An Economic Model of Training in an Industrial Setting

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Within the economics of education literature there are several examples of attempts to model the behavior of students and instructors in a microeconomic framework. These attempts have focused, however, on the student's behavior toward learning in a general educational setting—a setting in which the student is assumed to desire learning for the satisfaction it brings and the future income that may be obtained upon completion of the given course of study (Becker, 1982). Similarly, the development and implementation strategies treated in literature are typically those of an academic setting (Becker, 1979). The economics of training within the industrial setting has received little attention. Yet well over $40,000,000,000 is spent annually by private, U.S. Corporations on the direct training of their employees (Carnevale, 1982).

This industrial training, unlike general education, tends to be job specific and particular to a given firm or industry. Benefits of training accrue primarily to the firm and only indirectly to the individual being trained. Thus, economic models developed for general education cannot be directly transferred to industrial training situation.

This article presents a microeconomic model of training and it's development for a profit maximizing firm. In this model we are particularly concerned with the impact of training on the production process—the fundamental activity of the firm. We argue that since training is not part of the direct production process itself (training functions may be performed by staff positions and not line positions), its contribution to the production process must be to augment or enhance the physical and human capital that is used in the production process. In short, trainers seek to make workers more productive, but are not part of the production process themselves.

When an organization undertakes a program of instructional development and training, such efforts constitute a drain on the firm's resources. The *cost* of instructional development and program implementation in the training period is the production lost by diverting resources from direct production. The *benefit* of instructional development and training program implementation is the expected gain in productivity following the training period. At the time of initiating the instructional effort this gain is a probablistic gain, the magnitude of which cannot be known with certainty. It is management's job to assess the degree to which the resources diverted from current production actually do bring about greater future production. It is our purpose to illuminate some of the underlying economic principles which impact this decision.

Microeconomic Theory of Resource Employment

Our first step is to develop an overview of the economic theory of resource employment (Henderson and Quandt, 1980). Our model is mathematical, as most economic models are, and may be new ground for some readers. We have tried to highlight the key points and relate them closely to training.

In the classic microeconomic view, a firm is seen as a profit maximizer. As it is looked at in many economic models, the firm seeks to maximize profits in a competitive product and factor market. All wages, rents and prices are specified in markets; the firm attempts to select the optimum mix of labor and capital to maximize its total revenue minus its total cost. Algebraically, the firm attempts to maximize this function:

(1) The Profit Objective Function

$$g(L, K) - wL - rK,$$

where L (Labor) is the quantity of labor time employed, and K (Capital) is the quantity of capital employed in the firm's production process of value g. A unit of labor costs the form w, and a unit of capital costs r.

Figure 1 shows graphically the typical production process. As the firm begins to employ labor, total revenue (g) rises rapidly. But with a fixed capital stock, a point is soon reached at which total revenue begins to rise less rapidly as more and more labor is added. In the short run, where capital is fixed and the firm is restricted to a given technology in its production process, the firm attempts to select the quantity of labor that maximizes profits. As long as the additional revenue from hiring one more unitof labor (the marginal revenue of labor), which is given by the partial derivative of g with respect to L and is denoted by g_L) is greater than the added cost of that labor (the marginal cost of labor, g_L, exceeds the wage rate, w) the firm will increase its profits by hiring more people. The marginal revenue and the marginal cost of labor will beequal at some labor employment level L_x, where the slope of the total revenue curve is equal to w (the marginal revenue of labor equals its marginal cost, i.e., $g_L = w$).

A comparison of Figures 1 and 2 shows that a rise in the marginal cost of labor results in a decrease in the profit maximizing level of labor to be employed. A rise in w (as occurs in moving from Figure 1 to Figure 2) implies that the firm will raise the marginal revenue attributed to labor by cutting back on the amount of labor employed, i.e., $L_z < L_x$.

Total revenue and profits will be lower at L_z than at L_x, but given the higher wage rate, the reduced labor employment level represented by L_z is the best the firm can achieve with a fixed capital stock and given technology. The practical point is this: For any given firm with fixed capital and fixed technology, there is some level of employment at which the profitability of the firm is greatest. The firm has neither too many nor too few employees.

