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ABSTRACT

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This paper reviews Jacob Mincer's contributions to the analyses of earnings and the distribution of earnings through his pioneering focus on labor market experience or on-the-job training. It begins with a brief discussion of the theoretical literature on the distribution of earnings in the pre-Mincer period, and then discusses his analysis of human capital and earnings developed in his 1957 doctoral dissertation and 1958 Journal of Political Economy (JPE) article. Further analyses of on-the-job training, and in particular estimates of the rate of return from on-the-job training, are presented in his 1962 JPE paper. The synergy between Mincer and Becker during the 1960s is discussed, as is the development of the schooling-earnings function by Becker and Chiswick (1966). Mincer (1974) extended this relationship by incorporating experience to form the "human capital earnings function" in his Schooling, Experience and Earnings (1974). Subsequent modifications, extensions, tests of robustness and the wide applicability of the human capital earnings functions are presented.

JEL Classification: B21, J24, J31, D31

Keywords: human capital, labor market experience, earnings, income distribution, Jacob Mincer

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This is to acknowledge my intellectual debt to Jacob Mincer as a student in his courses in Statistics and Labor Economics at Columbia University, as a reader of his research and as a beneficiary of his comments on my research. He is a master teacher as well as a pioneering scholar who stimulated my own research, as well as that of many others. I appreciate the comments on an earlier draft of this paper from Carmel U. Chiswick, Shoshana Grossbard-Shechtman, Evelyn Lehrer, Paul W. Miller, Harry Patrinos and Richard Peck. I am, however, solely responsible for any errors of omission or commission.

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"Jacob Mincer, Experience and the Distribution of Earnings"

Barry R. Chiswick

"Experience on the job is often the most essential part of the learning process."
Jacob Mincer, *Journal of Political Economy*, 1958, p. 287.

1. Introduction

The purpose of this paper is to review Jacob Mincer's contribution to the analysis of earnings and the distribution of earnings through his pioneering focus on labor market experience or on-the-job training. This includes the development of the "human capital earnings function." This review puts Mincer's contributions in the broader context. It explores antecedents to Mincer's research, as well as the interaction of his contributions with those of others.

In addition to recognizing and celebrating Mincer's own crucial contributions, the paper implicitly emphasizes both the linear and the interactive progression of research. Each step in this area was built on the previous step, and each step served as a stepping-stone for the next step. This is an ongoing process, and we are not near the end.

This paper begins (section 2) with a brief discussion of the literature on human capital and earnings distribution in the pre-Mincer period, starting with Adam Smith. Section 3 discusses Mincer's early work in his Ph.D. dissertation and 1958 *Journal of Political Economy* article where, for the first time, there is an explicit modeling of the relationship between earnings and both schooling and labor market experience. The

synergy between the work of Mincer and Gary S. Becker is the topic of section 4, while section 5 discusses the development of the schooling-earnings function. Section 6 focuses on Mincer's book, Schooling, Experience and Earnings, and in particular on the development of the expanded earnings function to include on-the-job training, which has become known as the human capital earnings function. This paper closes (section 7) with a discussion of the lasting impact of Mincer's contribution in this area.

2. The Early Period

In his *Wealth of Nations*, Adam Smith lists five "principal circumstances, which, so far as I have been able to observe, make up for a small pecuniary gain in some employments, and counter-balance a great one in others…" (Smith 1937, Book 1, Chapter X, pp.100-103). The second of these "circumstances" is the "easiness and cheapness, or the difficulty and expense of learning them." In his discussion of this "circumstance" Smith first considers two categories of workers, "common labour" and "skilled labour", where the latter includes "mechanics, artificers and manufacturers." He then relates that the skilled workers are required to go through an apprenticeship program, in contrast to common labor, which is "free and open to every body". Moreover, "the whole labour of the apprentice belongs to his master…Some money too is commonly given to the master for teaching him his trade…They who cannot give money give time…." A third category of labor is those "in the ingenious arts and in the liberal professions," and, as is the situation today, their education is "still more tedious and expensive."

In this discussion, Smith relates earnings to investment in education or training, at least some of which (apprenticeships) is undertaken in the workplace. Some of the time

of the master and the apprentice, and perhaps other resources as well, are devoted to this training activity. Thus, Smith highlights what we would now call investment in on-the-job training.

Over the next century and a half there was little work by economists on the issue of investment in skills or human capital.[1] This is not to say there was no interest in labor earnings. In the United States there were numerous state labor surveys and studies that estimated wages by occupation and interest in immigration resulted in the 41 volume Dillingham Immigration Commission Report (1911) that, among other analyses, collected and analyzed data on the occupational attainment and earnings (wages) of immigrant and native born workers by country of birth and race/ethnicity, as well as a host of other characteristics. Analyses using the census were limited by the data collected. Although the U.S. Census of Population has asked for the respondent's occupation in every census since 1850, there was no question on earnings or income until the 1940 Census, and this was limited to the earnings of wage and salary workers. Income was asked in 1950, and only since 1960 has the census asked both earnings and income.

When interest in human capital resumed the focus was on the contribution of education to economic growth, investment in education in less developed countries and earnings differences across professional occupations (Milton Friedman and Simon Kuznets 1945, Theodore W. Schultz 1961, and the references therein). During this period, one of the important studies was the Milton Friedman and Simon Kuznets *Income from Independent Professional Practice*, published after a long delay in 1945 by the

National Bureau of Economic Research. Net present values of earnings streams for five professional occupations were computed using a four percent discount rate.

