety or efficiency every year. These improvements are also shared across sites. The lines are continuous flow process lines, not assembly lines. Assembly lines can manage effort from employees by managing the speed of the lines. The speed of continuous flow process lines is contingent upon the engineering of the line rather than the effort of the associated employees. Effort from the employees can increase output by reducing waste and improving uptime. The role of employees in working on these lines is to manage the equipment, to adjust speeds and settings, to address emergencies and to make process improvements. Additional employees provide the continuously needed supplies and maintain and repair the equipment. From time to time mechanical problems arise which require manual intervention until the problem can be fixed.

The process lines all exhibit certain characteristics. They operate with a variable relationship between capital and labour. The capital and labour are partially substitutable and partially complementary. Some problems or improvements can be addressed with only labour or capital rather than always requiring fixed amounts of both. However, additional capital can replace employees, or additional employees could be used for some operations instead of automating.

Because the lines are well established and operate in a consistent range of capacity over the period of the study, a single return to scale is appropriate regarding labour and capital. Labour and capital are added to the lines in small increments of a few percentage points difference per year rather than fundamental changes in operations.

Production data

The subject firm believed very strongly that lasting competitive advantage could only be obtained through manufacturing excellence and technology. As a result every plant was required to submit engineering plant performance along with financial data. The unique data are available for a 10 year period (1993-2002) in the company's centralized historical repository. The key pieces of data used in this study end up being:

Output (O) is measured in metric tonnes of confectionary food product produced. The measure used is yearly total output moved into finished goods (this excludes any waste or rejected product). Headcount (L) is reported in equivalent full time employees and is tracked through the payroll system. The measure used is the average of weekly headcount for the year. Standard operating capacity (K) is also measured in metric tonnes. A consistent set of rules is used by all plant industrial engineers to calculate the standard operating capacity.

There are several reasons that standard operating capacity is used as a proxy for capital. The first is that the dollar value of capital is recorded in the accounting records at cost and so equipment that is 30 years old would not have a comparable value to recently added equipment. The second is that much of ongoing capital spending is related to issues of safety and quality which do not affect output quantities. The third is that standard operating capacity captures any of the minor technology changes introduced throughout the study. Standard operating capacity shows the impact of capital on output quantity without regard to labour.

The statistical description of the data used for these empirical fittings is shown in table 1. Given the statistics for kurtosis and skewness, the hypothesis that the data follow a normal distribution will not be rejected.

Table 1 - Descriptive statistics for 10 years of production data

	<i>Volume</i>	<i>SOC</i>	<i>Headcount</i>
Mean	27.5	39.4	115.6
Standard Error	1.3	1.9	4.3
Median	29.0	36.9	121.0
Mode	33.3	13.8	136.0
Standard Deviation	17.7	26.9	61.1
Kurtosis	-0.3	-0.2	0.2
Skewness	0.4	0.7	0.3
Range	72.8	100.0	304.0
Minimum	0.7	2.9	3.0
Maximum	73.5	102.9	307.0
Count	199	200	199

All 10 years of data will be used to obtain the best possible fit of production functions (1993-2002), however, corresponding payroll data only exists for four of these years (1993, 1994, 2000, 2001). Once the best possible production equation forms are determined with the 10 years of data, the fitted equations will be recreated using only the four years in which wage premium can be included as an additional input factor.

4. Methodology

This study will test efficiency wage by empirically fitting production functions to the production data. This approach has been used at the industry level by Huang *et al.* (1998), Liu and Sakamoto (2005) and Levin (1992). The data is structured as panel data with 20 production lines across four plants over a 10 year period. Using the fitted production functions it can be determined if wage premium has a positive and significant impact on production output.

According to Cappelli and Chauvin (1991, p.769) the most widely used and discussed efficiency wage model is the shirking model which relates wage to effort (Stiglitz and Shapiro, 1984). This is the model that will be tested econometrically in this study. The other models, the turnover model (Salop, 1979) and the loyalty model (Akerlof, 1982) relate heavily to corporate culture and would require qualitative survey data to be tested. However, any versions of the efficiency wage model that relate wage to effort are covered in this study.

