Are Manufacturing Workers Really Worth Their Pay?

WPS/94-12

Patricia Jones

March 1994

Centre for the Study of African Economies
Institute of Statistics and Economics
University of Oxford
St Cross Building
Mnor Road
Oxford OX1 3UL

Introduction

Much attention has been focused in recent years on the importance of education in raising labor productivity. Policy makers repeatedly stress the value of investing in education because it is believed that formal schooling and on-the-job training raise the quality of workers. Countries with highly skilled work forces are more productive than those with less skilled workers[1] and have a competitive advantage in several strategic areas. Empirical evidence suggests that workers with above average levels of education are quicker to implement new technology,[2] are more complementary to physical capital[3], and improve both technical and allocative efficiency.[4] Moreover, numerous studies have revealed a significant relationship between the accumulation of human capital and per capita growth rates[5], particularly in developing countries. For example, Lau *et al* (1990) estimate that a one year increase in the average years of schooling of the workforce in East Asia and Latin America could raise real GDP by 3–5%.

While there is little doubt that the expansion of high quality education at the national level has very high returns, no empirical study to date has estimated the direct effect of education on *physical* output at the firm level. This void in the literature is surprising given the fact that all human capital theory rests upon the assumption that education raises the marginal physical product of workers. This paper aims partially to fill this void by presenting evidence on the direct impact of education on productivity using applied production analysis. Specifically, the paper has two aims: (1) to provide empirical evidence on the effect of different levels of education on marginal productivity at the firm level, and (2) to test how closely wages proxy marginal product. To date, there is no other study to the author's knowledge which estimates the elasticity of firm output with respect to human capital using production analysis. Instead, the conventional approach has been that earnings are used as a proxy for productivity and then earnings functions are used to estimate the effect of education on productivity.

The organization of this paper is as follows. Section 1 discusses the data that are used for analysis. Section 2 presents the theoretical background on the effects of education on production and discusses the advantages of a production function approach. Section 3 specifies a modified form of a Cobb-Douglas production function which permits the inclusion of educational categories and other variables affecting productivity. Section 4 presents the estimates obtained from the production function analysis which are associated with various levels of formal and non-formal schooling. Section 5 contains the concluding remarks.

---

[1]That is, countries with more skilled labour should have higher productivity than countries with less skilled workers, holding all factors constant.

[2]Bartel and Lichetenberg (1987) show that firms with new capital stock have a higher demand for educated workers relative to uneducated workers because skilled workers are able to implement innovations more quickly and thereby reduce a firm's costs of adjustment.

[3]Layard and Fallon (1975) run cross-country production functions on 23 countries to test the `capital-skill` complementarity hypothesis. They find that the share of physical capital in national income falls as the share of human capital rises.

[4]Quite a substantial literature was written during the 1970s on the effects of education on farmer efficiency. See Lockheed *et al* (1980) for a good summary of the main findings of these studies.

[5]See World Bank (1993), Khatkate (1993), Lau *et al* (1993), Lau *et al* (1990),and Jorgenson (1987).

1. Data

The data used in this analysis are from a survey of 200 manufacturing firms in Ghana organized under the World Bank's `Regional Program for Enterprise Development' (RPED) during the summer of 1993. This survey is part of a nine country (Burundi, Cameroon, Cote d'Ivoire, Ghana, Kenya, Rwanda, Tanzania, Zambia, and Zimbabwe) study of the manufacturing sector in Africa which is being funded by several European governments and the Canadian government. The Ghana case study was funded by the British Overseas Development Administration (ODA) and conducted by a team from the Centre for the Study of African Economies at Oxford University and the University of Ghana at Legon.

The data collected are extremely rich for an industrial survey and provide numerous indicators of how firms have performed in Ghana during the post-structural adjustment period. The sample includes firms which operate in six manufacturing sectors (food processing, garments, textiles, wood products, furniture, and metal working) and which are located in four regions (Accra, Kumasi, Takoradi, and Cape Coast). Although 200 firms were interviewed, the final sample for the paper was reduced to 117 because all public sector firms in the sample were deleted and a number of observations were dropped due to missing data. In the final sample, there were 21 food manufacturers, 29 garment firms, 1 textile firm, 8 wood processors, 27 furniture makers, and 31 firms in metal works.

The format of the survey was that interviews were conducted with either the firm's entrepreneur or one (or more) of its managers. The RPED survey asked questions on a wide range of financial details which included the firm's production accounts, the value of its capital stock, and the composition of its labor force. With respect to firm labor, the interviewee was asked to provide details on how many workers were employed by the enterprise and to give a breakdown of the workforce by occupation, including the average standard of education of workers in each occupational category. Personal information on both the education of the entrepreneur and a sub-sample of workers was also collected.