Another strand in the economics literature was an interest in the inequality and shape of the distribution of income or earnings. What was the cause of income inequality and why did the distribution of income have a positive skewness? If ability was normally distributed, as it was assumed, then why was the distribution of income not also normally distributed but rather positively skewed? The literature in this area considered the consequences of combining separate distributions of ability or considered the effects of purely random or stochastic events ("chance") as a determinant of the distribution of income. To reconcile some of these models with the apparent stability over time of the distribution of income required adding complexity that would assure stability. These models had mathematical underpinnings, but were essentially devoid of economic behavior. In 1953 Milton Friedman (p. 277) wrote: "The absence of a satisfactory theory of the personal distribution of income and of a theoretical bridge connecting the functional distribution of income with the personal distribution is a major gap in modern economic theory."

3. Mincer's Early Work on Experience

In his path breaking doctoral dissertation and in the seminal article, "Investment in Human Capital and Personal Income Distribution", based on his dissertation, Mincer (1957, 1958) pioneered the explicit study of the effect of labor market experience or on-the-job training on the determination and distribution of earnings. His model provided an analysis of the manner in which on-the-job training influences differences in earnings across individuals and how this determines the inequality and skewness of earnings. It is

a model based on rational economic behavior by individuals in the labor market. As a result, this work served as the base for several strands of research in labor economics.

In Figure 1 in his 1958 *Journal of Political Economy* article Mincer draws what we would now call an experience-earnings profile, with the assumption of a linear relation between earnings and age. It is only in later work that he identifies and emphasizes the important distinction between age and labor market experience, and the concave shape of the experience-earnings profile. Indeed, he wrote that "formal training" is more difficult to measure than informal on-the-job training (Mincer 1958, p.291). In the empirical section he demonstrates the concave age-earnings profile through the graphing of income profiles by level of schooling for adult males for 1949.

With this analysis Mincer (1957, 1958) shows that within an occupation earnings inequality increases with the steepness of the age-earnings profile, and that this profile is steeper for occupations requiring more skill, whether acquired in school or on the job. He also shows theoretically and empirically that inequality increases with age, schooling level and occupational rank (income). He writes that "the greater the average amount of training in the group, the greater the inequality in its income distribution", whether the group is defined by industry, race, gender, marital status or city size (Mincer 1958, p.300). An implication of the model that was to be essential in the subsequent development of the human capital earnings function is that: "absolute differences in the length of training result in percentage differences in annual earnings" (Mincer 1958, p.301). This implication also generates the positive skewness in earnings.

While there have been numerous studies over the years of rates of return from formal education or from specific formal job training programs, the literature in

economics is virtually devoid of studies of the magnitude of and rates of return from investments in on-the-job training, especially experience or merely learning by doing.[2] This may be due, at least in part, to the difficulty of measuring the cost of the investment in on-the-job training.

In October 1962, the *Journal of Political Economy* published a supplement edited by T.W. Schultz entitled *Investment in Human Beings*.[3] This path-breaking study included chapters on various aspects of human capital: Gary Becker on human capital theory, Larry Sjaasted on migration, Selma Mushkin on health, George Stigler on information in labor markets (job search), Burton Weisbrod on the non-pecuniary benefits of education, Edward Denison on education and economic growth, and Jacob Mincer on labor market experience. In this study, Mincer (1962) explicitly focuses on estimating the magnitude of on-the-job training, the rate of return from on-the-job training and the implications of on-the-job training for the distribution of earnings. Here he notes explicitly that earnings profiles imply a decline in on-the-job training investments with age, which is attributed to the decline with age in the length of the remaining working life.[4] Among other findings, Mincer's estimates of the dollar magnitude of on-the-job training increase with the level of schooling. Although at the margin schooling and on-the-job training can be alternative ways of acquiring skills (i.e., they are substitutes), overall school and experience investments are positively correlated across individuals. This is the first empirical demonstration of the positive relationship between these two forms of human capital.

Estimates of the value of the foregone earnings component of investment in on-the-job training made by workers were obtained by comparing earnings streams of

workers that differ by level of schooling. Rates of return from the earnings streams were computed (Mincer 1962). By assuming that rates of return from schooling and on-the-job training were the same, and subtracting investments in schooling from the total investment, Mincer was able to estimate the investment in training. These estimates suggested that for males the dollar value of investments in on-the-job training were about the same as the value of investments in schooling.[5] Investments in schooling had increased over time in terms of years and dollar value, and investment in labor market experience did not seem to be any less and may have even increased in dollar value during the same period.

Mincer (1962) estimated rates of return from on-the-job training for several different occupations. For three occupations with apprenticeship programs (metal, printing and building trades), he assumes that their alternative employment would be operatives, and by comparing earnings as apprentices and as journeymen in contrast to those of operatives Mincer computes rates of return from on-the-job training. He estimates that the rates of return from investment in on-the-job training are about 9 to 13 percent (Mincer, 1962, p.66). These are slightly higher than estimates of rates of return from college but given the numerous measurement issues with both types of estimates, they are in the same neighborhood.

Foreshadowing his later work, Mincer (1962, pp.66-68) discusses investment in on-the-job training by women compared to men. The incentives for women to make these investments are less because "the average female expects to spend less than half her working life in the labor force," and has a high probability of dropping out of the labor

force for child-rearing. Mincer notes that for these reasons employers would be more reluctant to invest in firm-specific training for women than for men.

