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EARNINGS OVER THE LIFE CYCLE: WHAT DO HUMAN CAPITAL MODELS EXPLAIN?

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I INTRODUCTION: MOTIVATING THE REBIRTH OF HUMAN CAPITAL THEORY

Based on the theory of comparative advantage, one would think it paradoxical for a country to export labour intensive commodities at a time when its wages were relatively high compared to other countries. Yet using an input-output table for 1939, a year when US wages were relatively high, Leontief (1946) noticed US exports to be labour, and not capital intensive.

About 15 years later, Schultz (1961) found that prevailing economic models failed to fully account for US growth. Between 1919 and 1957 per annum US output rose by 3·1%, while labour and capital increased by a mere 1% (p. 50). According to Schultz, output rose more quickly than one would expect given the secular increases in capital and labour. Similarly in Britain and other countries, changes in physical capital and labour as conventionally measured explained only a fraction of the growth of national income.

At the time when these two findings emerged, the theory of comparative advantage and the prevailing models of growth relied on a standard neoclassical production function framework. One limitation of this framework is the assumption of input homogeneity: all capital and all labour were assumed to be identical. Because few countries achieved sustained levels of economic growth without having invested substantially in education, researchers began to question whether input quality, particularly for labour really was constant, either over time or across countries. Since labour quality is reflected in a worker's education and training, a new line of research, namely human capital theory developed to study how society invests to enhance worker quality, and hence worker productivity. Leontief's paradoxical finding that US exports are labour intensive could be solved by realizing that US workers had a relatively high skill embodiment. Similarly, unmeasured worker human capital could explain Schultz's observation regarding US growth.

Although these developments took place in the 1950s and 1960s, human capital theory actually has roots at least back to Sir William Petty who considered labour 'the father of wealth' (Kiker, 1971, p. 62). Indeed according to Kiker 'human capital was somewhat prominent in economic thinking until Marshall discarded the notion as 'unrealistic' (*ibid.*, p. 51) ... since human beings are not marketable (*ibid.*, p. 60).' Since Petty, prominent economists who have considered human capital include Say, Senior, List, von Thünen,

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Engel, Walras, Fisher (*ibid.*, p. 51).[1] But these economists were primarily concerned with the capitalized value of labour particularly as it applied to measuring national wealth and the resulting changes in national wealth caused by war (e.g., Giffen, 1980; Guyot, 1914; or Boag, 1916) or immigration (e.g., Kapp, 1870). Apparently, not considered were life cycle aspects of an individual's investment decisions, though in 1935 Walsh produced tables essentially containing age-earnings profiles for select occupations (law, engineering and medicine) and in the process computed net present values (i.e., benefits minus costs) for each.

With an interest primarily to explain a country's growth, initial research considered aggregate measures of human capital. Perhaps this is why Schultz (1961) developed exhaustive measures of US human capital stock. From these he tried to quantify the portion of GNP growth unexplained by conventional models. While macroeconomic growth considerations can explain motives for public human capital investment, other patterns, such as repeated evidence that the most educated workers have the highest earnings led researchers to explore reasons why individuals devote their own resources to educational investments. Clearly, if education enhances personal earnings then private spending on education pays. Understanding such investments in education resulted in studies deriving methods to estimate private returns (Becker, 1975).[2]

Mincer (1958), in his quest to devise econometric techniques to estimate these returns, is probably the first to model human capital investment using capital theory's mathematical tools. By showing that individuals invest up to the point where investment costs just equal the present value of schooling gains, he obtained a simple and tractable econometric specification leading to the now famous log-linear earnings function.[3] Not only did this formulation provide a measure of private rates of return to schooling, but it easily generalized to get at post-school on-the-job training, as well. Mincer's measures of on-the-job training are contained in his 1962 article and updated in Mincer (1993). On-the-job training accounts for between 11 and 15% of total worker compensation (*ibid.*, p. 279).

Mincer's work showed that a worker's wages consistently rise over the life cycle at a decreasing rate, yielding a concave earnings profile for most individuals. Not only does human capital theory explain this concavity, but human capital theory has strong implications concerning the rate at which earnings rise at each phase of the life cycle. Human capital theory also explains gender, race, and ethnic differences in earnings, geographic and job mobility, occupational choice as well as worker turnover, unemployment, and other labour market issues. But these applications came later in the development of human capital theory, so I relegate their discussion to later in this article.

[1] Street (1988) emphasizes that one should also remember Gaspar Melchor de Jovellanos (pp. 1744–1811), a not too well known Spanish economist as one of the founding fathers of human capital.

[2] A host of studies with actual country estimates emerged and are surveyed by Psacharopoulos (1985). Many of these explicitly distinguish between private and social rates of return.

[3] For an alternative derivation see Becker and Chiswick (1966).

Before going on, let me note that other theories of earnings are now becoming popular. The most recent approaches involve incentive based compensation schemes. In these models, firms provide an earnings contract to workers to maximize effort and hence productivity. Some argue that such contract models complement human capital in explaining wages and other labour market phenomena; others argue that contract models substitute for the human capital model. This survey explores the question and concludes that to determine the relative merits of each, one has to consider both type models simultaneously in a unified framework. Perhaps one contribution of this survey paper is to present a framework encompassing both sets of models which I hope can be used as a basis for future empirical testing.

II HUMAN CAPITAL'S THEORETICAL DEVELOPMENT: A LIFE CYCLE APPROACH

To begin to understand these labour market patterns alluded to above, the human capital model explores how an individual invests over his[4] lifetime. Perhaps the first to do this was Ben-Porath (1967) in his classic article.[5] Under the assumption that investments in oneself enhance earnings, Ben-Porath claimed that individuals make investment decisions based on maximizing the present value of lifetime earnings. His innovation was to take advantage of the finite life constraint by realizing that investment gains decline as one gets older. Declining investment gains imply a continually decreasing human capital investment which in turn implies a rise in one's human capital stock and earnings power, but at a decreasing rate. This process explains why most individuals acquire all their schooling early in life, why geographic mobility is prevalent more among the young, as well as why earnings rise quickly for the young but taper off as workers age. In short, the life cycle approach explains the basic patterns for earnings as well as some aspects of job and geographic mobility.