2. Theoretical Background

According to Welch (1970) education can have three possible effects on production. First, education can raise the direct productivity of a firm by making workers more productive.[6] Second, education can improve a firm's technical efficiency since more educated workers are presumed to have an advantage over less educated workers in gaining information on how to choose the correct mix of outputs and inputs for achieving productive efficiency.[7] And, third, an educated workforce facilitates a more rapid response to price changes so that firms are able to maintain allocative efficiency. These last two effects of education on production are not strictly within the bounds of neoclassical theory which assumes perfect information. Nevertheless, education appears to have several residual effects on production which means that its total

---

[6]That is, a firm's output is assumed to be a function of both raw inputs and education. This relationship can be expressed as Y=y(X,E), where Y is a firm's physical output, X is a vector of inputs, and E is the educational standard of the workforce. The marginal product of education is simply the partial derivative, $\delta y/\delta E$.

[7]In mathematical terms, the effect of education on allocative efficiency can be expressed as follows. Assume a firm produces two commodities (y_1,y_2) with two inputs (x_1,x_2) and the two commodities are sold at prices (p_1,p_2) which are determined exogenously. That is, $Y = p_1q_1(x_1) + p_2q_2(x_2)$. To maximize Y, we simply solve the first-order conditions. However, suppose that the allocation of inputs, x_1 and x_2, is a function of education. That is, $x_1=x_1(E)$ and $x_2=x_2(E)$. Now, the marginal product of education becomes

$$\frac{\delta Y}{\delta E}=\left[p_1\left(\frac{dq_1}{dx_1}\right)-p_2\left(\frac{dq_2}{dx_2}\right)\right]\frac{dx_1}{dE}$$

That is, the marginal product of education includes any gains in allocative efficiency. See Welch (1970) for a more thorough derivation.

contribution to output is often greater than its marginal product. These spillover effects of education have been described by economists as resulting from either entrepreneurial ability[8] or increasing returns due to educational externalities[9].

To date, nearly all the empirical studies which have examined the effect of education on production have used an earnings function framework. These studies have found very high private and social returns to schooling, particularly in LDCs, a fact which has undoubtedly been influential in sparking the dramatic expansion of educational systems throughout the Third World. Two main trends have emerged from this work: (1) the incremental returns to schooling fall as the level of education rises, and (2) both the private and social rates of return fall as the level of development rises. As expected, African countries tend to have very high returns to schooling, with average private rates at about 45% for primary, 28% for secondary, and 33% for higher education (Psacharopoulos, 1985, Tables I and II). However, the private returns to Ghanaian education are estimated to be much lower at around 8–9% (Glewwe, 1991, p. 11).

While a great deal has been written on the returns to education with respect to labor income, little is known about the marginal effect of different levels of education on the physical output of a firm. In the past, empirical tests which use production function analysis to estimate the effect of education on firm output have been impossible because of data constraints, despite the advantages to a production function approach. First, when estimating production functions there is no need to make any assumptions about the equivalence of wages and marginal product so the possibility of screening or credentialism does not cloud any interpretation of the results. Second, the production function approach permits the inclusion of non-wage workers, like apprentices or family members, who contribute to firm output but receive zero wages. Such workers are difficult to incorporate into a conventional, semi-logarithmic earnings function. Third, the coefficients on education obtained from production function analysis can be compared to the coefficients on education obtained from earnings function analysis to determine whether firms are behaving competitively and paying workers their marginal product. There is some evidence that considerable inefficiency occurs in the transformation of human capital into wages. That is, the conventional specifications of educational production functions have not been faithful to the concept of a production function which assumes such functions `yields the maximum output for an input vector` (Chambers, 1988)[10].

The flexibility of the production function approach with respect to non-wage labor is especially important within an African context because of the large number of small and medium firms which make use of apprenticeship labor. In Ghana it is common practice for smaller firms to take on young workers and provide them with vocational training. Such training schemes are known as apprenticeships and take a variety of forms. In general, they involve firms providing on-the-job training to apprentices in exchange for fees. However, the cost of apprenticeships vary by firm and by the initial skill level which the apprentice brings to the firm when joining. The most common practice is for an apprentice to pay an initiation fee when he/she joins the firm and then another fee when he/she completes the training. However, the graduation fee is often traditional in nature (e.g., bottles of schnapps, goats, etc.) and is often used by firms to host a graduation party for the apprentice. Such in-kind payments are not really fees in any strict sense of the word. Unfortunately, our data do not distinguish between which graduation payments are used to

---

[8]See Baumol (1993) for a good account of how entrepreneurs can speed the adoption of technology throughout a market.

[9]A great deal has been written in recent years within the framework of endogenous growth theory on the positive externalities associated with learning-by-doing and adopting state of the art technology. See Lucus (1988) and Grossman and Helpman (1990) for a general discussion of these issues.