4. Mincer and Becker

Although Jacob Mincer and Gary Becker did not have a publication co-authored with each other, they enjoyed a mutually beneficial intellectual relationship which each has often acknowledged.[6] At the July 15, 2002 conference Mincer referred to the "synergy between Gary and me," while Becker referred to their "continuous unending intellectual collaboration" and their "great complementarity" during his years at Columbia University.

Jacob Mincer's theoretical and empirical work on human capital (schooling and on-the-job training) referred to above stimulated and influenced subsequent work in this area, including that of Gary Becker (1962, 1964, 1966, 1967 and Becker and Barry R. Chiswick 1966), and Mincer's subsequent work was, in turn, influenced by that of Becker. The decade long workshop that they jointly operated at Columbia University, and their work at the NBER New York office, largely overlapping with the 1960's, served as a hotbed for research on human capital and the New Home Economics (Shoshana Grossbard –Shechtman 2001).

Gary Becker's major theoretical and empirical research on human capital are in his article in T.W. Schultz's edited volume *Investment in Human Beings* (1962) and in his book, *Human Capital* (1964). These studies further demonstrated the power of the human capital approach for understanding the theory of investment in human capital, and demonstrated a range of implications for the determination of earnings and, in the context of on-the-job training, job turnover in the labor market (quits and layoffs). Among other

concepts, Becker expanded on the distinction between "firm specific" and "general" training, where the former is training useful only in the firm in which it was acquired, whereas the latter training is as useful in that firm as in other firms. This distinction regarding the specificity of types of on-the-job training or labor market experience offered many insights regarding labor market activities and investment in human capital.

Moreover, this distinction foreshadowed the distinction between "market specific" and "home specific" human capital on the one hand and skills useful in both sectors on the other hand, that proved so valuable in the analysis of female earnings, labor supply, and the New Home Economics (Mincer and Soloman Polachek 1974). Furthermore, the distinction between "country specific" and "internationally transferable" human capital has proved valuable in analyses for research on immigrants, and migrants in general (Chiswick, 1978).

Becker and Chiswick (1966) reported on two inter-related strands of research in progress on human capital and the distribution of earnings.[7] One was a model of the supply and demand for funds for investment in human capital. While the basic idea that the individual's optimal level of human capital investment occurs where the marginal rate of return from the investment equals the marginal interest cost of funds had been developed earlier, the supply and demand functions for funds for investment were made explicit. Assuming differences in supply and demand conditions across individuals, and under alternative assumptions as to the correlation between individual supply and demand curves, implications were generated regarding investments in human capital and the distribution of earnings. The fuller analysis was presented in Becker's (1967) Woytinsky Lecture.[8]

5. The Schooling-Earnings Function

The other strand in Becker and Chiswick (1966) was to present an alternative approach to estimating rates of return from human capital and to use it to understand the determinants of the distribution (inequality and skewness) of earnings.

Previous estimates of the profitability of investments in human capital used earnings streams and the net present value approach. In Friedman and Kuznets (1945) net present values of earnings streams were computed using a 4 percent discount rate. In Mincer (1962) the net present value formula was converted into a ratio of a constant stream of benefits received indefinitely to the cost of the investment so as to obtain an estimate of the rate of return from on-the-job training. In particular, the rate of return was estimated from average annual earnings relative to the cost of the training. In Mincer (1962, p. 64), the formula was $d/c = (1+r)^n$, where r is the rate of return from the investment, c is the cost of the investment (measured by the annual forgone earnings during the training period), d is the increment in earnings over the alternative job after training is completed, and n is the number of years of training. The net present value formula collapses to this simple formulation for constant benefits and costs, and an infinite working life. Becker (1962, 1964) estimated the internal rate of return on the investment by computing the discount rate that set the present value of the stream of net earnings (benefits minus costs) equal to zero. These procedures were computationally awkward and limited by the scarcity of data, especially on dollars invested in human capital.

In the simplest formulation, in Becker and Chiswick (1966), earnings for person i in year j (E_{ij}) were related to earnings if there were no investment (E_{io}) plus the sum of the annual returns from past human capital investments, $\sum_{j=1}^{n} r_{ij} C_{ij}$, where r_{ij} is the i^{th} person's rate of return from this person's investment (C_{ij}) in the j^{th} period. Defining k_j as the investment (forgone earnings and direct costs) in year j relative to what the earnings would have been if there were no investments in year j, $k_j = C_j / E_{j-1}$. Then it can be shown,

$$(1) \qquad E_{ij} = E_{io} + \sum_{j=1}^{n} r_{ij} C_{ij} = E_{io} + \sum_{j=1}^{n} r_{ij} k_{ij} E_{i,j-1} ,$$

and using the principle of mathematical induction,

$$(2) \qquad E_{ij} = E_{io} \prod_{j=1}^{n} \left(1 + r_{ij} k_{ij}\right).$$

Taking logarithms,

$$(3) \qquad Ln\ E_{ij} = Ln\ E_{io} + \sum_{j=1}^{n} Ln\left(1 + r_{ij} k_{ij}\right).$$

Using the property that $\mathrm{Ln}\ (1+\partial) \approx \partial$ if ∂ is a small number,

$$(4) \qquad \mathrm{Ln}\ E_{ij} \cong LnE_{io} + \sum_{j=1}^{n} r_{ij} k_{ij}.$$

Thus, the natural logarithm of earnings is expressed in terms of the rate of return from the investment (r_{ij}), the investment ratio (k_{ij}) and the number of periods of investment

(n). The product rk is referred to in Becker and Chiswick (1966) as the "adjusted rate of return," r' .