This study will avoid the issue of directly measuring effort by looking instead at output.

$$\text{if Output} = f(e) \quad (1)$$

$$\text{and Effort} = E(w) \quad (2)$$

$$\text{then Output} = f(E(w)) \quad (3)$$

It is assumed that throughout the relevant range that the first derivative of both $f(e)$ and $E(w)$ is positive, giving output a monotonic and positive relationship with wage. As a result wage premium's impact on output can be measured directly if all other variables can be controlled.

In this case control will be afforded because the various production lines used are substantially similar.¹ The lines are owned and operated by the same company, with the same manufacturing philosophy and policy, the same management approach, with the same technology and making essentially the same confectionary products. This will allow a comparison of communal labour effort from line to line based on output while wage premium varies. The key measures are both static and dynamic tests as wage premiums vary significantly between lines and over time. Because of the direct production information for similar lines across multiple geographies, a mathematical production function can be built and a tested for the impact of wage premiums on productivity.

The steps in this test will involve first choosing an appropriate production function and then testing if wage premiums play a role in the chosen production functions. This modelling approach is very similar to that conducted by Huang *et al.* (1998) and Liu and Sakamoto, (2005). A production function should be chosen first to ensure that the processes of the production line are appropriately represented in real terms (non-currency values). This will assure that the production function, which may or may not be a good fit when the wage premiums are included, is an appropriate model.

5. Empirical production function

A production function must be selected that provides a reasonable explanation of labour's role in the output process so that the theories around wage, effort and output can be tested. Given a production function, the role of labour can be defined mathematically with a marginal product of labour, a technical rate of substitution and the elasticity of substitution. The selection of the function will be accomplished using a two-step process.

- Step 1: Pick functional forms that logically match the design characteristics of the production lines being tested.
- Step 2: Run regressions of the various logical models to see which ones provide reasonable empirical fits.

The judgment of functional fit is usually accomplished by measuring residual errors as either root mean squared errors or mean absolute percentage errors (Wilson, 2009). In addition the coefficients will be measured for significance and the overall formula for reasonability.

¹ A method also employed by Cappelli and Chauvin in their 1991 study.

Step one - logical match

The various functional forms for production functions have different characteristics built into the mathematics. These would include the inputs coming in fixed or variable proportion and being either complements or substitutes. The functional form would also include the returns to scale being limited to a single form or having the ability to change from diminishing returns to increasing returns within the same function. The features of difference would also include how technology and scale are applied to the process. For a more complete discussion of the features of various production functions refer to Chambers' *Applied Production Analysis* (1988). The features of the production lines in this study would include:

1. having variable proportions of inputs possible and
2. the inputs can act as either substitutes or complements and
3. a single return to scale (approximately constant) would be used through the entire production function.

Given the above, the leontief and additive production forms can be eliminated from consideration. That leaves the Cobb-Douglas, constant elasticity and translog formats, which can fit the required logical constructs.

$$\text{Cobb-Douglas} \quad \text{Output} = B_0 * K^{B_1} * L^{B_2} \quad (4)$$

$$\text{Constant Elasticity} \quad \text{Output} = B_0 * (B_1 * K^{B_2} + (1-B_1) * L^{B_2})^{B_3/B_2} \quad (5)$$

$$\text{Translog} \quad \ln(\text{Output}) = B_0 + B_1 * \ln K + B_2 * \ln L + B_3 * \ln^2 K + B_4 * \ln^2 L + B_5 * \ln K * \ln L \quad (6)$$

The Cobb-Douglas and constant elasticity forms are actually restrictions of the more general translog functional form which does not assume constant elasticity or returns to scale. The translog form permits the elasticity of substitution between inputs to vary. Also the elasticity of scale can vary with output and factor proportions permitting the long run average cost curve to take the traditional U shape. The Cobb-Douglas is perhaps the most commonly used production functional form. However, it is one of the most restrictive. The Cobb-Douglas form forces the function to have a constant elasticity of substitution of one. And the constant elasticity form does not allow the elasticity to vary between inputs. Because of the parametric approaches used in the empirical fit each form is solved independently.

Step two - empirical fit

The data are all in physical measures with no dollar values. No production lines have been eliminated for the overall fit even though some of them have high estimated errors. Classical linear regression and nonlinear techniques will give slopes and intercepts that fit the data as a whole. However, to capture the different relationships for each technology, a panel data structure with fixed effects is utilized. The fixed effect model for the Cobb-Douglas form is as follows:

$$\ln(\text{Volume})_{it} = \ln(\text{Technology}) + \alpha * \ln(\text{Capital})_{it} + \beta * \ln(\text{Labor})_{it} + C_i + \epsilon_{it} \quad (7)$$

Where i represent the fixed effect group and t represents time. Here C_i represents the impact of the specific technology group used across plants (chocolate, shell coating, bar lines etc.) and allows for a different intercept for each technology group. A further test can be conducted to determine if the fixed effect variables add significance to the resulting equation.