This life cycle process can best be seen within the context of an optimization process. The individual[6] maximizes expected value of discounted earnings (one could also incorporate unearned income acquired through nonhuman capital investments as well) by appropriately allocating resources to human capital investment. These investments augment the individual's human capital *stock* which in turn raises earnings power (though not necessarily actual observed take-home pay because some of the human capital stock is used to further invest). Current human capital stock is composed of last year's non-depreciated human capital augmented by new investment.

[4] I use *his* here on purpose. Initial human capital models (Ben-Porath, 1967) dealt with workers who exhibit continuous labour force participation. Modifying the approach to deal with discontinuous labour force participation more typical of women came later. See Mincer and Polachek (1974) and Polachek (1975a).

[5] Also see Sheshinski (1968). Becker (1967) abstracts from the life cycle by dealing with investment decisions over the whole lifetime rather than in each phase of the life cycle.

[6] Some have looked at this process within a family context. See Mincer (1978), Polachek (1975b), and Polachek and Horvath (1977).

This process can be illustrated mathematically: If $K(t)$ is human capital stock at time t; and w is the rental rate (or wage) per unit of human capital; then $wK(t)$ is *potential* (not necessarily actual) earnings. Note that all human capital receives the *same* wage, implying homogeneous human capital as well as a neoclassical *non-incentive* based wage setting mechanism. (I return to this later.) Actual earnings (the pay cheque one actually receives) are potential earnings $[wk(t)]$ minus investment costs $[I(t)]$ so that take home disposable earnings are $[wk(t)-I(t)]$.[7] Investment costs $I(t)$ consist of the cost of purchased inputs and foregone earnings. However, for simplicity one can assume that all investment costs are opportunity costs so that $I(t)$ simply equals $s(t)wK(t)$ where $s(t)$ is the time spent in period t investing in human capital.

Thus individuals seek to maximize the present value of lifetime earnings

$$\underset{s(t)}{\text{Max}} \int_0^T Y(t)e^{-rt}dt \tag{1}$$

where $Y(t)=[1-s(t)]wK(t)$, by appropriately choosing the time they spend $[s(t)]$ investing in human capital.[8] As will be illustrated, investment has a benefit (increased future earnings) and as was illustrated a cost (foregone earnings); equating both cost and benefits at the margin in each year is the optimal strategy to maximize the present value of earnings.

To see this, write out the annual change in human capital as

$$\dot{K}(t)=Q(t)-\sigma K(t) \tag{2}$$

where $\dot{K}(t)=dK(t)/dt$; $Q(t)$ is the amount of human capital created; and σ is the depreciation rate of old human capital. New human capital $[Q(t)]$ is created by combining one's own time $s(t)$ with already existing human capital (recall that I assume no purchased inputs) so that $Q(t)=f[s(t),K(t)]$, the cost of which is $wsK(t)$ as already mentioned.

The maximization problem entails setting up a Hamiltonian (the dynamic analogue to the LaGrangean multiplier)

$$H=[(1-s(t))wK(t)]e^{-rt}-\mu(t)[f(s(t),K(t))-\sigma K(t)$$

where each term is already defined with the exception of $\mu(t)$ which represents the present value of added human capital investment.

First order conditions dictate that individuals equate the marginal costs of investment time $[wK(t)]$ to the marginal gains $[\sigma(t)f'_{s(t)}]$. Ben-Porath followed

[7] In this formulation, I ignore hours of work which can be brought in either of two ways: one possibility is to assume one works less than 24 hours per day to invest in mental health to preserve one's sanity. This approach makes labour supply a health investment decision. An alternative approach is to generalize the individual's objective function to maximize lifetime *utility* rather than maximize wealth. This latter approach adopted by Blinder-Weiss (1976), Heckman (1976), and Ryder *et. al.* (1976), and later modified to incorporate the feedback effect of human capital investments on future labour supply (Jiang and Polachek, 1991) embeds the traditional labour leisure labour supply model into the human capital acquisition process.

[8] Uncertainty can be incorporated. For example, see Levhari and Weiss (1974), Snow and Warren (1990), Orazem and Mattila (1991) and Altonji (1993). However, considering uncertainty would not alter this paper's conclusions.

by Wallace and Ihnen (1975), Ryder, Stafford and Stephan (1976), Johnson (1978), and others describe several phases of investment. The initial phase resulting from a corner solution in the maximization process is pure specialization of investment—what some call schooling.[9] During schooling, human capital stock rises at an increasing rate. Though (for most definitions of school) there is no actual disposable earnings (since one specializes in learning rather than earning) potential earnings are rising at an increasing rate. (See Polachek and Siebert, 1993, Ch. 3, especially Figure 3.3.)

During the next phase individuals both work and invest. This phase is either called post-school investment (PSI) or on-the-job training (OJT). One important result emerges during the OJT phase: For the typical human capital production function, time spent investing declines monotonically over the life cycle.[10] This means that individuals annually create less human capital as they get older. Thus human capital stock increases at a decreasing rate as does potential earnings which are proportional to human capital stock (recall that earnings potential $E(t) = wK(t)$). As such, both one's earnings potential and one's observed earnings (i.e., one's earnings potential minus one's human capital investment) can be depicted as concave functions. Indeed assuming that the schooling phase lasts S years, and that during the OJT phase time spent investing declines linearly, Mincer (1974) derives a quadratic log-linear earnings function[11]

$$\ln y = a_0 + a_1 S + a_2 e + a_3 e^2 \tag{3}$$

mentioned above. Here a_0 is related to initial earnings capacity,[12] a_1 is the rate of return to education (assuming all schooling costs are opportunity costs), and a_2 and a_3 are related to *both* the amount and the financial return to on-the-job training. This function is often referred to simply as the Mincer earnings function.