[10]Hunt-McCool and Warren (1993) apply a modified version of the Aigner, Lovell, and Schmidt (1977) production frontier model to estimate two distinct earnings functions for US workers using stochastic specifications. They compare stochastic earnings functions with OLS estimates and state that `approximately one fourth of the unexplained variance in earnings across individuals may be ascribed to earnings inefficiency` (208).

host a party and which are actually delayed fees for the apprenticeship training. Therefore, graduation payments are not included in the calculation of apprentice fees.

Despite the fact that most firms charge apprenticeship fees, it is also common practice for firms to pay apprentices a daily allowance or even a reduced wage. Many firms have graduated pay ladders which roughly correspond to different skill levels so that apprentices are paid more after they have completed a certain length of their apprenticeship. A few firms even pay their apprentices the same wage as skilled workers, but such apprenticeships are unusual in that no fees are paid to the firm. It appears that apprentices in these firms differ from the full-fledged workers only by the fact that they are young recruits.

The RPED data reveal that the net compensation that apprentices receive (i.e. the fees paid by apprentices to the firm minus the wages paid to apprentices) is neither constant across firms nor constant within firms but, instead, varies according to the contractual relationship between firm and apprentice. The variation in compensation makes the incorporation of apprentices into the earnings function analysis slightly cumbersome. The approach taken in this paper is to first assume that apprenticeship schemes provide general on-the-job training and then to follow the theoretical assumptions outlined by Becker (1993). That is, it is assumed that the earnings of apprentices do not equal their *opportunity* marginal product. Instead, earnings reflect the opportunity marginal product of apprentices *less* the total cost of training. The idea behind Becker's theory is that employees pay for general training because it raises their future marginal product and thereby increases their future stream of earnings. During the period of training, apprentices receive earnings that are less than their current productivity which can be expressed as

$$W_0 = MP_0 - k \tag{1}$$

or

$$MP_O = W_0 + k, \tag{2}$$

where W_0 is the earnings of apprentices, MP_o is the opportunity marginal product of apprentice labor, and *k* is the training costs of the apprenticeship scheme. In other words, the opportunity marginal product of apprentices is equal to wages plus all fees. When estimating the earnings function in this paper, the value of opportunity marginal product of apprentices was used instead of wages so that training costs could be incorporated into the model.

3. Empirical Formulation

The effect of education on production can be estimated using a similar approach to that developed by Brown and Medoff (1978) to determine the impact of unionization on labor productivity. Suppose that output is produced according to a traditional Cobb-Douglas relationship[11]

$$Y = AK^{1-\alpha} L^{\alpha} \tag{1}$$

[11]The hypotheses of both a Cobb-Douglas model and constant returns to scale were tested. F-tests revealed that a Cobb-Douglas model was appropriate and rejected a translog model. The data are also consistent with the hypothesis of constant returns to scale.

where Y is the output per firm, K is the effective capital input, L is the effective labor input, α is the elasticity of output with respect to capital, and A reflects the state of firm technology. If we assume that L is not homogenous but, instead, comprised of heterogenous labor which is differentiated by six categories of educational attainment, then we can rewrite equation (1) as

(2) $$Y = AK^{1-\alpha}\left[L_0 + \sum_{i=1}^{5} (c_i+1)L_i\right]^{\alpha}$$

where

$$L = \sum_{i=0}^{6}$$

and the subscript i denotes a category of education. Each L_i represents the total number of workers in the firm who have completed i level of education, where L_0 is none, L_1 is primary or middle school, L_2 is secondary school, L_3 is vocational training, L_4 is polytechnic training, and L_5 is university or professional training. In other words, L represents a weighted sum of quality-adjusted labor, where the weights are average years of schooling. These weights were derived using the responses given by the firm manager on the `average education of each type of worker`[12]. If the manager failed to provide firm level data on any occupation, then data from the worker survey were used. In such cases, the average years of schooling was calculated from all the individual data on the same type of worker. Any firm with missing education data on any occupation was deleted.

In equation (2) the parameters c_i reflect differences in labor productivity between L_i and the educational base category, L_0. Differentiation of equation (2) with respect to L_i reveals that c_i+1 is simply the ratio of the marginal products of the workers in educational category i relative to those in category zero.