Another approach which will be used in the fitting process is to fit all the functions in a natural logarithmic form. Because the Cobb-Douglas and translog forms will be solved using logarithmic formats it is important that all of the equations do so. The estimates, residuals and the R squared results cannot be compared if some equations have the dependent variables as a natural log transformation and others do not. Wooldridge (2009) explains the importance of this by showing that the exponent of the predicted log $\hat{Y}$ will systematically underestimate the expected value of Y .

The fitted functions, the adjusted R squared and the t statistics for each coefficient are shown in table 2. The resulting fitted equations all provide good fits and a reasonable estimation of the coefficients as determined by the R squared, the t statistics and logic (size and signs of coefficients).

Table 2 - Fitted production functions

	<i>Fitted Function</i>	<i>R</i> ²	<i>t Statistics (from left to right)</i>					
Cobb-D	$=.226 * K^{.698} * L^{.457}$	90	8.15	9.04	4.18			
CES	$=.16 * (.91K^{1.141} + .088 * L^{1.144})^{1.321/1.141}$	99	18.25	32.2	4.95	4.91		
Translog	$\ln(\text{Output}) = -1.247 + 1.669 * \ln K - .537 * \ln L + .0227 * \ln^2 K + .206 * \ln^2 L - .233 * \ln K * \ln L$	92	2.05	4.16	2.95	.38	4.95	2.83

Discussion of results

The fitted exponents for Cobb-Douglas add up close to one which implies constant returns to scale. This conclusion is confirmed by the following test: $F(1, 154) = 0.58$ Prob = 0.4492 and as a result the hypothesis that the coefficients equal one cannot be rejected. The test for the significance of the fixed effects factors shows: $F(22, 174) = 9.4$ Prob = 0.0000. Clearly the fixed effects add explanatory power to the model.

In the constant elasticity of substitution function the coefficient B_2 used to calculate the constant elasticity of substitution factor is 1.141. This would imply an elasticity of substitution of:

$$\frac{1}{1-1.141} = -7.1$$

A negative elasticity of substitution is meaningless and results from the fact that this equation assumes concavity in the function and in this case the function is convex (Mos-Colell *et al.*, 1995). Because this factor is close to one (1.141), the result is an almost flat plane in three dimensional production space. If B_3 were equal to 1 then the function would have constant returns to scale. Because B_3 is more than 1 (1.32) there are increasing returns to scale.

The solution for the fitted translog form is significant as shown by the F test (5,171) that all coefficients are equal to zero gives a probability of .0000. In order to have constant returns to scale the conditions outlined in table 3 must be met (Bairam, 1998):

Table 3 - Translog constant returns to scale

<i>Condition</i>	<i>Results</i>	<i>F Test probability</i>
$B_1 + B_2 = 1$	$1.669 - .5378 = 1.13$ is close not equal to 1	73.3%
$-B_3 = B_1$	$-.0227 =$ is not equal to 1.669	0.00%
$-B_4 = B_2$	$-.206 =$ is not equal to $-.5378$	2.97%

This fit does not yield constant returns to scale as shown by the results and F test probability in table 3. Also, this fit has an unreasonable area of the curve where if capital is very high and labour is very low the marginal product of labour will be negative. While this does not happen normally in our current data set, it is not a particularly meaningful portion of the curve.

A comparison of the three production function models

As previously identified the key way to judge the goodness of fit is to measure the size of the residual errors resulting from the estimations. The two most common methods are to use the root mean square error and the mean absolute per cent error. These comparisons are shown in table 4.

Table 4 - A comparison of the goodness of fit

<i>METHOD</i>	<i>Cobb-Douglas</i>	<i>Constant Elasticity</i>	<i>Trans Log</i>
RMSE	.284	.020	.313
MAPE	9%	7%	10%

Under both of these measures the constant elasticity function shows a better empirical fit. However, because as demonstrated, it has some minor logical flaws, the other production functional forms which provide very good fits should not be summarily dismissed.