Before going any further, one should note some limitations of this basic model. First individuals are assumed to be risk neutral so that stochastic effects play no role in determining decision choices. Second, individuals are assumed to know (with certainty) how many years they shall work over their lifetime. Third, as was already mentioned, individuals are assumed to work fully over their lifetime. Clearly this isn't always the case since it is well known that both work hours and labour force participation vary over the life cycle. Variations in

[9] The precise definition depends on whether purchased goods can substitute for time as an input to produce human capital, whether human capital purchases are subsidized, and what one assumes about the individual's ability to borrow.

[10] There are exceptions: For example, early in the life cycle when individuals specialize in school and later in life when the intermittent worker just re-enters the labour force. More on these later. Also Ehrlich and Chuma (1990) show that health investments can rise because the gain in longevity increases as one approaches death.

[11] Other investment decay functions yield alternative functional forms for the earnings function. In nested tests using Box-Cox and Box-Tidwell variable transformations Heckman and Polachek (1974) showed that the log-linear earnings function appears to be the best fitting simple functional form. Murphy and Welch (1990) found some evidence that quartic fits might also have merit.

[12] A precise definition of these coefficients takes into account parameters describing the rate of investment and the rate of human capital depreciation. See Mincer (1974 p. 21 and 91), Johnson (1970) and Polachek and Siebert (1993, Appendix 4.1).

labour force participation (which will be discussed later) is especially prevalent among women. Fourth, all individuals are assumed identical in every respect. This includes one's ability to create more human capital (i.e., individual human capital production functions), one's commodity rate of time preference (in models incorporating leisure and labour supply), one's ability to borrow to finance human capital investment (applying to models in which purchased goods are important to human capital acquisition), and one's discount rate. Fifth, human capital is assumed to be homogeneous. All individuals differ in the amount of human capital, but not in the type of human capital. Sixth, the rental rate per unit of human capital is assumed to be exogenously fixed over one's entire lifetime. Indeed how the human capital rental rate (w) is determined is completely neglected in human capital literature. Each of these limitations (especially the sixth which has blossomed into a large literature on contracting type models) have been addressed in the literature. I view contract type models as considering only *one* type of limitation of the early human capital models. Introducing human capital heterogeneity and information are others. Before addressing these modifications, I go on to the current model's implications.

III TESTING THE HUMAN CAPITAL MODEL

Education

By now all take for granted the positive correlation between earnings and schooling, though as I shall explain later there are some different interpretations.[13] Griliches (1963, 1964) was the first to directly test whether schooling had any real effect on output. His 'natural experiment' was to see if a farmer's education affects farm output. From state (and regional) data, he found far greater farm production in states with higher levels of education. While having data on each individual farmer's education and output would be more appropriate than aggregate data, the results are nevertheless consistent with predictions generated by human capital models. Indeed generalizing these results to country economic growth Barro *et. al.* (1993) find that the higher a population's education, the higher its GNP and GNP growth per capita. Also educated immigrants assimilate far more quickly into the US economy (Borjas, 1992, 1993). Still in fairness to those advocating screening and signalling hypotheses, it is possible that education serves as a screen or signal to better match people to jobs thus enhancing industry specific and national productivity without enhancing a given individual's productivity *per se*.

[13] For example, Spence (1973) claims that while costly, school acts as a signal by which employees can screen workers. In this case, schooling doesn't enhance a worker's productivity *per se* even though education is associated with higher earnings and more productivity. On the other hand, using an innovative test which distinguishes one's relative educational position from one's actual schooling level, Kroch and Sjoblom (1994) conclude that human capital 'is the predominant explanation of schooling's value' (p. 156). In a different vein, empirical work such as by Taubman (1976) argues that econometric rate of return estimates are biased upward because an individual's ability, omitted from rate of return computations, is positively correlated with school. Ashenfelter and Krueger (1994) argue in favour of a negative bias, but one might question this interpretation given the uniqueness of their data.

Race, education and the black-white wage differential

Prior to 'Brown vs. the Board of Education' blacks in the US were relegated to separate but 'equal' schooling. Welch (1974) argued that at least a portion of the black-white wage gap can be explained by school quality deficiencies. Using data on several black cohorts he shows dramatic increases in educational rates of return to 'newer' vintage black cohorts. Welch attributed these greater schooling returns to increases in black school quality relative to whites, and went on to claim that school quality is an important aspect of the black-white wage gap. Despite its persuasiveness the Welch study is limited because there were no direct measures of per capita inputs in black compared to white schools. However, going back to state data, Card and Kreuger (1992) rectified this deficiency by compiling direct measures of school quality. These include pupil-teacher ratios, annual teacher pay, and school term length, all of which are linked to US Census data. Changes in school quality explain at least 50–80% of the relative increase in black educational rates of return and at least 15–25% of the narrowing of the black-white earnings gap between 1960 and 1980. Again while some might offer explanations other than human capital, there is striking consistency with human capital predictions: education positively affects labour market success, and the better the school quality the greater the success.

Earnings function concavity

Turning back to the earnings function, there is one finding obtained by virtually every study. This universal finding is earnings function concavity. Earnings consistently rise at a decreasing rate throughout one's life. Early studies (Mincer, 1974) tested this proposition using OLS regression with cross-sectional data, but the results hold when one adjusts for Gronau-Heckman type selectivity biases (Hartog, *et. al.*, 1989; Kiker and de Oliveira, 1992; or Baldwin, Zeager and Flacco, 1994), as well as when panel data are used to correct for individual specific heterogeneity (Mincer-Polachek, 1978; Licht-Steiner, 1991; Kim-Polachek, 1994; Polachek and Kim, 1994; Light and Ureta, forthcoming).