Suppose we define W_0 as

(2.a) $$W_0 = \frac{\delta Y}{\delta L_0} = \alpha AK^{1-\alpha}\left[L_0 + \sum_{i=1}^{5} (c_i+1)L_i\right]^{\alpha-1}$$

and W_i as

(2.b.) $$W_i = \frac{\delta Y}{\delta L_0} = \alpha AK^{1-\alpha}\left[L_0 + \sum_{i=1}^{5} (c_i+1)\right]^{\alpha-1} (c_i+1),$$

(2.c) $$\frac{W_i}{W_0} = c_i + 1$$

[12]Workers were classified into eight types of occupations: (1) management, (2) administration/clerical, (3) commercial/sales, (4) production, (5) maintenance, (6) supervisors/foreman, (7) masters, and (8) apprentices. If the firm had only one manager, then data on the firm's entrepreneur were used to replace missing observations on the `average education of management`. This method of reducing missing data is justified since the entrepreneur and the manager are the same in most firms, except in very large ones. State enterprises are not included in the sample.

Theoretically, the coefficients c_i+1 which are estimated in equation (2) are equivalent to the coefficients on the same categories of education which are estimated in a logarithmic earnings function. That is,

$$(3) \qquad lnW_i = Ln(c_i+1) + logW_0 \approx c_i + logW_0$$

the earnings function estimated in this paper is a generalised form of the model

$$(4) \qquad lnW_i = logW_0 + \Sigma c_i E_i$$

where E_i takes the value one if the worker has completed educational class i[13]. Therefore, the coefficients on E_i in the earnings function represent the earnings (i.e., productivity) differential between a worker with education E_i and a worker with the base category of education, E_0.

An algebraic transformation of equation (2) can be carried out by defining $\lambda_i = L_i/L$ so that equation (2) becomes

$$(5) \qquad Y = AK^{1-\alpha}L^{\alpha}\left[1+\sum_{i=0}^{5} c_i\lambda_i\right]^{\alpha}$$

The variable λ_i represents the proportion of each firm's workforce whose highest educational achievement is category i so $\Sigma\ \lambda_i=1$. That is, the coefficient on each λ_i represents the productivity differential between educational category i and the base category λ_0. By definition, if c_i is greater than zero then the educational category λ_i is more productive than λ_0; if c_i is less than zero then the educational category λ_i is less productive than λ_0. In theory, if firms are paying workers their marginal product, the c_i obtained from estimating equation (2) will be identical to the c_i obtained from estimating equation (3).

By dividing both sides by L and taking logarithms, we get

$$(6) \qquad Ln\left(\frac{Y}{L}\right) = lnA + (1-\alpha)\ln\left(\frac{K}{L}\right) + \alpha\ln\left[1+\sum_{i=0}^{5} c_i\lambda_i\right]$$

However, if we make use of the Taylor series approximation ln(1+x)≈x, then it is possible to rewrite equation (6) as

$$(7) \qquad \ln\left(\frac{Y}{L}\right) \approx lnA + (1-\alpha)\ln\left(\frac{K}{L}\right) + \alpha\sum_{i=0}^{5} c_i\lambda_i$$

This approximation holds if $\sum c_i L_i$ is between 0 and 1 which, fortunately, is the case for the Ghanaian data. The value of $\sum c_i L_i$ for the sample is 0.63.

Now by relaxing the assumption of constant returns to scale and adding $\theta\ln L$, we get the basic productivity equation

$$(8) \qquad \ln\left(\frac{Y}{L}\right) \approx lnA + (1-\alpha)\ln\left(\frac{K}{L}\right) + \Theta lnL + \alpha\sum_{i=1}^{5} c_i\lambda_i$$

[13]The fact that c_i + log W_0 approximates log(c_i+1) + log W_0 holds by applying the Taylor expansion ln(x+1)≈ x.

Once again, the estimates of c_i represent the average productivity differential between workers with education λ_i and workers with education λ_0. However, one slight problem arises when estimating c_i. in equation (8). The coefficients on λ_i are not c_i but, instead, they are αc_i which means that the c_i must be separated from this multiplicative term. Fortunately, extracting the parameter estimates on c_i is straight forward since the c_i are simply the coefficients on λ_i divided by one minus the coefficient on *K/L*. That is,

(9) $$c_i = \frac{\alpha c^i}{[1-(1-\alpha)]}.$$

However, separating the standard errors of c_i from αc_i is slightly more cumbersome, although necessary in order to perform the statistical tests carried out in this paper. Two steps are taken to obtain the standard errors of c_i:

(1) c_i is defined as $Y/(1-X)$, where X=1-α, and $Y=\alpha c_i$
(2) The total differential of c_i is calculated. That is,

(10) $$dc_i = \frac{1}{(1-X)}dY + \frac{Y}{(1-X)^2}dX.$$

Once the standard errors of c_i are known, the usual hypothesis tests can be carried out on the results from the production analysis[14]. The actual variables estimated in the productivity equation are defined as follows:

(i) *vaddl*. The log of value-added divided by total labor input. Value-added is calculated as the sum of 1991 profits (i.e., the value of sales minus all variable costs) plus labor costs. Effective labor input, totl, is defined as all full-time workers plus all apprentices.
(ii) *kl*. The log of the capital-labor ratio. Capital is defined as the 1991 replacement value of total capital stock.
(iii) *lntotl*. The log of total labor input.
(iv) *educ0* or c_0. The proportion of a firm's workforce with no formal schooling. This is the omitted educational category.
(v) *educ1* or c_1. The proportion of a firm's workforce that has completed either primary school or middle school. This educational category corresponds to approximately 6–10 years of schooling.
(vi) *educ2* or c_2. The proportion of a firm's workforce that has completed secondary school. This educational category corresponds to approximately 14 years of schooling.
(vii) *educ3* or c_3. The proportion of a firm's workforce that has completed vocational school. This educational category corresponds to roughly 11 or 15 years of schooling, depending upon whether the worker first attended middle school or secondary school.

[14] After dc_i has been found, the variances of c_i are easily derived by squaring dc_i. That is,

$$(dc_i)^2 = \left[\frac{1}{(1-X)}\right]^2 (dY)^2 + \left[\frac{Y^2}{(1-X)^4}\right](dX)^2 + \left[\frac{2Y}{(1-X)^3}\right]dYdX$$

or

$$(dc_i)^2 = \left[\frac{1}{(1-X)}\right]^2 \sigma_y^2 + \left[\frac{Y^2}{(1-X)^4}\right]\sigma_x^2 + \left[\frac{2Y}{(1-X)^3}\right]\sigma_{xy}^2$$

where σ_y^2 are the variances of c_i, σ_x^2 is the variance of ln(*K/L*) and σ_{xy}^2 are the covariances between *X* and *Y*. See G.L. Squires (1976) for a full explanation of this method of obtaining the variances.

(viii) *educ4* or c_4. The proportion of a firm's workforce that has completed polytechnic training. Like vocational training, this educational category cannot be defined as one exact number. Instead, the category corresponds to roughly 12 or 16 years of schooling, depending upon whether the worker first attended middle school or secondary school.

(ix) *educ5* or c_5. The proportion of a firm's workforce with either a university degree or some type of professional training. This category includes advanced qualifications, like MBAs, as well as less-advanced qualifications, such as accountancy diplomas. In general, these courses take 1–2 years so 1.5 years were added to the workers' formal education. The category corresponds to 19, 11.5, 15.5, or 20.5 years of schooling, depending upon the number of years the worker spent in formal schooling.

The basic framework of equation (8) relies on a modified Cobb-Douglas production function whose residual includes the effect of numerous omitted variables. Such factors are well-known in the literature on productivity and include worker effort[15], unionization[16], R&D[17], and product market structure.[18] To capture the effect of these factors, the productivity equation was extended to include the following variables:

(x) *lnhrs*. The log of average weekly hours worked per employee.

(xi) *union*92. Dummy variable that equals one if firm has union members.

(xii) *tech92*. Dummy variable that equals one if firm has any foreign licenses or foreign technical assistance contracts,

(xiii) *olig92*. Dummy variable that equals one if firm reports that it faces less than 6 competitors for its principal product or product range

(xiv) *rratio92*. Variable designed to capture the vintage of firm capital. It is defined as the ratio of the sale value of capital in 1992 to its replacement value.

The following six sector dummies were also included to capture any industry-specific variations in technology:

(xv) *food92*. Dummy variable that equals one if firm engages in food processing (i.e., firm has a SIC classification 311–313).

(xvi) *garm92*. Dummy variable that equals one if firm engages in the manufacture of wearing apparel, except footwear (i.e., firm has a SIC classification 322). This is the omitted sector dummy.

(xvii) *wood92*. Dummy variable that equals one if firm engages in the manufacture of wood products, except furniture (i.e., firm has a SIC classification 331).

(xviii) *furn92*. Dummy variable that equals one if firm engages in the manufacture of furniture and fixtures, except primarily of metal (i.e., firm has a SIC classification 332).

(xix) *metal92*. Dummy variable that equals one if firm engages in the manufacture of fabricated metal products, except machinery and equipment (i.e., firm has a SIC classification 381).

(xx) *text92* Dummy variable that equals one if firm engages in the manufacture of textiles (i.e., firm has a SIC classification 321).

[15]See Haskel and Martin (1993) and Nickell *et al* (1992).

[16]See Stewart (1990), Allen (1984), Clark (1984), and Brown and Medoff (1978).

[17]See Geroski (1990), Griliches (1986), and Dasgupta and Stiglitz (1980).

[18]See Nickell (1993), Haskel and Martin (1993), Stewart (1990), Geroski (1990), Porter (1990), and Dickens and Katz (1987).

Finally, two last variables were added so the production function would more closely resemble the specification of the earnings function.