If r' is constant for all levels of investment, equation (4) can be written as:

$$(5)\ Ln\ E_{i,j} = Ln\ E_0 + r_i' n_i + U_i,$$

where the error term (U_i) measures differences across individuals in the omitted variables that influence earnings, including other forms of human capital and luck.

Chiswick (1967, Chapter 2) notes that investment in human capital in the earnings equation can be separated into its components, namely, schooling, on-the-job training and other human capital. Using the notation above, he shows that equation (4) can be written as

$$(6)\ LnE_{ij} = LnE_0 + \sum_{s=1}^{Si} r'_{i,s} + \sum_{j=1}^{Ji} r'_{i,j} + U_i,$$

where r'_{is} and r'_{ij} are the "adjusted rates of return," that is $r_s k_s$ and $r_j k_j$, respectively, from years of investment in schooling (S_i) and years of investment in on-the-job training (J_i), as defined above. Chiswick (1967) also shows how other forms of human capital can be incorporated into the earnings equation. Apart from this equation, Chiswick focuses on understanding rates of return from schooling, and the effects of rates of return from schooling and the distribution of schooling, among other factors, on the distribution of earnings.[9] The evaluation of the on-the-job training component had to wait for Mincer (1974).

Becker and Chiswick (1966, p.364) write that "although the period of formal schooling is now known with tolerable accuracy…only bits and pieces are known about the periods of formal and informal on-the-job training and still less about other kinds of human capital. Unfortunately the only recourse at present is to simplify further: by separating formal schooling from other human capital." Then using equation (4), assuming r'_{ij} is the same for all levels of schooling, and putting differences in r'_i across levels of schooling, on-the-job training and other effects in the residual (u'_i),

$$(7)\quad LnE_{ij} = LnE_{io} + r'_i S_{ij} + u'_i$$

Then the regression of LnE_{ij} on S_{ij} gives an estimate of $r' = rk$.[10] It was also demonstrated in Becker and Chiswick (1966) that estimates of rates of return for distinct levels of schooling can be obtained by creating separate variables, say, for years of primary, secondary and higher education.

When this work was initially undertaken microdata files were not yet available from the decennial census. Published crosstabulations of earnings by education (schooling levels) were available, but not jointly by earnings, schooling and age. The regression of the natural logarithm of earnings on years of schooling, which has been referred to as the "schooling earnings function", was used to estimate the adjusted rate of return from schooling, which, because k was estimated as close to unity, was an estimate of the rate of return (Becker and Chiswick 1966, Chiswick 1967). These estimates were computed overall, by regions and by states of the United States from the 1960 Census and the provinces of Canada for the 1961 Census of Canada, among other countries, for

analyses of the effect of schooling on the inequality and skewness of earnings across regions (Chiswick 1967, 1970, 1974).

This "schooling-earnings function" has been used to demonstrate theoretically and empirically several propositions about the distribution of earnings (Becker and Chiswick 1966, Chiswick 1967, 1970, 1974 Part B). These include: the relative inequality of earnings is larger the greater is the absolute inequality in schooling, the greater the rate of return from schooling, and the greater the inequality in rates of returns from schooling.[11] If rates of return are constant, a normal distribution of schooling generates a log normal (or positively skewed) distribution of earnings.[12]

Becker and Chiswick (1966, p. 365) discuss sources of possible upward and downward bias in the rates of returns from schooling estimated from the schooling earnings function.[13] Included in this discussion is the comment that "the correlation between years of schooling and years invested in other human capital…might well be negative. Certainly persons leaving school early begin their on-the-job learning early, and possibly continue for a relatively long time period." It is noted in Becker and Chiswick (1966 p. 367) that the schooling-earnings function produces rates of return from schooling that are somewhat lower than the internal rates of return estimated from the present value method. They write (p. 367) that this suggests "a negative correlation between school years and the years invested in other human capital."

6. The Human Capital Earnings Function

In 1974, Jacob Mincer published his classic study, *Schooling, Experience and Earnings*.[14] In a very real sense, this book extends the analysis from Mincer's earlier work, especially Mincer 1957 and 1958, yet it also reflects the advances in and the spirit

of human capital theory that had been carried forward by Mincer and others in the intervening years. While it extends the analysis of the effect of human capital on the inequality and skewness of earnings developed in his earlier work, this has received less attention than the development of the human capital earnings function. In this study, Mincer shows that "the inclusion in the earnings function of even crude measures of 'post school investments' in addition to schooling lends a great deal of scope to the analysis of income distribution," and he coins the term "the human capital earnings function" for this expanded relationship (Mincer, 1974, p.2).[15]

In his discussion of investment in human capital, Mincer notes that full-time investment, which is primarily acquired in schools, precedes part-time investment which is generally conducted on the job. Moreover, for several reasons investments in on-the-job training would decline relative to earning potential and in absolute value as experience increases (see also Becker 1967 and Yoram Ben-Porath 1967).[16] These factors include the finiteness of the working life, that profitable investments (i.e., investments where the internal rate of return exceeds the discount rate) are more profitable if made sooner rather than later, and the rising opportunity cost of investment as more skill is acquired. On the other hand, to the extent that the stock of human capital due to prior investments in training increases the productivity of new investments in on-the-job training, additional investments are encouraged. If the interest cost of funds schedule has a non-negative slope, optimal investment occurs in the downward sloping portion of the marginal rate of return schedule. Mincer shows that the concave experience earnings profile that we observe in the data is implied by declining investment ratios (i.e., investment relative to potential earnings).