Earnings distribution over the life cycle

Perhaps other human capital model predictions are even more interesting. Take implications concerning the earnings distribution. Imagine two hypothetical earnings profiles depicting earnings streams for two individuals (Figure 1). Individual one works upon high school graduation achieving an earnings stream GA; individual two works only after attending college achieving an earnings path CDEOB. All the while in college and in the early phases of work, individual two earns less than individual one (CDEO<GO). Only later does school pay higher earnings. If society were divided between two groups: one attending only high school, and the other attending college, then the population's earnings distribution would be relatively large for the young, decline to

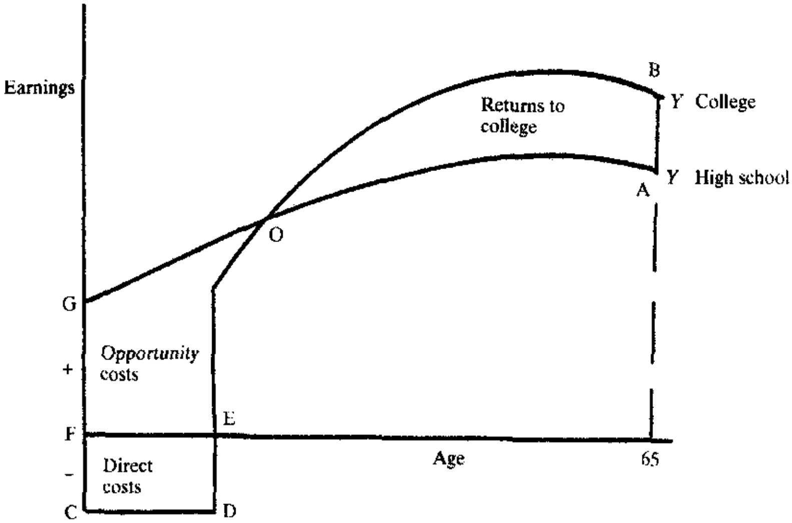

Figure 1. The Mincer overtaking point.

zero at point O (what Mincer calls the 'overtaking' point) and finally increase dramatically afterwards. In addition, because human wealth is the present value of lifetime earnings, the distribution of earnings should exceed the distribution of 'human wealth' for most experience levels. Indeed, this prediction is precisely what is found in the data. Mincer (1974) observes that 'experience profiles of log variances are largely U-shaped' and Lillard (1977) observes a larger variation in earnings than human wealth.

IV EXTENDING THE BASIC HUMAN CAPITAL MODEL

Adding categorical dummy variables to the basic Mincer log-linear earnings equation yields estimates of earnings differences by demographic group. Literally a slew of studies appeared beginning in the 1970s adopting this technique to estimate the effects of race, gender, ethnicity, union membership, region, city size, health and other factors affecting earnings. Many take wage differences holding education and experience constant as measures of discrimination. However, such 'discrimination' can be explained by the human capital model.

Human capital and the earnings of women

Take the case of gender. Regression results yield approximately a 20–30% male-female wage gap, with the exact magnitude depending on the year and what other variables are held constant. For most countries the gap was roughly 30% in the 1960s and less than about 20% in the 1990s (Blau and Kahn, 1992; Nager, 1993).

Early work (Bergmann, 1974) attributed these differentials to market discrimination: corporations relegate women to the worst low paying jobs—what Bergmann calls occupational segregation. Because she asserts that women are disproportionately assigned poor quality, low paying jobs, she argues that occupational segregation explains why wage differentials are relatively small within narrow occupations but large for aggregate data. On the other hand, such a theory of discrimination cannot explain observed wage differences by marital status (Polachek, 1975b) yielding a wage gap exceeding 50% for married men and women yet less than 15% for singles obtained from adding a marital status-gender interaction categorical dummy variable to the Mincer earnings function (amounting to running the earnings function separately for marrieds and singles).[14] Clearly if discrimination were the prime reason for gender wage differentials, one would need an alternative theory explaining why the model applies to marrieds but not to singles.

At least in the past, the average woman exhibited intermittent labour force participation. She entered the labour market after school completion, dropped out sometime after marriage to bear and raise children, and finally re-entered the labour market after her children were sufficiently old. Such labour market patterns have implications for human capital investment. In this case, human capital investment need not decline monotonically over the life cycle as it does for continuous workers (Polachek, 1975a; Weiss-Gronau, 1981; Goldin-Polachek, 1987; Kao-Polachek-Wunnava, 1994). To see this, the life cycle human capital model discussed above must be modified to incorporate intermittent labour force participation simply by adding a categorical variable (N_t) equal to one when the individual is in the labour market in period t, otherwise 0.[15] The objective function (1) then becomes

$$\underset{s(t)}{\text{Max}} \int_0^T N(t)[1 - s(t)]wk(t)e^{-rt}dt \tag{4}$$

where now note $[1 - s(t)]wK(t)$ is multiplied by $N(t)$. If $N(t) = 0$ for $t_1 < t < t_2$, then the objective function becomes

$$\int_0^{t_1} [1 - s(t)]wK(t)e^{-rt}dt + \int_{t_2}^{T} [1 - s(t)]wK(t)e^{-rt}dt.$$

In general, dropping out lowers the marginal gain from investment, thereby lowering investment incentives. Clearly a decreased investment incentive diminishes human capital investments resulting in smaller earnings and a flatter age-earnings profile. However, even anticipating dropping out of the labour market similarly lowers investment incentives. According to Polachek (1975) the marginal gains from investment equal

$$MG(t) = -w_0 N(t)e^{-t(T-\tau)} + w_0 re^{rt} \int_t^T N(\tau) - N(t)e^{-r\tau}d\tau. \tag{5}$$

There are two terms. The first is the standard negative term indicating that gains from investment decline as one gets older. The second illustrates the change in

[14] An international comparison performed by Blau and Kahn (1992) yields about a 5% wage gap for singles and a 45% gap for marrieds.