(xx) *pfem*. The proportion of the workforce comprised of female workers.
(xxi) *expind*. Firm level index of worker experience. The index is constructed as a weighted average of worker experience, using weights based on responses from the worker survey. The weights are defined as the average years of worker experience split by occupation and sector.

The addition of variables (x)–(xxi) to equation (8) gives us the final estimating equation[19]

$$(11)\quad \begin{aligned} lnvaddla = & a_1 kl + a_2 totl + a_3 expind + a_4 pfem \\ & + a_5 educ1 + a_6 educ2 + a_7 educ3 + a_8 educ4 + a_9 educ5 \\ & + a_{10} lnhrs + a_{11} union92 + a_{12} tech92 + a_{13} olig92 \\ & + a_{14} food92 + a_{16} text92 + a_{17} wood92 + a_{18} metal92 + _{19} rratio92 + \epsilon. \end{aligned}$$

The results from estimating equation (11) are presented in the next section.

An earnings function is also estimated since one of the primary aims of this paper is to test how well earnings proxy marginal product. All the data used in the earnings function are obtained from a survey of workers and apprentices which was conducted as part of the RPED firm questionnaire. These data are at the individual level, whereas the data used in the production function are at the firm level. An attempt was made to make the earnings function as similar as possible to the production function. The variables added to the earnings function are defined as follows:

(i) *lnearn*. The log of weekly wages plus allowances.
(ii) *female*. Dummy variable which equals one if the worker is female.
(iii) *appw*. Dummy variable which equals one if the worker is currently an apprentice.
(iv) *exp*. Number of years of work experience.
(v) *expsq*. Number of years of work experience squared.

The earnings function is specified as

$$(12)\quad \begin{aligned} lnearn = & a_1 female + a_2 exp + a_3 expsq + a_4 app \\ & + a_5 educ1 + a_6 educ2 + a_7 educ3 + a_8 educ4 + a_9 educ5 \\ & + a_{10} lntotl + a_{11} food92 + a_{12} text92 + a_{13} wood92 + a_{14} furn92 + \\ & + a_{15} metal92 + a_{16} lnhrs + a_{17} union92 + a_{18} olig92 \\ & + a_{19} tech92 + a2_{20} rratio92 + \epsilon. \end{aligned}$$

The results from the earnings function are presented in the next section.

4. Results

The results of the production and earnings function analyses are presented in Table I. The main findings are as follows.

First, vocational and polytechnic training are the only levels of education which have any significant impact on firm productivity. Both categories are outside the formal educational system, a result suggesting that the Ghanaian curriculum is not providing workers with skills that are easily transferred to the manufacturing sector. This result supports the finding by Glewwe (1992) that Ghanaian formal education has very low returns in the private sector. Estimates of equation (11) reveal that workers who have completed both middle school and secondary school do not contribute more to firm output than those workers with primary schooling or less.

---

[19] All variable names written in italics are estimated as logarithms.

Second, the more experienced the workers are in a firm, the higher is the level of labor productivity. This result is consistent with the notion of learning-by-doing and the idea that workers become more productive as they learn both firm specific and industry specific skills. Indeed, the assumption that experience raises productivity is the rationale behind including experience in the specification of earnings functions. As expected, the coefficients on experience are highly significant in both the earnings and productivity equations. A Wald test was carried out to test whether these coefficients are statistically the same in the two models. For this test, it is assumed that the coefficients are normally distributed with a hypothesized mean of zero and a combined variance. The Wald statistic suggests that the coefficients are not statistically different in the two models.

Third, the coefficients on education do *not* rise monotonically with higher levels of education. The coefficient on vocational schooling (EDUC3) is less than the coefficient on polytechnic schooling (EDUC4). Moreover, *t*-statistics testing the difference between each educational category and the one immediately above it (e.g., the hypothesis $H_0:\beta_9 - \beta_8 = 0$ where β_9 is the coefficient on EDUC4 and β_8 is the coefficient on EDUC3) reveal that the coefficients on four out of the five educational categories are not significantly different from the class immediately above it. This result contradicts the fundamental assumption of human capital theory that education raises productivity.

Lastly, the hypothesis that the coefficients on education estimated in the production function and the earnings function are not statistically different *cannot* be rejected. This result supports the standard assumption that wages reflect the marginal product of labor. To test this hypothesis, a Wald test was carried out which compared the coefficients on education for each category in the two models. The Wald statistic has a chi-squared distribution with one degree of freedom which takes a value of 6.63 at the 0.99 level of significance. It can be seen from Table II that all the Wald statistics have a value less than 6.0. Therefore, the hypothesis cannot be rejected that the coefficients estimated in the earnings function are the same as those estimated in the production function. To the author's knowledge, this is the only empirical evidence to date which tests the standard assumption that wages reflect the marginal physical product of labor.