Mincer also shows (1974, pp. 28-32) that there is an important distinction between age-earnings profiles and experience-earning profiles, where experience means years since leaving school.[17] [18] If individuals differ in their level of schooling, they differ in the age at which post-school (on-the-job training) investments begin, and hence the two profiles differ. Mincer demonstrates that there would tend to be a positive correlation between schooling and on-the-job training investments, not because they are necessarily complements, but because "it reflects the dominance of individual differences in factors determining the scale of total human capital accumulation. Individuals who invest more in human capital, invest more in both forms of it" (Mincer 1974, p.31). [19] That is, those with greater ability and a lower interest cost of funds would tend to have these characteristics for both schooling and on-the-job training.[20] Research suggests that there is a positive correlation in dollar investments among all forms of human capital, even though at the margin various types of human capital can be substituted for each other to attain the same earnings. In the absence of direct information on investments in on-the-job training or on years of labor market experience Mincer suggests "subtracting the age of completion of schooling from reported age" (Mincer 1974, p.47). He recognizes that age is relevant if only because of the depreciation of human capital with age, but in the absence of a mechanism for measuring experience independent of age, experience is to be preferred. Using data that permit independent measures of age and experience, Mincer shows that the latter has a greater partial correlation with earnings (Mincer, 1974, pp.78-80).

In addition to past work effort (labor market experience), Mincer also explicitly incorporates into the analysis current work effort, and in particular weeks worked. Rates

of return from schooling are higher when weeks worked are not held constant. Weeks worked is, not surprisingly, positively correlated with annual earnings, but it is also positively correlated with years of schooling. If the latter positive correlation is due to labor supply effects (higher weekly earnings due to more schooling result in greater weeks worked), Mincer argues (1974 pp.53-55) that rates of return should be estimated on the basis of weekly earnings.[21] On the other hand, to the extent that schooling raises weeks worked by lowering job turnover, unemployment and absenteeism, controlling for weeks worked biases downward the partial effect of schooling.[22] Unfortunately, the issue of the interpretation of the role of employment in the human capital earnings function has received too little attention either conceptually or empirically, whether earnings are measured on an annual, weekly or hourly basis.

To expand the earnings function in equation (6) into what we now refer to as the human capital earnings function, Mincer needed to make assumptions as to how the investment in on-the-job training in each year declines as years of experience increase. Concerned with "mathematical simplicity and statistical tractability" he shows the development of four functional forms, one for each of the four cells defined by dollar investments $\left(C_t\right)$ vs. "time equivalent" investments $\left(k_t = \frac{C_t}{E_{t-1}}\right)$, and linear vs. exponential forms of declines in investments (Mincer 1974, pp.84-89). Largely due to data availability (that is, the data on schooling and potential experience are available in years), time equivalent investment ratios are preferred, and for simplicity the assumption of a linear decline is preferred to the exponential decline in investment, even though the latter would have greater consistency with economic theory.

The investment ratio/linear decline specification is that $k_t = k_o - \frac{k_o}{T^*} T_t$, where k_t is the investment ratio in the T^{th} year of on-the-job training, k_o is the ratio in the initial year and T^* is the number of years of positive net investment in training beyond which $k_t = 0$. Then if LnE_t is the log of earnings in year t and $r_s k_s$ is the same for all levels of schooling,[23]

(8) $$LnE_{it} = LnE_{io} + r_s k_s S_i + \left(r_j k_o\right) T_i - \left(\frac{r_j k_o}{2T^*}\right) T_i^2,$$

where r_j is the rate of return from investments in on-the-job training. Then the logarithm of gross earnings (i.e., earnings in year t if there is no further investment in on-the-job training) can be expressed as a quadratic function of years of labor market experience. It is this functional form that has become the dominant specification in analyses of earnings:

(9) $$LnE_i = b_0 + b_1 S_i + b_2 T_i + b_3 T_i^2 + U_i,$$

where E_i, S_i and T_i, are earnings, years of schooling and years of potential post-school labor market experience (age minus years of schooling minus six), the b's are the regression coefficients and it is assumed that U_i is a normally distributed homoskedastic residual.

It may be noted that this specification provides two estimates of the rate of return from on-the-job training. If there are estimates of k_o and T^*, the rate of return from on-the-job training can be estimated from the coefficient of T or T^2. These two estimates tend to differ in part because the data are for earnings net of current investments, but perhaps more importantly because the investment ratio (k_t) is assumed to decline linearly.[24] Although an exponential decline is a closer approximation of reality, it generates a computationally more complex function (Mincer, 1974, pp.85-90).[25] The variables E, S and T are available in a wide range of data across time and space and their coefficients can be estimated from multiple regression analysis.[26]

Using data on the annual earnings of white non-farm men from the 1960 Census public use microdata sample, Mincer (1974, p.92, Table 5.1) estimates earnings functions for several specifications, including the linear and exponential decline in on-the-job training investment ratios, and with and without holding constant the natural logarithm of weeks worked. He shows that the estimated coefficient of schooling is lower when experience and its square are not included in the earnings function (7 percent compared to 11 percent), but that there is little difference in the schooling coefficient depending on whether it is assumed there is a linear or exponential decline in the experience investment ratios. The partial effect of schooling on earnings is shown to decline with higher levels of schooling for annual earnings, but it is approximately linear for weekly or hourly earnings.