[15] Without loss of generality one can specify N_t to be hours of work which fall to zero when one drops out of the labour market.

marginal gains as labour force participation changes over the life cycle. As expected, a decline in labour force participation quickens the rate at which marginal gains decline. However, an increase in labour force participation can cause the marginal gain to rise rather than fall. In part, this explains why the simple concave Mincer earnings function does not work for women, and why upon re-entry into the labour market women's earnings move towards quickly getting restored. Discrimination based models of women's wages cannot explain these patterns.

Indeed, modifying the Mincer earnings function to take account of periods of intermittent labour force participation by creating a 'segmented' earnings function (Mincer-Polachek, 1974) indicates flatter earnings profile slopes for those anticipating the most intermittent labour force participation when they just graduate and first enter the labour market (Sandell and Shapiro, 1980), as well as significant earnings depreciation ('atrophy') after exiting the labour force. Yet after finally re-entering the labour market for good there is a rapid restoration of earnings (Mincer-Ofek, 1982), as predicted by human capital theory. (Again see Polachek, 1975 as well as Yoram Weiss and Reuben Gronau, 1981.)

Heterogeneous human capital

One limitation of human capital theory is that all human capital acquired is assumed homogeneous. As such all earnings variations arise because of individual variations in human capital stock ($K(t)$ in the above formulation). Yet it seems so obvious that not everyone acquires the same *type* of human capital. Clearly, college majors vary, as do even the very basic high school courses (Polachek, 1978; Paglin-Rufolo, 1990). Likewise evidence from the *Dictionary of Occupational Titles* clearly indicates that job skill requirements differ.

One can extend human capital theory to deal with heterogeneous human capital. One approach (Polachek, 1976, 1979) is to index *type* of human capital by its characteristics. With this approach there is a continuum of human capital types, so that now an individual maximizes

$$\operatorname*{Max}_{s(t,\delta)} \int_0^T [1 - s(t)]w(\delta)K(\delta, t)e^{-rt}dt \tag{6}$$

by spending time $s(t, \delta)$ purchasing *type* δ human capital, where δ is the index of human capital type. Note too that because of compensating wage differentials, the wage of each type of human capital differs—hence wage w is also indexed by δ. To empirically implement this model Polachek zeroed in on only one characteristic, namely atrophy, and applied the model to gender occupational segregation. He argued that if type of human capital differs in depreciation rate (atrophy) then those individuals with the most intermittent labour force participation specialize in human capital with the least atrophy.[16]

[16] To derive this theorem Polachek further assumed that individuals specialize in only one type of human capital and that each type of human capital's wage was determined by hedonic wage models (Rosen, 1974; Tinbergen, 1951).

Equating type human capital with occupation he showed that those workers expecting to drop out of the labour force minimize losses from intermittent labour force behavior by choosing occupations with the lowest atrophy rates. Data clearly indicate atrophy rates to vary by education and occupation with a sorting of the more intermittent individuals to occupations with the lowest atrophy rates. Unquestionably this has implications regarding gender occupational segregation. Indeed he showed that a doubling of women professionals and managerial workers if their labour market intermittency would drop to zero. Again theories of discrimination do not lead to this result.

Human capital and matching

Looking at occupational choice this way implies that occupations differ from each other in skill content. Some skills depreciate more quickly when not used (atrophy) while others become obsolete as technology changes. As such, human capital is heterogeneous with each individual choosing one type of human capital (occupation) to best match his or her own attributes. This matching describes the above occupational choice model (Polachek, 1979, 1981), but also has been applied to explain college major (Paglin-Rufolo, 1990), and geographic and job mobility (Polachek and Horvath, 1977), as well as to explain why turnover declines with tenure on the job (Jovanovic, 1979b). Becker (1974) even carries this one step further by applying matching to assortive mating, thereby getting at family investments in human capital.

Human capital and search

In a sense the whole matching process is really a form of search. Workers search for the best job matches, and employers for employees with the best job skills. Search and matching models developed independently of human capital research (Rees, 1966; Stigler, 1961) but in reality information is a valuable resource in which employees and employers both invest. The more information each party obtains, the better the match and the higher are worker wages and productivity. In most of these models a worker selects a reservation wage that equates marginal costs (including opportunity costs of not accepting an offer) and marginal benefits of search. This search strategy has two implications: First, there is incomplete information, since the stopping rule of just meeting one's reservation wage likely leads one to compromise by sufficing instead of ending up in the *best* job possible. (The same can be said of employers compromising in the quest for the best employee.) Second, incomplete information likely results in eventual job turnover because imperfect information on both sides likely leads to some bad matches.

The degree of imperfect information can be measured by applying generalized frontier estimation techniques (Hofler and Polachek, 1983; Polachek and Yoon, 1987 and forthcoming; Groot and Oosterbeek, 1994) to the Mincer earnings function to separate observed wage dispersion into purely random variation (i.e., noise in the data), variation due to incomplete employee information and variation due to incomplete employer information.[17] The approach is based on search theory. With incomplete information, workers receive a wage less than the best available, and firms pay a wage more than need be paid to an appropriately skilled worker. *Ceteris paribus*, the difference between the wage paid by the best employer (if the worker could identify the employer) and the wage a worker actually gets can be defined as incomplete employee information. Similarly, the difference between the wage a firm actually pays and the wage it need pay if it could identify a possible employee with a lower reservation wage can be defined as incomplete firm information.

To get at these differences, one can re-estimate Mincer's earnings function (3)

$$\ln y = a_0 + a_1 S + a_2 e + a_3 e^2 + u + v + w \tag{7}$$

with a three-component error term such that $-\infty < u < \infty$, $-\infty < v < 0$, and $0 < w < \infty$. The error component u represents the typical two-sided error term representing pure noise. The negative error term v represents a worker's incomplete information since it represents the difference between the wage a worker receives and the wage that could have been obtained with knowledge of a higher paying firm. The positive error term w represents a firm's incomplete information since it represents the difference between the wage a firm pays and the wage it could have paid if it knew of workers willing to work at lower wages.