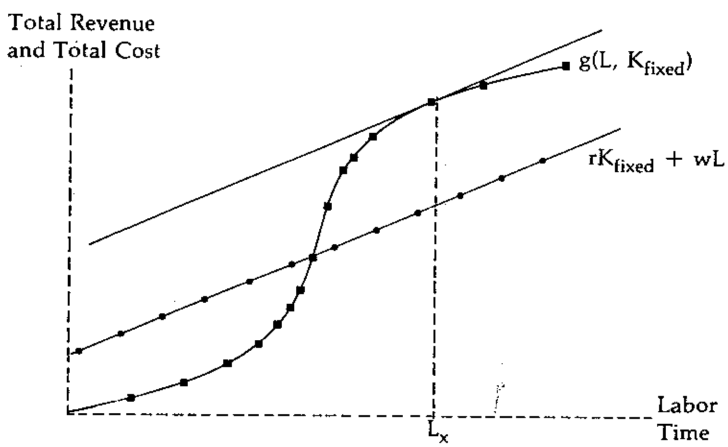

Figure 1. Profit maximization with low wage rate.

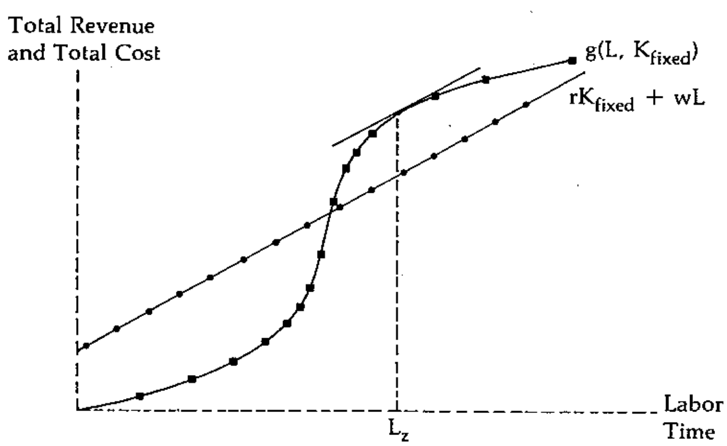

Figure 2. Profit maximization with high wage rate.

Over a longer period of time, a capital stock *is* variable, and the firm is not restricted to the world depicted in Figures 1 and 2. In the long run, the theoretical firm will attempt to select profit maximizing levels of output, labor and capital in a more complex way. Mathematically, it will differentiate the objective function (1) with respect to both L and K. Setting these first derivatives equal to zero yields the profit maximizing level of capital and labor employment:

(2) First Order Conditions for Labor and Capital

$$g_L - w = 0 \text{ and } g_K - r = 0$$

These functions show that the higher w (wages) and the lower r (rents, or cost of capital), the less labor and more capital the firm will employ. The effect of a rise in the wage rate can be assessed in this scheme by differentiating the first order conditions (2) with respepct to w. In matrix notation this differentiation is given by:

(3) Second Order Conditions and Changing Labor Costs

$$\begin{bmatrix} g_{LL} & g_{LK} \\ g_{KL} & g_{kk} \end{bmatrix} \begin{bmatrix} \delta L \\ \delta K \end{bmatrix} = \begin{bmatrix} \delta w \\ 0 \end{bmatrix}$$

Solving the second order conditions (3) for the change in labor and capital resulting from a rise in w yields:

(4) Slope of the Factor Demand Curves

$\delta L/\delta w = g_{LL}/(g_{LL}g_{KK} - g_{KL}g_{LK})$ for labor, and

$\delta K/\delta w = -g_{KL}/(g_{LL}g_{KK} - g_{KL}g_{LK})$ for capital

The first observation which can be drawn from these equations (4) is the same as the one demonstrated in Figure 1. At the higher end of the production process function (g) where total revenue is largest, the rate of increase in marginal revenue decreases (total revenue rises at a decreasing rate as L is increased, i.e., $g_{LL} < 0$). This is one example of what is commonly called the law of diminishing marginal returns. In addition, the mathematics of profit maximization require that the determinant of the Hessian matrix in the second order condititons (3) be posititve. The Hessian matrix is the left-most box of equation (3); the requirement about determinants means that the value of the denominator on the right-hand side of equation (4), $(g_{LL}g_{KK} - g_{KL}g_{LK})$, must be positive. But in order for that to be true, both g_{KK} and g_{LL} must be negative.