The elasticity of annual earnings with respect to weeks worked is estimated at about 1.2, and is significantly greater than unity (Mincer, 1974, p. 92, Table 5.1). This suggests that weekly earnings are higher for those who work more weeks in the year.

Moreover, Mincer (1974, p. 92, Table 5.1) shows that whereas the explanatory power of the schooling-earnings function in these data is only 7 percent, the explanatory power of the function with the quadratic experience profile is 29 percent, which is increased to 53 percent when dummy variables are used for schooling and the log weeks worked variable is added to the equation. The explanatory power is increased even further when the analysis is computed at the "overtaking age," that is, at the number of years of experience where the variance in earnings by experience level is smallest (about 8 to 10 years of experience). Thus, the human capital earnings function provides a high explanatory power for earnings in spite of the simple measures of investment in human capital, namely, years of schooling and years since leaving school.

Mincer (1974, Chapter 6) then proceeded to analyze the residual, that is, differences in earnings when years of both schooling and experience are held constant. These differences are attributable to differences in the intensity, quality and rates of return from schooling and experience investments, as well as variations in employment. He also considers the distinction between the permanent component and the transitory component (e.g., luck, random shocks) of earnings.

The functional form of the human capital earnings function also served as the basis for the analysis of earnings inequality across time and across space (Chiswick and Mincer 1972, Chiswick 1974 Part C). By taking the variance of both sides of equation (8) the relative variance in earnings is related to the absolute inequality in years of

schooling and in years of labor market experience, as well as the rates of return from these investments. This structure explains most of the variation in earnings inequality over time and across countries and regions of countries.

The "human capital earnings function" has several distinct characteristics that make it particularly attractive:

- The functional form is not ad hoc. It is an identity based on the optimizing behavior of individuals, and represents the outcome of a labor market process.
- It converts "immeasurables" into "measurables," that is, the dollar cost of the investment in human capital becomes converted into years of schooling and years of labor market experience.
- It is readily adaptable to the inclusion of other variables that affect earnings.[27]
- The coefficients of the regression equation have economic interpretations, they are pure numbers (devoid of units) and their standard errors can be estimated. This permits comparisons across time, space and demographic groups.
- Although earnings are positively skewed and the inequality of earnings rises with the level of schooling, by using the natural logarithm of earnings as the dependent variable, the residuals are closer to being normally distributed and homoskedastic.
- The functional form generates a commonly used measure of relative inequality, the variance of the natural logarithm of earnings, thereby

facilitating the study of earnings and income inequality across time and space.

Thomas Lemieux (2000) reviews the literature on alternative specifications of the earnings function to determine whether the simple structure in equation (9) is the most appropriate. He concludes that to a first approximation it is appropriate. He writes "the human capital earnings function remains a parsimonious and relatively accurate way of modelling the relationship between earnings, schooling and experience. Its status as the 'workhorse' of empirical labour economic research on earnings determination is well deserved" (Lemieux 2000, pp.10-11).[28]

7. The Lasting Impact

The human capital earnings function has not been a static development. Just as it evolved from earlier research, so too has it served as the basis for additional developments in theory and measurement.

The insight Mincer developed regarding the distinction between age and labor market experience has proved invaluable in terms of analyses for groups that are not in continuous attachment to a single labor market. Mincer and Polachek (1974), for example, analyze the earnings of women as a function of the timing and length of periods engaged in the labor market, the alternative activity being home production, largely related to child care.[29] This approach has proved invaluable in the New Home Economics literature, as well as demonstrating that adjusting for actual labor market experience and human capital depreciation, rather than only age or years since leaving school, the gender difference in earnings decreases substantially (June O'Neill and Polachek 1993).

Another modification, most useful in analysis for a very low skilled population and for less developed countries, is adjusting the measure of potential experience for those without schooling or who leave school as children. Potential experience is defined as the lesser of years since leaving school or years since the onset of labor market experience that is relevant for adult earnings. Thus, rather than assigning 19 years of experience to a 25 year old with no schooling, if labor market experience relevant for the adult labor market begins at age 15, then 10 years of potential experience would be assigned (Chiswick, 1991).

The human capital earnings function in equation (9) was developed in the context of wage and salary income.[30] Data are often available only for wage, salary and self-employment income combined. Moreover, self-employment is an important type of economic activity. Self-employment income includes the entrepreneur's implicit wage, return on the entrepreneur's investment of his or her own capital, and economic profit which may be positive or negative. One common solution to this problem is to exclude the self-employed from the analysis, as did Mincer, but this creates selectivity bias. To use selectivity correction techniques requires the modeling and estimation of an auxiliary equation to explain self-employment status. Moreover, in some circumstances, especially in rural areas of less developed countries, unpaid family workers are an important component of the labor force, and their productivity appears in the measured earnings or income of the self-employed person or household head. Following in the tradition, Carmel Chiswick (1983) has developed and implemented a methodology for explicitly incorporating into the human capital earnings function the self-employed and the contribution to their income of unpaid family workers.

The insight regarding the distinction between specific and general human capital and the insight regarding the location of labor market investment sparked a new literature on the earnings of immigrants (Chiswick 1978). Where labor market experience occurs matters, and if skills are not perfectly transferable across labor markets, incentives for migration differ across individuals, and post-migration investments in skills relevant for the destination have higher rates of return, with implications for investments and earnings profiles in the destination. The literature on immigrant labor market adjustment and impacts emerged form these propositions.