Using a midpoint of the data range (50 for capital and 150 for labour) the functions would estimate the following output shown in table 5. These are incredibly consistent results and are reflective of the extremely good fits across the various estimated functional forms.

Table 5 - Comparison of outputs

<i>METHOD</i>	<i>Cobb-Douglas</i>	<i>Constant Elasticity</i>	<i>Trans Log</i>
<i>Volume Output</i>	34	34	35

While one might argue that one of the forms is superior to the other based on either the consistency with the engineering design of the lines, or the goodness of fit, it is clear that they all represent very good fits with the data as is shown in table 6.

Table 6 - Comparison of R² and MAPE

METHOD	Cobb-Douglas	Constant Elasticity	Trans Log
R ²	90%	99%	92%
MAPE	9%	7%	10%

There is no need to eliminate forms at this time. The purpose of the empirical fitting is to ensure that we have reasonable forms on which to test the impact of wage premiums. We can use all these forms to test the efficiency wage hypothesis and if there are consistent results in all circumstances it will serve to strengthen the findings.

A graphical representation of each of the fitted production functions is shown in figures 3-5. These shapes show a generally flat area for the middle portion of the curve where most of the data exists, but show significant differences around the edges of the curves.

Figure 3 - Resulting Cobb-Douglas functional form

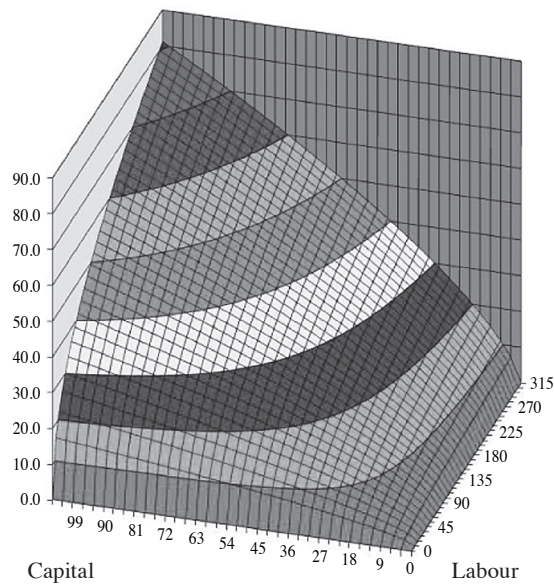


Figure 4 - Resulting constant elasticity functional

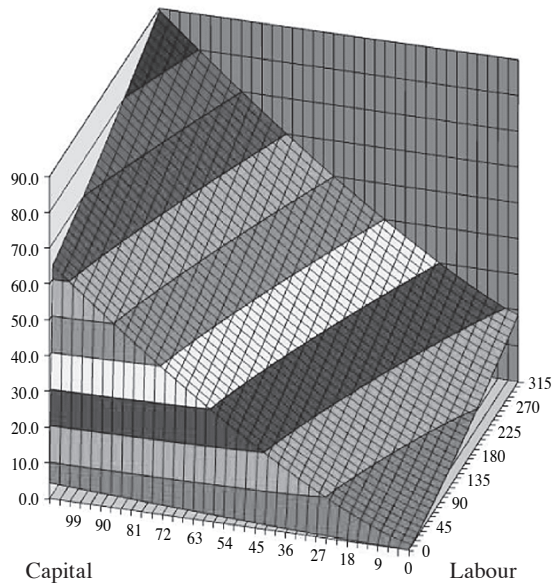
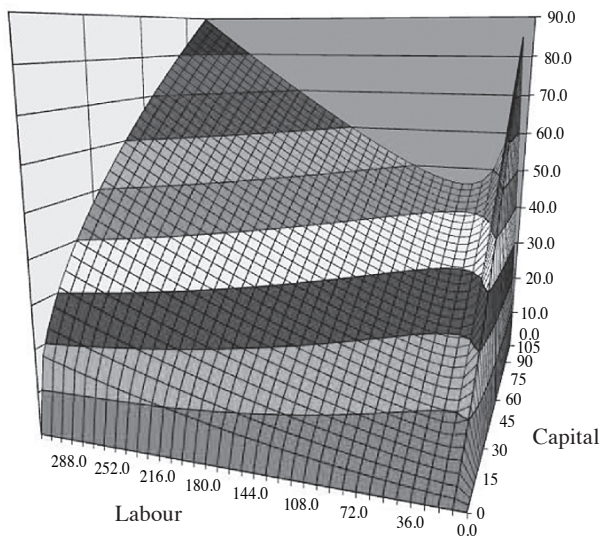