Estimates clearly indicate imperfect markets (Polachek and Yoon, 1987). Incomplete information appears larger for employees than employers. Workers receiving unemployment insurance (UI) subsidies for search have less incomplete information than those without subsidies, and union workers appear to have more information than non-union workers. UI appears not to help firms increase information, but on the other hand, unionized firms appear to have more information than nonunionized firms.

As indicated, incomplete information likely leads to job turnover because incomplete information may result in an imperfect match. One set of literature views jobs as 'experience goods' in which worker productivity is not known ex ante, but instead 'becomes known more precisely as the workers' job tenure increases' (Javanovic, 1979b, p. 972). Another set of literature views workers as continually searching even after being gainfully employed (Parsons, 1973; Burdett, 1978; Jovanovic, 1979a). In these latter models workers gain by finding a better higher paying job. Both sets of models primarily have one implication: turnover decreases with tenure. However, not considered is turnover periodicity: how long it takes to change jobs over the life cycle.

Although originally developed to focus on geographic mobility, Polachek and Horvath (1977) combine aspects of experience goods and search to model a

[17] More traditional procedures merely look at price and wage dispersion usually taking the variance (Stigler, 1961; Stigler and Kindahl, 1978; Dahlby and West, 1986; Van Hoomissen, 1988; and Lach and Tsiddon, 1992). However, there are two disadvantages to using dispersion. First, as illustrated by the human capital model, wages can vary for many reasons other than incomplete information. Second, wage dispersion encompasses both the employee's and employer's incomplete information.

'perspicacious perigrinator'. Workers (migrants) are perspicacious in that they seek and weigh information, and they are perigrinators in that their mobility is treated in a life cycle context. In the model, information is defined as the knowledge of wages in *other* geographic areas or *other* jobs *relative* to one's *own* area or job. Because migration implies moving towards higher wages, actualizing a move implies a decrease in *relative* wage gains if one were to move again right away, since now by having taken a new job one is higher in one's potential wage distribution. As such, accumulating knowledge while searching, increases *potential* wages, but it isn't until one actually moves that wage gains are achieved. And when this move actually occurs relative wages in *other* jobs are again below the current job, so the information acquisition process begins afresh. Such changes in wage gains imply a periodicity which varies over the life cycle. A good summary of this process is in Polachek and Siebert (1993, pp. 242–7).

The underlying model is that individuals weigh the gains and costs of mobility. As such, mobility can be altered by affecting search costs and benefits. If costs can be raised and benefits reduced then mobility declines. This is the idea behind contracting schemes. Here by engaging in an implicit or explicit contract, such as specific training or efficiency wage schemes, the firm's and worker's cost and benefit shares of staying on the job are altered thereby affecting mobility. I now turn to how contract models relate to the above human capital acquisition process.

V INCENTIVE BASED CONTRACTS

The human capital models described above essentially analyze lifetime earnings from the vantage of the employee: workers purchase human capital and as a result enhance future earnings by accumulating human capital stock. In a sense such models are one-sided since they neglect the role of *firms* in the investment and wage processes. The reason is obvious: all training was considered general, and as such workers pay for and receive the rewards from training.[18] Though motivated by a different reason, as I shall indicate later, incentive based contract models address this deficiency (of omitting firms) by concentrating on the firm's role in setting the per unit human capital rental rate. (Recall that this rental rate was previously assumed to be exogenous.) Specific training models motivate bringing in firms by realizing that some types of training benefit the worker only while he or she remains in the firm, but not if he or she is laid off or quits. Thus, the benefits of a worker's enhanced productivity are asymmetric. The firm loses if the worker quits, but gains if the worker remains; the worker gains by remaining with the firm but loses if laid off. This asymmetry provides mutual benefits from trade, and this trade results in a contract. The resulting contract is the specific training model.

Efficiency wage and other incentive-based contract models motivate bringing in firms by realizing that workers in especially difficult to monitor jobs need not

[18] Even learning by doing can be construed as general training. Market forces drive down earnings profiles so that workers are forced to take lower initial wages in jobs with learning by doing. See Rosen (1972).

put out maximal effort especially if the worker is guaranteed lifetime employment at going wages. Here workers gain and firms lose when workers shirk. But often firing workers cause a firm to lose reputation, not to mention costly training investments. Here, too, workers and firms can gain from a mutually advantageous contract. These are often known simply as incentive-based contract models.[19] Many of these models look only at increasing output immediately in the short run (e.g., piece rate models when worker output can be easily observed, and profit sharing models when worker output is difficult to measure), and neglect life cycle considerations . Other compensation packages which have life cycle implications based on delayed payment schemes outlined by Becker and Stigler (1974) as well as Lazear (1979, 1981) are surveyed in Hutchens (1989) and Carmichael (1989). Still others based on rank-order tournaments (Lazear and Rosen, 1981; Rosen, 1986) introduce risk and employment uncertainty into the intertemporal compensation process and although these too can be handled within human capital life cycle models, they are beyond the scope of this survey.

Specific training

Typically, specific training raises a worker's productivity primarily within a given firm. If training is t^* years (Figure 2) then MP before and after training can be illustrated as MP_0 and post-training worker marginal product as MP_p. Assume w_c equals the wage and marginal product elsewhere without specific training MP_c. If the firm pays entirely for training and receives all the benefit (wage path w_c) then the worker has no unusually strong incentive to remain with the firm post-training. If the worker pays entirely for the training and receives all the benefits (wage path MP_0 if $t \leq t^*$ and MP_p if $t > t^*$) then the firm has no incentive to retain the worker. Thus there is room for an incentive compatible bargain leading to wage path w^0 if $t \leq t^*$ and w_p if $t > t^*$, implying that the worker and firm share investment costs and benefits.[20]

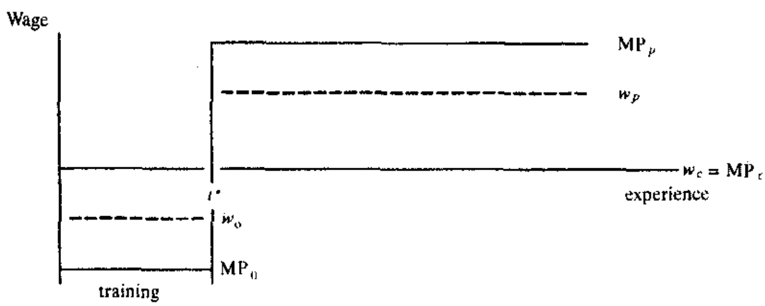

Figure 2. The specific training model.