The importance of this last finding is two-fold. First, the result that wages are a good proxy for the marginal product of labor gives empirical support to the earnings function approach as a means of estimating the effects of education on productivity. Given the fact that data on earnings and education are more easily accessible at the individual level than at the firm level data, and the fact that results from earnings functions are commonly used by policy makers to make decisions about public expenditures, it is reassuring that wage differentials do reflect productivity differentials. However, two caveats must be mentioned. First, education has a more pronounced influence on wages than it does on productivity, a fact illustrated by the insignificance of formal education in the productivity equation and its significance in the earnings function. Second, higher levels of education do not necessarily lead to higher productivity. Despite these caveats, the finding that wages are a good proxy for marginal physical product within a developing country context suggests that profit-maximizing behaviour leads firms to `get the prices right`, despite the existence of market imperfections.

5. Summary of Conclusions

To date, the conventional approach to examining the effect of education on production has been via an earnings function framework. This paper presents evidence on the impact of various classes of education on labor productivity in Ghana by directing estimating the marginal product of education through its coefficient in a production function. To the author's knowledge, it is the only study which tests the basic assumptions of human capital theory using micro data. After estimating a modified Cobb-Douglas production function, two important results emerge: (1) that education does not always lead to greater productivity, and (2) that wages are a good proxy for marginal product. The first result contradicts the basic assumption of human capital theory, although the second result supports the neoclassical assumption that firms equate wages to marginal product.

In addition, the production analysis reveals that formal education has little impact on manufacturing productivity. This finding suggests that formal schooling is not providing workers with the basic skills which they need to be productive. Previous work investigating the effect of education on African manufacturing has shown that education affects productivity only indirectly. That is, education makes workers more literate and numerate and it is these skills which make them more productive.[20] While formal schooling does not appear to be providing these basic skills, the goods news is that training at higher levels does make a difference. The results obtained from the production function analysis reveal that both vocational and polytechnic training have a significant impact on firm productivity. Unfortunately, only 19% of the workers in the RPED sample have such training, while the majority (68%) stopped their education at middle school or secondary school. Therefore, the most important policy recommendation to emerge from this paper is that the quality of formal education must rise in order to provide workers with the skills needed to make them productive.

[20]See the study by Boissiere *et al* (1984) on the effect of education on labor productivity in Kenya and Tanzania.

TABLE I: PRODUCTION & EARNINGS FUNCTION ANALYSIS			
	Simple Cobb-Douglas	**Productivity Equation**	**Earnings Function**
Constant	4.6199 (0.74)	5.9019 (1.65)	4.1567 (0.74)
lnkl	0.2928 (0.06)	0.0328 (0.07)	----
lntotl	0.1096 (0.12)	0.0372 (0.37)	-0.5043* (0.17)
expind/exp		0.1079* (0.05)	0.0422* (0.01)
expsq		----	-0.0007* (0.00)
pfem/female		-0.7591 (0.46)	-0.5900* (0.12)
educ1		0.1996 (0.39)	0.4030* (0.15)
educ2		0.5485 (0.48)	0.7396* (0.16)
educ3		1.8903* (0.47)	0.7067* (0.15)
educ4		1.4931* (0.47)	0.7608* (0.16)
educ5		2.0012 (1.61)	1.4263* (0.20)
Number of Observations	117	117	522
Adj. R-squared	0.2198	0.4231	0.7051

Source: RPED Wave II. The reported coefficients of Educ1-Educ5 in the productivity equation are the c_i from equation (11). All standard errors have been corrected for heteroscedasticity using White's procedure and are reported in the parentheses. In addition to the variables reported, the productivity and earnings functions include the following variables: the log of weekly hours, capital vintage, union dummy, oligopoly dummy, foreign technical assistance dummy, and 5 sector dummies.

TABLE II: WALD TEST WITH ONE RESTRICTION

C_1= EDUC1=0.0997

C_2= EDUC2=0.0725

C_3= EDUC3=2.8091

C_4= EDUC4=1.0865

C_5= EDUC5=0.1761

VARIANCES OF C_i AND COVARIANCES BETWEEN C_i AND LN(K/L)			
	α_y^2	α_x^2	α_{xy}^2
C_1	0.3701	0.0054	-0.0101
C_2	0.4600	0.0054	-0.0142
C_3	0.4940	0.0054	-0.0176
C_4	0.4803	0.0054	-0.0169
C_5	1.5891	0.0054	-0.0234

References

Allen, S.G. (1984) `Unionized Construction Workers Are More Productive`, *Quarterly Journal of Economics*, 251–74.

Bartel, A.P. and F.R. Lichtenberg (1987) `The Comparative Advantage of Educated Workers in Implementing New Technology`, *The Review of Economics and Statistics*, LXIX: 1–11.