Figure 5 - Resulting translog production functional form



6. Testing the wage premium

Payroll data

During the study period the subject firm placed all non-exempt jobs within a pay zone. In this study these zones are called high, medium and low. Employees were paid at one of the several pay steps within the zone for the job they had. Over time an employee could move up the steps within their zone as long as they were performing well. Once an employee reached the top step in the zone they would receive no more pay increases unless they were promoted to a different job at a higher zone, or the company changed the pay scale within the zone. Over time most employees working within the same job ended up being paid at the top of the zone and were paid the same amount. Payroll data is available by associate by plant for 1993, 1994, 2000 and 2001.

Clearly a total rewards package would include non-pay related benefits. Benefits have been shown to be important factors in motivation and moral. The remuneration practices at the plants in this study included very generous health, vacation and retirement packages. However, the comparison data from the U.S. Bureau of Labor statistics hourly pay surveys does not include benefits, vacation or bonuses and so a comparison limited to wage in a necessary starting point. If it were possible to properly include non-pay related benefits they would increase any calculation of pay premium. Importantly the non-pay related benefits remained consistent at all four plants throughout the scope of this study.

While paying premium pay was a stated company policy, it was allowed to vary over time and across sites, as local plant managers were able to operate autonomously as they balanced their internal and external environment. A premium pay calculation rather than total or cost of living standard comparison must be made in order to decompose pay into observable human capital and excess pay which is the cost of job change. Many previous studies have not been able to do this and used a single pay number. 'Cappelli and Chauvin, Wadhawani and Wall and Levine all used a single observed relative wage as their measure of the efficiency wage, which confuses human capital with wage premia' (Huang *et al.*, 1996, p.126).

Calculating the wage premium

The wage premium is calculated as an average percentage of pay for the subject firm's employees over the average pay for similar jobs in the local market. This included the appropriate weighting of high, medium and low zoned jobs at each plant.

The Bureau of Labor Statistics (BLS) reports of interest to this research are the hourly pay by job type within a market. The data needed for the 1990s are nothing new to the BLS as it is a continuation of surveys that have been completed for many years. In 1991 and 1992 the BLS prepared what they call Area Wage Surveys. The name was change in 1992 to Occupational Wage Survey. These were completed every year for 120 markets (geographies) and show, by job classifications the hours worked, number of employees and average and medium pay. The data were compiled by the BLS through surveying establishments with over 50 employees and reaching a sample size of over 50 per cent of the market. The data were then projected by the BLS to represent all establishments in the area.

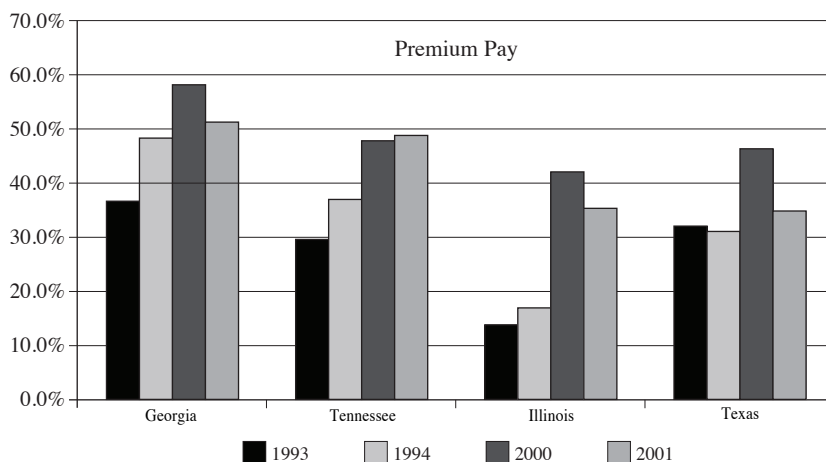
Specific market occupations need to be selected and weighted together to provide an appropriate match for the subject firm's average wage. This is done by matching jobs for each of the high pay, medium pay and low pay groupings. The criteria used to pick BLS occupations to match to the subject firm's jobs were:

1. The occupation was consistently available across the years,
2. The occupation was consistently available across the geographic markets,
3. The data included a large number of survey participants so that the firm data could not drive the numbers, and
4. The occupation was viewed as a reasonable market match with the subject firm's jobs by the researcher.