The key profit in all of this is not a mathematical one, but a very practical one indeed. The slope of the Labor demand curve, the first equation in (4), shows that an increase in wages implies reductions in labor employed to optimize total revenue, even when capital is variable. Unfortunately, the capital effect of an increase in wages cannot be determined without an additional assumption because the crosspartials g_{KL} and g_{LK} are signwise unknown.

Some other important observations can be drawn from this elementary model of the firm. If capital and labor are complements in production, then an increase in labor increases the marginal revenue product of of capital, i.e., $g_{KL} = g_{LK} > 0$. Labor is required; labor knows how to work with current capital. Suppose, for example, that every person working on an assembly line were given an air wrench to replace a ratchet wrench. The marginal product of labor would increase purely in response to an increase in capital. In this case a rise in labor cost (w) would still result in a fall in total labor required (L), but the marginal product of capital also falls as labor is reduced ($g_{KL} > 0$). In response to this decrease, the firm cuts back on capital employed as well as labor to get capital's marginal revenue product back up to equal the marginal cost of capital (r), i.e., $\delta k/\delta w < 0$. So the whole firm retrenches to make the most money.

But if capital and labor are substitutes in production, i.e., $g_{KL} = g_{LK} < 0$, something very different occurs. Suppose, for example, that welding robots were introduced on the assembly line. The marginal product of labor would decrease in response to this increase in capital. Now, a rise in labor cost (w)cost(w) results in a fall in labor employed (L), but the marginal revenue product of capital rises. The firm increases its use of capital to get its marginal product back *down* to the marginal cost of capital (r) thus $\delta k/\delta w > 0$.

Regardless of whether capital and labor are complements or substitutes in production, any rise in the marginal cost of either labor or capital will make the firm worse off given its current technology as represented by the production function g(L, K). As long as the production process (g) is fixed, the firm will cut back production when its marginal costs rise. The only way the firm can return to its old profit level or increase it is to change the production process itself by improving the technology it uses.

The Role of Training: A Microeconomic Theory

It is precisely for the implementation of new technologies that the need for firm-specific training arises. If the firm is willing to gamble that better technology can be brought on line, then it may be necessary for the firm to divert some of its resources to the training of its labor force so that it can function under a new technology. Unlike what occurs in capital deepening, where the firm just adds more robots or more wrenches to the current production process, a change in technology associated with a change in production process requires that labor be trained in the new approach. For example, the acquisition of word processing equipment cannot be described as either a substitute or complement for labor in a particular office. The mere acquisition of the equipment in no way implies that the marginal product of labor for the existing labor force is increased or decreased. Changes in the production process accomplished not only through the additional capital but through training of the work force, underlie increases in the firm's productivity. Because of its direct tie to productivity, training must be considered in any economic view of the production process. But not only does training play a central role in the technological change of the firm's production process. Training implies opportunity costs of two kinds, since training costs money and takes time.

Unfortunately, the simple model introduced above is not sophisticated enough to capture the changes in the production function we are now interested in considering. Nor does it permit us to examine how training indirectly enters the production process. We will now proceed to develop a model which does deal with these considerations.

If the firm is willing to gamble that better technology can be brought on line, then it may be necessary for the firm to divert some of its resources to the training of its labor force so that it can function under a new technology.

The Two-Period Model

The in-house training of labor cannot be viewed as entering the production function of a firm directly, since training does not enhance productivity immediately. Management hopes, rather, that after training is completed, the productivity of labor will increase. But during the period in which the training occurs, the firm faces additional costs with no immediate return. The firm must take part of its labor force out of productive activity to attend training; it must hire trainers and training developers; it must divert capital from production to training. Besides, since the effects of education and training are imprecise, the impact of training on productivity cannot be assured. With the best of intentions, the firm may invest substantial funds on training, get high participant reviews, but obtain little if anything in increased productivity—its real objective.