These insights also had a major influence in subsequent research on the formation, duration and dissolution of marriage in the New Home Economics literature. Using a labor market analogy, the research on marriage made a distinction between human capital investments valuable in home production and human capital that is labor market specific (Becker, Lisa Landes, Robert Michael 1976). This analogy was subsequently extended to distinguish between general marital and spouse-specific marital human capital, that is, between marital human capital that would be valuable in any marriage and investments that are relevant only for a specific mate (Chiswick and Evelyn Lehrer 1990).

The human capital earnings function has also become a technique accepted by the courts in analyses of earnings (Joseph Gastwirth 1988, Federal Judiciary Centre 1994). It is used to estimate the value of lost earnings due to injury or death or resulting from discrimination.

One of the most important uses of the human capital earnings function has been the estimation of rates of return from schooling.[31] Hundreds of such estimates have been

computed.[32] Most references to Mincer's *Schooling, Experience and Earnings* are to the specification of the human capital earnings function. In the year 2000, 26 years after the publication of the book, there were still a remarkable 44 citations listed in the Social Science Citation Index. Yet this substantially underestimates its impact as most users of the technique do not cite, and many may never have read, the source. Perhaps far more telling of its impact is that it has made its way into textbooks in labor economics, personnel economics and econometrics.[33]

Indeed, perhaps the highest compliment that can be paid is that the structure of the equation has become a standard feature of research in labor economics, the economics of education and in labor market analyses by sociologists. Its origins are often taken for granted. This is unfortunate as the subtleties Mincer developed in *Schooling, Experience and Earnings* are too often lost on the users of the human capital earnings function.

[1] A word search in June 2002 indicated that the term "human capital" first appeared in the title of an article in a journal covered by JSTOR in Mincer (1958). The term appeared in the text of an economics journal article in JSTOR in only 29 articles published in 1957 or earlier (starting with two articles on the meaning of capital by Irving Fisher in the *Economic Journal* in 1897), twice in 1958 (including Mincer's article), in 188 articles in the decade 1959-1968, in 756 articles in the decade 1969-1978, in 1,137 articles in 1979-1988 and 1,713 in 1989-1998, even though not all of the included journals go through 1998.

[2] Although there have been numerous studies that have examined the slopes of experience earnings profiles across groups (e.g., males vs. females, blacks vs. whites, immigrants vs. natives), this is distinct from estimating rates of return from investment in experience or on-the-job training.

[3] It is fitting that this conference honoring Jacob Mincer's intellectual contributions to economics was held in the 40th anniversary year of the publication of *Investment in Human Beings.*

[4] For workers several decades away from retirement the effect of the finiteness of life on the rate of return from investment in on-the-job-training is small. Additional explanations, including the rising opportunity cost of time, are presented in Yoram Ben Porath (1967) and Mincer (1974).

[5] In later research Mincer (1974, p. 74) shows that the dollar value of investments in on-the-job training rises with the level of schooling and that they are the equivalent of an additional 3 to 5 years of schooling.

[6] They do have one unpublished co-authored paper. They each co-authored with several of their students, although up to this date I am the only person who co-authored with both of them.

[7] The major products of this research were Becker (1967) and Chiswick (1967), as well as Becker and Chiswick (1966).

[8] Becker (1967) uses the framework to analyze the effects on the distribution of income of differences in "ability" (demand conditions) and differences in "opportunities" (supply conditions), as well as the correlation between these conditions. Chiswick (1988) uses the framework to analyze differences in the levels of investment in human capital and differences in earnings across racial and ethnic groups in the United States.

[9] Parts of Chiswick (1967) were published as Chiswick (1970) and Chiswick (1974, Part B).

[10] Note that conceptually this coefficient is not the rate of return from investment in schooling, but rather is the product of the average rate of return and the average investment ratio. Only if it can be assumed that $k=1$ is this the rate of return. Nearly all

estimates of rates of return from schooling using this procedure unwittingly assume that k=1. This need not be the case. For example, if out of pocket costs and some forgone earnings costs of schooling are subsidized (as in the educational benefits under the post-WWII GI Bill of Rights or university education more generally in some countries), k is smaller than unity and r' is an underestimate of the rate of return from schooling.

Arleen Leibowitz (1976) presents theoretical arguments for why k and S may be correlated and demonstrates that they are positively correlated for higher education in the Terman sample. James Heckman and Edward Vytlacil (1998) demonstrate an instrumental variable technique to correct for bias when the coefficient of a variable is correlated with the variable, and apply this technique to the schooling-earnings function.

[11] For example, if LnE_o and r′ are constant across individuals, and if S_i and u'_i are uncorrelated, $Ln E_{ij} = Ln E_0 + r' S_i + u_i'$, and taking variances, $Var(Ln E_i) = (r')^2 Var(S_i) + Var(u_i')$. If r_i' and S_i vary, but are independent of each other, the inequality in earnings is a function of the level and inequality of r_i' and S_i (see Leo Goodman 1960). The ratio of the explained variation in earnings $\left[(r')^2 VarS\right]$ to the total variation in earnings $\left[VarLnE\right]$ is the coefficient of determination for log earnings.