The occupations matched to the firms high pay zone includes, electrical technicians, and machinery maintenance mechanics, team leaders and quality technicians. The middle pay group would be matched to experienced machine operators and the lower group would include newer associates who have not yet learned key firm specific skills such as hand packaging, material movement and general labour.

The calculated wage premiums show a premium level starting at a range of 16 to 39 per cent and increasing to a range of 41 to 53 per cent. These premiums are shown by plant in figure 6.

Figure 6 - Wage premiums by plant



Testing the wage premiums in the production functions

All three production models can now be run with wage premiums included as an additional factor input. This will determine the impact of wage premium on production as outlined in equation 3 from the methodology section of this paper. This approach is also consistent with the referenced studies of Liu and Sakamoto (2005) and Huang *et al.* (1996) which utilize production functions including wage to test efficiency wage.

The models will then be assessed in two ways. The first is for overall enhancement: Does the model including wage premiums have better accuracy and fit? The second is for individual assessment of the wage premium itself: Does the coefficient of the premium make logical sense and is it statistically significant? These two assessments will allow us to conclude that wage premiums do or do not help us explain production output.

The best fitting production models were selected based on the full 10 years of data available in order to insure the best possible fit. However, because wage data were only available for four years, the three accepted models from the first fitting will need to be rerun and limited to the year's corresponding to available wage data. This will significantly reduce the number of observations.² However, there will still be 80 observations for each of the tests, enough to reasonably calculate comparisons.

The same model structure determined most appropriate from the full 10 year fitting will be incorporated into the new base models. As before, all models will be run in logarithmic format and fixed effects will be utilised.

The descriptive statistics for the data which will be used in this regression test are shown in table 7. These are slightly different from the statistics shown in table 1 because they only include the four years 1993, 1994, 2000 and 2001. However, the means are similar and while standard deviation increases the measures for Kurtosis and Skewness are still roughly within two standard deviations and as a result are accepted as normal.

Table 7 - Descriptive statistics for 4 years with wage premiums

	<i>Volume</i>	<i>SOC</i>	<i>Headcount</i>	<i>Premium</i>
Mean	27.1	38.5	117.7	1.39
Standard Error	2.0	3.0	6.7	0.01
Median	28.1	32.1	128.0	1.39
Mode	3.4	14.0	142.0	1.50
Standard Deviation	18.3	27.0	60.0	0.12
Kurtosis	-0.3	-0.1	-0.6	-0.55
Skewness	0.5	0.8	0.0	-0.39
Range	72.8	99.4	241.0	0.44
Minimum	0.7	2.9	8.0	1.16
Maximum	73.5	102.3	249.0	1.60
Count	80	80	80	80

The results of fitting the production functions with a wage premium are shown in table 8. A comparison with the wage premium and without is found in table 9, which shows the R squared, the overall F test (or standard error for the non-liner CES) and the t statistics for each coefficient.

² An additional model maintaining the full 10 years of production data with straight lined estimates for missing wage premiums has been run with consistent results.

Table 8 - Fitted equations

Cobb-Douglas	Output = $t * K^{.916} * L^{.491} * WP^{-.146}$	(8)
CES	$\ln(\text{Output}) = \ln(-1.8) + \frac{1.34}{.928} * \ln(.76 * K^{.928} + .14 * WP^{.928} + .1 * L^{.928})$	(9)
Translog	$\ln(\text{Output}) = 2.396 - .166 * \ln(K) - .604 * \ln(L) + 1.223 * \ln(WP) + .237 * \ln^2(K) + .194 * \ln^2(L) + .409 * \ln^2(WP) - .166 * \ln(K) \times \ln(L) - .0028 * \ln(K) * \ln(WP) - .04 * \ln(L) * \ln(WP)$	(10)

Table 9 - Fitted results with and without the wage premium

	Cobb-Douglas		CES		Translog	
	Base	W/Prem	Base	w/Prem	Base	w/Prem
R^2	89%	91%	99.40	99.39	89.69	86.91
F	20.66	14.24	-7.6229	-7.6284	10.91	3.27
$t1$	4.05	4.02	10.74	.765	.57	.47
$t2$	5.26	4.69	2.62	2.59	-1.58	-1.13
$t3$		1.11	16.33	.53	.22	-.06
$t4$			2.64	2.63	2.05	1.74
$t5$				2.63	1.31	.73
$t6$					.89	-.84
$t7$						1.03
$t8$						1.47
$t9$						-.01
$t10$						-.21

Cobb-Douglas test

From an overall perspective the model is not improved by adding wage premium. The reduction in the overall F test shows that there is a slightly higher chance that the model is not significant. However from the individual assessment of the wage premium we learn that most. The resulting negative coefficient (-.146) for wage premium is counter intuitive. It implies that as wage premium goes up output is reduced. The coefficient is also not significantly different from zero.