Becker, G. (1993) *Human Capital: a Theoretical and Empirical Analysis with Special Reference to Education*, Third Edition, Chicago, IL: Chicago University Press.

Boissiere, M., J.B. Knight and R.H. Sabot (1984) `Earnings, Schooling, Ability, and Cognitive Skills`, *American Economic Review*, 75 (4): 1016–30.

Brown, C. and J. Medoff (1978) `Trade Unions in the Production Process`, *Journal of Political Economy*, 86 (3): 355–77.

Baumol, W.J. (1993) *Entrepreneurship, Management, and the Structure of Payoffs*, Cambridge, MA: MIT Press.

Chambers, R.G. (1988) *Applied Production Analysis: a Dual Approach*, Cambridge: Cambridge University Press.

Clark, K.B. (1984) `Unionization and Firm Performance: the Impact on Profits, Growth, and Productivity, *American Economic Review*, (74): 251–74.

Dasgupta, P. and J. Stiglitz (1980), `Industrial Structure and the Nature of Innovative Activity`, *Economic Journal*, 90: 95–106.

Dickens, W.T and L.F. Katz (1987) `Inter-Industry Wage Differences and Industry Characteristics`, in K. Lang and J.S. Leonard (eds), *Unemployment and the Structure of Labor Markets*, New York: Basil Blackwell.

Geroski, P. (1990) `Innovation, Technological Opportunity, and Market Structure`, *Oxford Economic Papers*, 42: 586–602.

Glewwe, P. (1991) `Schooling, Skills, and the Returns to Government Investment in Education: an Investigation Using Data from Ghana`, *LSMS Working Paper No. 76*, Washington DC: World Bank.

Griliches, Z. (1986) `Productivity, R and D and Basic Research at the Firm Level in the 1970s`, *American Economic Review*, 76: 141–54.

Grossman, G. and Helpman, E. (1990) `Comparative Advantage and Long-run Growth`, *American Economic Review*, 80: 796–815.

Hunt-McCool, J.C. and R.S. Warren (1993) `Earnings Frontiers and Labor Market Efficiency` in H.O. Fried, C.A. Knox-Lovell and S.S. Schmidt (eds) *The Measurement of Productive Efficiency: Techniques and Applications*, New York: Oxford University Press.

Jones, P. (1994) `Wage Determination in the Urban Labor Market in Ghana`, mimeo, Centre for the Study Of African Economies, Oxford University.

Jorgenson, D. (1987) *Productivity and US Economic Growth*, Cambridge, MA: Harvard University Press.

Haskel, J. and C. Martin (1993) `Do Skill Shortages Reduce Productivity? Theory and Evidence from the United Kingdom`, *Economic Journal*, 103: 386–94.

Khatkate, D.M. (1993) `Productivity in Manufacturing as a Determinant of Growth`, *World Development*, 21 (9): 1441–45.

Lau, L, D. Jamison, L. Shu-Cheng and S. Rivkin (1993) `Education and Economic Growth: Some Cross-Sectional Evidence from Brazil`, *Journal of Development Economics*, 41: 45–70.

Lau, L., D. Jamison and F. Louat (1990) `Education and Productivity in Developing Countries`, WPS 612, Washington, DC: World Bank.

Layard, R. and P. Fallon (1975) `Capital-Skill Complementarity, Income Distribution, and Output Accounting`, *Journal of Political Economy*, 83 (2): 279–301.

Lockheed, M., D. Jamison and L. Lau (1980) `Farmer Education and Farm Efficiency: a Survey`, *Economic Development and Cultural Change*, 29: 37–76.

Lucus, R.E. (1988). `On the Mechanics of Economic Development`, *Journal of Monetary Economics*, 29: 3–42.

Nickell, S. (1993) `Competition and Corporate Performance`, Applied Economics Discussion Paper No. 155, Oxford University.

Nickell, S., S. Wadhwani and M. Wall (1992) `Productivity Growth in U.K. Companies, 1975–86`, *European Economic Review*, 36: 1055–91.

Porter, M. (1990) *The Competitive Advantage of Nations*, London: MacMillan Press Ltd.

Psacharopoulos, G. (1985) `Returns to Education: A Further International Update and Implications`, *Journal of Human Resources*, 20 (4): 583–604.

Squires, G.L. (1976) *Practical Physics*, London: McGraw-Hill Press.

Stewart, M.B. (1990) `Union Wage Differentials, Product Market Influences and the Division of Rents`, *Economic Journal*, 100: 1122–37.

Welch, F. (1970) `Education in Production`, *Journal of Political Economy*, 38: 35–59.

World Bank (1993) *The East Asian Miracle*, New York: Oxford University Press.