So training represents a complex economic environment. If we are to move beyond the textbook idea of capital deepening we will need a model in which the production function itself changes. In economic terms, we will show that training involves large costs which can yield maximum benefit to the profit maximizing firm only if the production process itself changes as labor learns to work with new capital.

The model. Assume, first that there are two periods described in the model: In the first period training takes place; in the second period there is no training. In our model all training is specific to the firm. We do not address the problem of trained employees leaving the firm in search of higher wages. We assume that instructional developers and program implementers are employed only in the first period. We assume, furthermore, that all decisions in the firm are risk neutral; that is, individuals concern themselves with expected gains and not with the variability of those gains.

Activity in the model. While developing a training program, the decision maker recognizes that some labor and capital may have to be diverted from the current production process. Let k be the amount of capital that is diverted to training from the firm's capital stock of K; thus, (K-k) is the amount of capital available for current production. Similarly, let t be the amount of labor time diverted from current production, where l is the total amount of labor time hired in the first period. Thus, (l-t) is the amount of labor time employed in current production. The first period production function, or total revenue function, is now given:

(5) Total Revenue Function During Training

$$g(l\text{-}t,\ K\text{-}k)$$

Let the unit cost or *wage* of labor be represented by w_l. The unit cost of capital will be r—just as in the earlier model. Trainers are hired for an employment time e. Their unit cost is valued at a wage rate of w_e. The firm's first period profit function is now:

(6) Profit Function During Training

$g(l\text{-}t, K\text{-}k) - w_l l - w_e e - rK$

The cost of development and training is given by the lost production resulting from the fact that t hours are spent by labor in training, at a cost of $w_l t$; k amount of capital is used in that training, at a cost of rk, and development and training expertise costs $w_e e$.

In the second period, subsequent to training, the firm expects to achieve the fruits of its expenditures on training. In particular, it hopes to operate under a new technology that is better (i.e., more profitable) than the old. This technology is represented by the new production process:

(7) New Production Process

$g'(L, K)$

where L represents the augmented *L*abor hours used in the second time period in a production process described by g' (Note 2).

But in reality, g' may not be realized. There is a chance that the firm can never do better than the old production process described by g. Let P represent the probability that the firm does actually realize the production process g' in the second period, and represent the probability that it continues with the existing output of the old production process by (1 - P). The probability of realizing the new technology is a function of the amount of expert time devoted to development, e, the amount of time spent in training, t, and the amount of capital used in development and training, k. In addition, let the wage rate in the second period be W_L, which may not be equal to the wage rate in the first period. The expected profit in the second period is now given by:

(8) Expected Profit After Training

$$\frac{P(t,e,k)\,G(L,K) + g(L,K) - W_L L - rK}{(1 + r)}$$

G, in this equation, is the change in the production process from the old one(g) to the new one (g') (i.e., $G(L,K) = g'(L,K) - g(L,K)$.

Given a two period horizon, we can assume that the firm attempts to maximize its profits described in equations (6) and (8) with respect to the parameters of the model: l, L, K, t, e, and k (Note 3). The first order conditions for such maximization are given by:

First Order Condition for Profit Maximization with Respect to:

Labor

(9) $g_1 - w_l = 0$

(10) $g_L + PG_L - W_L = 0$

Capital

(11) $g_2 - r + (g_K + PG_K - r)/(1 + r) = 0$

Training

(12) $-g_1 + P_t G/(1 + r) = 0$

(13) $-w_e + P_e G/(1 + r) = 0$

(14) $-g_2 + P_k G/(1 + r) = 0$

where $g_1 = \partial g/\partial(l - t)$, and $g_2 = \partial g/\partial(K - k)$ and where all other partial derivatives are designated by letter subscripts.

Observations from the Model

Conceptually, equations (9) and (10) define the optimum employment of labor time in direct production in the first period, l - t, and the second period, L. Labor will be employed in direct production in the first period up to the point where its marginal product equals its wage rate, just as in the first model. But to the extent that labor time is diverted to training, more labor time will be employed than would be the case if training were not undertaken.

In the training period, the training actively itself creates jobs, even though training costs the firm additional money to hire that added labor. But what is particularly noteworthy is that training creates jobs in the second period (subsequent to training) as well. This finding runs directly contrary to the popular notion that you train in order to reduce employment.