[19] Other names include compensation practices and the 'new economics of personnel.'
[20] One could also look at continuously occurring training in which worker marginal product and wage increase continuously rather than once as at t^* in Figure 2.

The exact wage path clearly affects mobility. The higher is the post-training wage (w_p) relative to the alternative (w_c) the lower the quit probability. Similarly, the lower is the wage (w_p) relative to marginal product (MP_p) the lower the probability of layoff. Thus the terms of the contract affect mobility, as empirically shown by Oi (1962), Pencavel (1972), Hashimoto (1975) and Parsons (1977). Independent of the contract's terms long-term equilibrium dictates that the proportion of training costs borne by the firm must equal the proportion of gains obtained by the firm (Kuratani, 1973).

Worker productivity

Although the specific training contract necessarily implies that wages deviate from marginal product, worker performance and worker wages are still believed positively correlated over the life cycle. Yet not all agree that a positive correlation between a worker's wage and marginal product is upheld in the data. Medoff and Abraham (1980) claim to test this proposition by surveying supervisor ratings of workers. However, one major problem with supervisor ratings is that these performance measures can be very suspect if a supervisor's expectations are as much job as worker related. Clearly, a national leader receiving an inferior rating by the populace may still have higher productivity than a menial worker receiving an overwhelmingly positive supervisor rating.[21] Nevertheless, productivity and wages need not be positively correlated. In part, this possible lack of a correlation is what motivates effort enhancing contracts.

Effort enhancing contracts

Effort enhancing incentive based contract models take many forms: piece rates, tournaments, profit sharing, team incentives, up-or-out promotion rules, efficiency wages, and more. But given that these are surveyed elsewhere in this volume, I refrain from doing so here. Instead I ask whether these contract models can be viewed in the context of the life cycle human capital framework. And here my answer is in the affirmative. Further, I claim that not taking human capital into account can bias these models' life cycle earnings predictions.

Recall the structure of the basic life cycle human capital model. The worker maximizes the present value of lifetime earnings $Y(t) = [1 - s(t)]wK(t)$ by choosing optimal investment $s(t)$ over each year of one's life.[22] In contrast,

[21] Another problem is supervisor heterogeneity: A supervisor's standards can easily deviate from one another. To get around heterogeneity biases in these rankings, Bishop (1987) adopted an alternative strategy when using supervisor ratings. In the data he used (National Center for Research in Vocational Education Employer Survey conducted in late 1982) supervisors were asked to evaluate not just one worker but two recent hires. Although he found wages positively correlated with productivity he was more struck by the negative relationship between productivity and layoffs. Of course even Bishop's ordinal measures suffer the same problem as Medoff and Abraham's if supervisor rating are more job than person related. More recently Brown (1992a) finds wages uncorrelated with supervisor ratings for a sample of workers in 3,000 manufacturing plants. For a good survey of the evidence on wages and productivity see Brown (1992b).

[22] As noted earlier, one can incorporate labour supply by maximizing a utility function incorporating leisure.

efficiency wage contract models assume human capital accumulation to be exogenous, but instead assume that firms set the wage per unit of human capital (w) to maximize effort in each time period.[23] To do this, firms pay a premium to induce effort. As such, rather than paying a constant wage independent of effort the firm now rewards effort so that $w = w(E)$ with $w_E > 0$ and $W_{EE} < 0$, where E is worker effort. Given this wage structure, the problem for the worker is to choose an effort level to equate the marginal gain in wage (from added effort) to the marginal utility loss of expending extra effort. Letting $Y = [1 - s(t)]\ w(E)$ $K(t)$ be a worker's earnings, one can express a worker's utility as $U = U(Y,E)$ where $U_y > 0$, $U_{YY} < 0$, denotes the positive utility of earnings, and $U_E < 0$ and $U_{EE} > 0$ the disutility associated with putting out effort. Embedding the problem in a human capital life cycle context implies that the individual chooses investment time $[s(t)]$ in each time period as well as an optimal overall effort level (E) to maximize lifetime utility

$$\underset{E,s(t)}{\text{Max}} \int_0^T U(Y,E)e^{-rt}dt \tag{8}$$

subject to the constraints just imposed by $U(Y,E)$ and the human capital production function given earlier in equation (2).[24] By maximizing the Hamiltonian

$$H = U\{[1 - s(t)]w(E)K(t), E\} + \mu f(s(t), K(t))$$

one can obtain the standard efficiency wage conclusions regarding individual effort along with standard human capital model predictions concerning individual investments. With such a representation in which effort is independent of human capital stock, one can easily see how workers choose effort levels to exactly balance higher wages per unit of effort with the utility losses endemic to effort. And similarly one can easily see how workers choose investment levels in each period to balance the present value of marginal gains and costs of investing. But more complicated wage schemes can also be analyzed in a similar framework.

[23] Some may argue that incentive based schemes set salaries not wages per unit of human capital. However, as I shall show later, similar implications result.