Constant elasticity of substitution test

The constant elasticity model also requires a slightly different form with three factor inputs. The model including wage premium is expressed as follows:

$$\ln(\text{Output}) = \ln(B0) + \frac{B3}{B2} * \ln(B1 * K^{B2} + B4 * WP^{B2} + (1 - B1 - B4) * L^{B2}) \quad (11)$$

The fit of the CES models with and without wage premium are almost identical. The very minor changes in R squared and residual deviation imply a model moving in the wrong direction. The coefficients do not show much change but the significance of the constant and weight for capital take a steep drop. The significance of the scale and rho show only the smallest incremental drop, but again imply a model moving in the wrong direction.

Translog test

The translog model including wage premiums requires a three-factor model with additional cross terms. From an overall perspective the model is not improved, with slight negative adjustments to the R squared and the overall F Test. And while there is no single coefficient for premium wage, the coefficients are all now statistically insignificant. An F test on the four coefficients which contain wage premium gives $F(4,48) = .64$ with a probability of .637. As a result we conclude that there is no statistical significance to including the wage premium into the equation.

From the results of the Cobb-Douglas, CES and translog model comparisons we cannot conclude that wage premiums significantly influence output levels as the efficiency wage hypothesis proposes.

7. Conclusions

Given the consistent results across all three tests we reach the conclusion that this specific data sample does not provide any support for the idea that premium wages increase effort which increases output.

Possible reasons for these results

Given the popular support for the efficiency wage argument and the bulk of articles supporting the hypothesis it is a small surprise that we find absolutely no evidence of wage premiums' impact on production output. While this research was focused on the test itself, ideas about the reasons for this lack of significance can be proposed.

One must first consider that, at least in this case, the efficiency wage hypothesis is simply not valid. A corollary of this possibility is that the efficiency wage effect is small enough that it can be overpowered by cultural or institutional specific factors. This possibility has been supported in comments from Cappelli and Chauvin (1991, p.771).

Second, limited data or errors in the data may prevent a true result. Given that the data were sourced directly from payroll and operational reporting systems the data is believed to be as robust as business performance data can be and are more reliable than the overall averages and macro-data used in the other referenced studies of efficiency wage. The limited data extends across four plants each with multiple production lines over 10 years. The specific limits to the data are fully incorporated in the degrees of freedom used in the statistical tests of significance. The type I error that a population characteristic which actually exists will not be found is small (for every test less than five per cent).

Third, even if the efficiency wage hypothesis is valid when an employee is hired, over time, in a team production environment the impact may diminish. This may explain why no wage premium impact on output was detected in this study. Efficiency wage may have diminishing effects over time and eventually be replaced with a sense of entitlement. When an employee first starts she accepts the job understanding a wage premium in comparison to her alternative options. The wage premium can attract, motivate and retain per the efficiency wage hypothesis. In a team environment production output per associate is not visible, however, each manager and employee will form a subjective opinion of each team member's contribution. After many years

of working side by side with other employees who make the same wage, she will notice that some put forth less effort and are rewarded the same. As a result she will feel entitled to the wage given that she feels she puts forth an average effort. At the locations in the case study there are many long-time employees and this would be an interesting employee attitude to test for and understand.

Implications and recommendations

As shown in this case there is not always a connection between wage premium and output, therefore, managers should be careful about using wage premiums to increase effort and employee production.

Because we can conclude that the most popular forms of the efficiency wage hypothesis is not a universal maxim, it may not be the best answer to the observed labour market contradictions with neoclassical theory. There are other theories particularly within the areas of institutional thought and power relationships that do not require appendages to explain unemployment, lack of employee movement and wage dispersion. These theories related to wage and performance should be given an additional look by the main stream.

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