One trains to increase profits. In this model, increased profits are achieved not by cutting back on employment, but by increasing it to operate a more efficient production process. This improvement in the production process itself is the source of the increased labor utilization observed in the second period. Unlike simple capital deepening, where the production process (g) does not change, true innovation results in an increase in labor under profit maximization conditions. Thus, as a measurement of the effectiveness of training, one cannot use changes in the labor force. For example, a manager who feels that the introduction of word processing in an office will reduce staff may be confusing his or her goals. The purpose of changing the production process and providing training is to maximize profits. Profits may be maximized by increasing labor employment as production rises. Reducing labor employment may not be associated with profit maximization.

We can demonstrate our point most easily in the economic context of the model by noting the absence of a training effect with no likelihood of improving productivity, (P=0). Without training, the firm would employ labor in the second period to the point that $g_L - W_L = 0$. But to the extent that training actually does produce an expected positive productivity effect (i.e., $P > 0$), then the profit maximizing firm should employ labor in the second period to the point that $PG_L - g_L - W_L = 0$. The added product brought in by PG_L means that the marginal revenue product of labor must be lowered to the point that it equals the wage rate. This is accomplished by employing *more labor*, not less. Recall from the assumption of the model that W_L may be larger than w_l, so that more labor is required with training even if wages increase. Recall too, however, that training is firm specific. Thus, there need be no market pressure to pay higher wages in the second period.

Equation (11) yields the optimum levels of capital that will be employed in the first and second period. Unlike that situation described for labor, where different amounts of labor are employed in the first and second period of the model, capital employed (K) is assumed to be the same in both periods. But like the case of labor, equation (11) demonstrates that to the extent that instructional development and training can be expected to produce a positive effect in the second period, (again, $P > 0$), more capital will be employed by the firm in *both* periods than would be the case if this gain were not expected. The manager's focus must be on profit—not just cost or resource employment.

Equations (12) through (14) describe the profit maximizing conditions regarding the amount of training that the firm can be expected to attempt. In particular, (12) and (14) state that training effects are optimized when the firm diverts labor and capital from direct production to training in the following way: The loss of revenue product from one additional unit taken out of first period production *equals* the present value of the expected gain in revenue production in the second period. It is important here to clearly point out what these conditions do *not* state. One does *not* invest in training to the point that *total* cost of capital and labor equals the *total* expected revenue gain. That level of training is always too high because gains must be discounted since they occur in the future, and because profit maximization is based on marginality.

To make these conditions more meaningful, let us consider the behavior of the manager. Intuitively, a profit maximizing manager will adjust the amount of training given subordinates so that his or her estimate of the present value of the expected marginal benefit of training equals the marginal cost of providing that unit of training now. Poor management decisions will be revealed not by changes in the labor force or capital stock. Nor will the amount of training provided serve as an index of effectiveness. Failure to train adequately will be signalled by unrealized profit.

Conditions for optimizing development. Equation (13) states that the training development expert's time should be employed to the point that the present value of the expected gain in second period *production* from the last hour of the expert's time equals the instructional expert's wage rate. In short, you keep developing until the present value of the expected benefit from doing more development equals the wage rate of the developer.

The amount of time the instructional development expert is employed in the first period is totally dependent on his or her wage rate and on the present value of the expected production increase that his or her efforts will produce in the second period. Unlike labor that is employed in the direct production of the firm's product, for a given capital stock, the employment of the instructional expert will be sensitive to the rate of discount (interest rate) applied to the capital. The higher this rate, the less time an instructional developer will be demanded by the firm, for a given capital and labor stock. On the other hand, the greater the gain that the developer can lead the firm to expect, the greater the demand for the instructional developer's time. One fairly obvious consequence of this condition is that the developer should always address the training need which promises the greatest impact on profits for the firm.

Changes in the Parameters of the Model

From the equations presented so far, one cannot compute the simultaneous effect of multiple changes in labor, capital and the firm's demand for training development. To assess the effect of changes in the wage rate of instructional developers, the wages of laborers or the cost of capital, it is necessary to differentiate the entire equational system described in (9) through (14) with respect to these parameters. Such differentiation, in matrix from yields:

(15) Second Order Equations

$$Hv = y$$

The values of H, v, and y are given in Figure 3, where R denotes (1 - r) for convenience.