[24] I implicitly assume that all training is general (so that purchased human capital is useful throughout one's life) and that all firms pay an efficiency wage $W(E)$. Such a simple efficiency wage model yields higher worker effort. But because all jobs pay efficiency wages, unemployment should result as a by-product (Shapiro and Stiglitz, 1984), though more evidence on this is needed. (For example, Akerlof and Yellen (1986) note that the productivity-unemployment relation (1986, p. 11) and the quit-unemployment relation (1986, p. 16) go counter to simple efficiency wage hypotheses. Murphy and Topel (1990) conclude that inter-industry wage differentials ... frequently cited as the prime evidence of efficiency wages ... can easily be rationalized as the result of unobserved quality differences across workers (1990: p. 237) rather than efficiency wages.) To properly handle these efficiency wage models in a human capital context one should appropriately distinguish job duration from work life duration. This can be done by introducing information acquisition into the optimization process and modelling job change to occur when the individual acquires sufficient information about another job to make a switch economically feasible. One could further complicate the model by considering intermittent labour force participation and heterogeneous human capital, but adding these complications are not necessary to make the point.

Much like the case with modeling specific training, effort enhancing incentive based contracts differ from general training human capital models in that they explicitly account for firm behaviour. The problem is not solely one of the worker investing in human capital to maximize the present value of earnings given a constant wage or rental rate, but instead one in which the firm sets the wage or rental rate in a way to induce workers to put out maximal effort. It generalizes from static point in time analysis, such as how to choose a compensation scheme (e.g., wages per hour versus piece rates) to maximize a worker's work hours in one time period to a compensation scheme which varies wages over the life cycle. In this sense incentive based compensation schemes relate to life cycle human capital models, since life cycle human capital models also deal with earnings variations over the life time.

Models in which workers post bonds (Becker-Stigler, 1974 or Lazear, 1979, 1981) introduce time into the wage function, so that $w = w(E,t)$. Paying a wage premium after a worker successfully completes a certain tenure level, for example such that $w(E,t) > W^*(E)$ for $t > t^*$, but $w(E,t) < W^*(E)$ for $t < t^*$, implies that increased effort in one time period is rewarded by higher wages in the next or far subsequent time period. Not only does this incentive scheme enhance effort, but it also decreases turnover since it is advantageous to stay with the firm long enough to recoup one's bond.[25] However, replacing $w(E)$ with $w(E,t)$ can have dramatic consequences on both effort as well as human capital investments in each time period.

Recall that in general one undertakes human capital investment to the point where in each time period (t) marginal investment costs equal marginal investment gains. Marginal gain is the present value of one additional unit of human capital

$$MG(t) = \int_0^{T-t} w(v)e^{-rv}dv.$$

Lowering current but raising future wage as in Lazear (1979, 1989) can affect each period's investment gains. Even if the initial time period's marginal gains are unaffected (because a lower current wage decreases while a higher future wage increases marginal gains), marginal gains in later periods are higher than when there is no incentive pay.[26] As such life cycle human capital investment paths are altered, in a way plausibly causing workers to forgo investing until they get older. Clearly this distortion of investment incentives is an unintended effect of incentive based contracts, and to my knowledge one not considered in the literature.

To make my case I specified an incentive-based pay scheme dependent on altering a wage defined to be proportional to human capital stock. Different

[25] As was already indicated one must introduce 'firm reputation' to give firms the incentive not to fire workers too early.

[26] Assume $w(E,T) > w(E,t)$ for all $t < T$, then marginal gain would decrease less quickly than otherwise yielding higher investment later in life compared to a wage contract with no wage incentive. (Remember I define wage $w(E,t)$ to be the rental rate per unit of human capital stock, not earnings attributable to one's entire human capital stock which would be $w(E,t)K(t)$.)

conclusions would emerge if incentive pay were a pure bonus or lump sum payment, independent of acquired human capital. But even with a pure bonus one's life cycle human capital accumulation path would be affected. A bonus payment for increased effort, even if designed to keep present value of earnings constant, must necessarily decrease lifetime utility (or the worker would have put forth that much effort in the first place). As such leisure and work hours are affected as is one's human capital investment path. This is analogous to biases in computing labour supply intertemporal substitution effects neglecting how life cycle human capital accumulation paths are affected by wealth changes occurring through exogenous wage shocks (Jiang and Polachek, 1991).

My point is that modern wage contract schemes can be embedded in a life cycle human capital accumulation framework. Embedding incentive contract models into a life cycle setting inextricably links efficiency wages to the life cycle human capital model. When looked at this way, human capital accumulation is affected by the compensation scheme, and this has implications regarding lifetime earnings profiles. As such, omitting human capital from contract models can have at least as many errors as omitting wage schemes from the analysis of human capital accumulation. Perhaps it thus might prove important to incorporate implications from both life cycle human capital earnings models as well as incentive based compensation schemes to better specify and understand individual earnings over the life cycle.

VI Conclusion

This paper claims that an individual's labour market success is perhaps the most important indicator of individual welfare. As such, studying how earnings are distributed across the population is of paramount importance. When looking at this distribution, many earnings-related patterns emerge: Education enhances earnings so that those with greater schooling levels earn more. Earnings increase with educational expenditures. Earnings rise at a diminishing rate as one ages. Earnings power depreciates with intermittent labour force participation. Earnings growth is smaller for those anticipating intermittent labour force participation. Men earn more than women. Married women earn relatively less than single women. Whites earn more than blacks. Occupational distributions differ by gender. Geographic and job mobility are more prevalent among the young. On-the-job tenure reduces turnover. Unemployment is lower for the skilled. And more.

Many theories emerged to explain some but not all the above patterns. For example, screening models look at why education enhances earnings. Occupational segregation models why women's occupational distribution differs from men's. Efficiency wage models explain unemployment but not necessarily its distribution among the population. And finally productivity enhancing contracts emerged to offer an alternative explanation for upward sloping (though not necessarily concave) earnings functions. This paper claims that despite each of these alternative theories having some predictive power, they each deal only with particular aspects of the problem of labour market success.

Only one theory—the human capital theory—seems to explain *each* of these patterns. The human capital model is well grounded in standard neoclassical economic theory and a theory I predict will continue to have a long life both in the economics literature and in the way economists approach the labour market. This review essay points out some of the recent developments in human capital theory as it applies to understanding labour economics issues.

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