[12] If rates of return vary across individuals but are uncorrelated with the individual's level of schooling, even the natural logarithm of earnings has a small positive skewness. This skewness is greater if rates of return and schooling levels are positively correlated. The

correlation would be positive if, as is likely, demand conditions vary more across individuals than supply conditions for funds for investment in human capital.

[13] See also Chiswick (1967, Chapter 2).

[14] This NBER book had circulated in manuscript form in 1972, two years prior to publication.

[15] For surveys of the literature see Mincer (1970), Robert Willis (1986) and Sherwin Rosen (1987, 1992).

[16] William Haley (1973) presents a model in which the decline in the specialization of investment in human capital begins even before the end of schooling. See also Leibowitz (1976).

[17] I recall someone asking Mincer where he came up with the fundamental insight regarding the distinction between age and labor market experience, and he replied that it was based on his own life experience.

[18] As discussed below, this was later expanded to a distinction between years since leaving school and years and timing of actual labor market experience.

[19] See Mincer (1974, pp.74-75) for his estimates of investment in schooling and on-the-job training by schooling level.

[21] At the investor's optimum, the marginal internal rates of return and the marginal interest cost of funds for all types of human capital investment should be equal.

[21] Moreover, if this is the case, weeks worked is endogenous and the coefficient of the log weeks worked variable in the human capital earnings function is biased. Seasonality in employment and a backward bending labor supply curve would tend to lower the elasticity of annual earnings with respect to weeks worked below unity.

[22] If $LnE = b_0 + b_1 S + b_2 LnW$ where E is annual earnings, S is schooling and W is weeks worked, $\frac{\partial LnE}{\partial S} = b_1 + b_2 \frac{\partial LnW}{\partial S}$, and the coefficient of schooling (b_1) needs to be augmented by the indirect effect of schooling through weeks worked to obtain its total effect.

[23] Using the continuous form, Mincer (1974) shows that the aggregate of the effects on log earnings of post-schooling training is $\int_{t=0}^{T} rk_t dt = \int_{0}^{T} r(k_0 - \frac{k_0}{T^*}t)dt = (rk_0)T - \frac{rk_0}{2T^*}T^2$, where r is assumed to be the constant rate of return from on-the-job training.

[24] To the extent that investments are made in the year for which the earnings data are available, $Y_t = E_t - C_t = E_t(1-k_t)$ or $LnY_t = LnE_t + Ln(1-k_t)$, where Y_t is earnings net of current period investments and $k_t = k_0(1-\frac{T}{T^*})$. The adjustment is small when T^* is a large number (Mincer, 1974, pp.90-91).

[25] If an exponential decline rather than a linear decline in investment ratios is more appropriate, the human capital earnings function would understate earnings growth in the early period of investment and overstate earnings growth in mid-career. Kevin Murphy and Finis Welch (1990) use higher order polynominals in experience and find that this appears to be the case.

[26] Indeed, this earnings function has been used to estimate the partial effect of schooling on the log of earnings (interpreted as rates of return from schooling) for about 100 different countries (George Psacharopoulos and Harry Patrinos, 2002).

[27] For example, if $E_{ij} = E^*_{ij}(1+\gamma)^{D_i}$, where E_{ij} is earnings, E^*_{ij} is earnings due to human capital, D_i is a dichotomous variable for some characteristic, and γ is the percent increase in earnings for those with characteristic D (D=1) compared to those without it (D=0), then $LnE_{ij} = LnE^*_{ij} + \gamma^* D_i$, where $\gamma^* = Ln(1+\gamma)$, which is approximately equal to γ if it is small.

[28] Heckman and Polachek (1974) came to a similar conclusion when the human capital earnings function was still quite new: "Evidence from several bodies of data suggests that among simple transformations the natural logarithm of earnings is the correct dependent variable while the best simple specification of the regressors is one advanced by Jacob Mincer on theoretical grounds" (p.350). Willis (1986, p. 526) writes: "As an empirical tool, the Mincer earnings function has been one of the great success stories of modern labor economics." Murphy and Welch (1990), however, show that higher order polynomials provide a better fit to the data than the quadratic specification. In more recent work in progress James Heckman, Lance Lochner and Petra Todd (2002) suggest that the human capital earnings function provides a better fit to the data for the 1940's to 1960's than in more recent decades.

[29] See also Mincer (1974, pp. 121-125) and Polachek (1973).

[30] Mincer (1974, p.125) notes that his study was focused on adult earners continuously attached to the labor market, with the empirical analysis on white non-farm males in the United States. The self-employed were explicitly excluded from consideration.

[31] Since the 1970's the estimation of rates of return from schooling using the human capital earnings function has become commonplace as a result of its low and falling cost and public interest. The falling cost is due to the combination of the availability of micro data files from censuses and surveys that include questions on earnings, age and schooling, among other variables, the falling cost of computing, and the ease of

estimation with the development of the human capital earnings function. While these factors also lowered the cost of estimating rates of return from on-the-job training, it is still more complex because of the lack of good data (in particular, the greater difficulty of estimating the amount of the investment) and there has been no similar explosion of research output.

[32] For references to estimates of rates of return from schooling for nearly 100 countries, see Psacharopoulos and Patrinos (2002). These estimates have a remarkably narrow range, primarily from 5 to 15 percent.

[33] See, for example, Ernst Berndt (1991, Chapter 5), Edward Lazear (1998, pp.164-165), George Borjas (2000, pp.264-268), and Bruce Kaufman and Julia Hotchkiss (2000, Appendix 7B, pp.401-405).

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