The second order conditions for profit maximization require a positive determinant for H, i.e., $|H| > 0$. Letting H_{ij} represent the cofactor of the element in the ith row and jth column of H (where i and j run from 1 through 6), then by the second order conditions the sign of H_{ii}, which is the cofactor of a diagonal element is known to be negative. The sign of H_{ij}, $i \neq j$, the cofactor of an element *off* the diagonal, is not known. The effect on l, L, K, t, e, and k of a change in w_l, w_L, w_e and r can now be analyzed by solving (15).

Effects of Changes in the Wage Rate of Labor

The effect on the demand for labor of an increase in the wage rate of labor in the first or second period is given by:

Slope of the Demand Curve for Labor

$$(16)\quad \delta l / \delta w_l = H_{11}/|H|$$

$$(17)\quad \delta L / \delta W_L = H_{22}/|H|$$

Since $H_{11} < 0$, $H_{22} < 0$, and $|H| > 0$, then $\delta l/\delta w_l < 0$ and $\delta L/\delta W_L < 0$. An increase in the first or second period wage rate of labor will cause the demand for labor in the respective period to fall. Correspondingly, a decrease in wage will cause demand to rise. The effect on the demand for the other variables of production is not known, however, since H_{ij} is signwise not determined by the second order conditions. For instance, the change in demand for an instructional development expert's time is given by:

(18) Shift of the Demand Curve for Instructional Development Due to the Wage Rate Change

$$\delta e / \delta w_l = H_{15}/|H|$$

Since the sign of H_{15} is unknown, the sign of $\delta e/\delta w_l$ is not known. As a result of a rise in the wage rate of labor, the demand for instructional development

$$H = \begin{bmatrix} g_{11} & 0 & g_{12} & -g_{11} & 0 & -g_{12} \\ 0 & PG_{LL}+g_{LL} & PG_{LK}+g_{LK} & P_tG_L & P_eG_L & P_kG_L \\ g_{21} & (g_{KL}+PG_{KL})/R & g_{22}+(PG_{KK}+g_{kk})/R & -g_{12}+P_tG_K/R & P_eG_K/R & -g_{22}+P_k\text{-}G_K/R \\ -g_{11} & P_tG_L/R & -g_{12}+P_tG_K/R & g_{11}+P_{tt}G/R & P_{te}G/R & g_{12}+P_{tk}G/R \\ 0 & P_eG_L/R & P_eG_K/R & P_{et}G/R & P_{ee}G/R & P_{ek}G/R \\ -g_{21} & P_kG_L/R & -g_{22}+P_k\text{-}G_K/R & g_{21}+P_{kt}G/R & P_{ke}G/R & g_{22}+P_{kk}G/R \end{bmatrix}$$

$$v = \begin{bmatrix} \delta l \\ \delta L \\ \delta K \\ \delta t \\ \delta e \\ \delta k \end{bmatrix} \qquad y = \begin{bmatrix} \delta w_l \\ \delta W_L \\ \{(g_K + r^2 + 2r + 2 + PG_K)/R^2\}\delta r \\ \{P_T G/R^2\}\underline{\delta}\, r \\ \{P_e G/R^2\}\underline{\delta}\, r + \delta w_e \\ \{P_k G/R^2\}\delta r \end{bmatrix}$$

Figure 3. Values for H, v, and y in equation (15).

could rise, fall or remain unchanged. It is not necessarily the case, as one might easily assume, that a rise in the cost of labor will lead to an increase in capital useage and an increase in the need for additional training of labor to work with that capital. The only thing we know for sure is that an increase in the unit cost of labor will result in a decrease in the demand for that labor.

Effects of Changes in the Unit Cost of Instructional Development

Similar to the above results for labor in general an increase in the unit cost of instructional development will result in a decrease in the demand for the development and vice-versa, i.e.,
(19) Slope of the Demand Curve for Training

$$\delta e/\delta w_e = H_{55}/|H| < 0$$

It is important to note here that instructional development is subject to forces of demand in a labor market. In short, developers can price themselves out of the market.

The effect of a change in the cost of instructional development on all the other variables of production is once again undefined since the signs of the cross partials contained in the respective H_{ij} cofactors are unknown.

Perhaps most surprising is the fact that a change in the unit cost of capital, r, yields no determinant effects. In the case of the demand for capital itself the results of a change in its cost is given by:
(20) Slope of the Demand Curve for Capital $\delta K/\delta r =$

$$\frac{(g_K + r^2 + 2r + 2 + PG_K)H_{33} + P_t GH_{34} + P_e GH_{35} + P_k GH_{36}}{|H|\,(1 + r)^2}$$

Since the signs of the H_{ij} cofactors are undefined, the sign of $\delta K/\delta r$ is known. A decrease in the cost of capital need not result in an increase in the demand for capital and an increase in the demand for instructional experts to train labor and training, however, the demand for capital need not rise as that capital becomes less expensive. But this observation may be an artifact of the model, as we assumed at the start that the rate of discounting is equal to the rental rate of capital (r).

Conclusions

In this paper we have developed a microeconomic model of training development that is based on the argument that training, unlike labor and capital, is an *indirect* factor in production. Training development, to the extent that it is successful, enhances or augments labor and capital in the direct production process following the actual training of labor. Training is fundamentally different from capital acquisition, even though the goal of both activities is the same—the increase of profit.

During the training period, training requires that capital and labor resources which could be used in direct production be diverted to the instructional program. This diversion of resources represents "opportunity cost" of training. The benefit to the firm is realized only after the labor completes training. Thus, at the time when the decision to invest in training is made, the decision to incur the opportunity cost must be based on a probabilistic benefit that may or may not materialize in the future. The firm takes a risk when it trains.

In the profit maximizing setting, the firm makes a trade-off between the opportunity cost of training and the present value of the expected gain in production from the training. The worth of that tradeoff (the amount of the benefit) determines the amount of training to be undertaken. In particular, instructional development should be undertaken to the point that the present value of the expected marginal benefit from training equals the marginal cost of that development. The greater the present value of the expect marginal benefit, the more training that should be undertaken. The model, in fact, suggests that training projects should be closely scaled to the expected marginal benefit if the firm's profit is to be maximized.

The implications of marginality and profit maximizing for training clearly suggest that some training might be undertaken with less than perfect competency expected, and yet with a major impact on profitability. At the same time, however, training with very high performance outcome standards might negatively effect profits. There is no *fixed* rule to apply in answering the question, "How much time and money for training is enough?" Good training is profitable training, no matter how much time and effort gets spent.

In planning, justifying and documenting training, changes in profitability need emphasis. It appears to make little sense to justify training on the basis of expected reductions in the labor force. In fact, if training is successful, labor increases are likely to prove profitable. Industry wants training because training increases profits by making people more productive; if people are more productive, the firm will want more of them.

It is comforting to be able to base these generalizations on a microeconomic model, rather than simply on the basis of management conjecture and heresay. The inferences drawn from the model—many of them counter intuitive—suggest that the formal modeling process is worthwhile.

Future directions. In general education, training is justified and evaluated in myriad ways. In industry, however, there is ultimately only one criterion—profitability. The effects of training on profits, employment levels and technological change itself, cannot be handled adequately through ad hoc theorizing or managerial rules of thumb. Through formal microeconomic models of the firm, however, we can analyze the interactions of the factors which operate here, and assess the contribution each makes.

We have provided the theoretical basis for a formal economic model of training in the profit maximizing firm. We hope that others are encouraged to develop models on a similar basis to seek out generalizable rules and frameworks for describing training in the industrial setting.

Reference Notes

1. The authors are indebted to Douglas Davis for the constructive criticism he provided in reviewing their model and its applications.

2. It is assumed that all labor time in the second period is homogeneous. Thus, the time of training in the first period must be divided evenly across the firm's labor force.

3. The expected value in the second period of the production process is Pg′ (the likelihood of achieving the new process and working with it,) plus (1-P)g (the likelihood of *not* achieving the new process and of working with the old one.) After rearranging terms:
$Pg' + (1 - P)g = Pg' + g - Pg =$
$g + P(g' + g) =$ (and substituting G for $g' - g$)
$g + PG$

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