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ON HUMAN CAPITAL AND INDIVIDUAL CAPABILITIES

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Starting out from a simple conceptual framework running from initial individual abilities to skills produced in school to the utilization of these skills in the labor market, this paper surveys empirical studies in labor economics, economics of education and occupational psychology to assess the empirical strength of the links between these sets of variables. Cognitive and non-cognitive abilities are relevant for economic success, but make a modest contribution. Occupational psychology is complementary to economics and supports the notion of interlocking heterogeneity of individuals and jobs.

1. INTRODUCTION

Individuals' earnings are vitally important, for the individuals themselves and for assessing distributive justice in a society. Hence, knowing what determines these earnings is just as important. Moreover, earnings functions are pricing functions of some sort and this makes them also relevant for questions of allocative efficiency in a market economy. Earnings functions are a worthy research target.

In the empirical economic literature on individual earnings functions, the standard explanatory variables are education, potential experience, its square, and gender. For some countries, race and region are commonly added. Individual abilities are acknowledged to be important, but they are often not observed in the dataset and only leave their trace in concern over bias in the estimates of the remaining coefficients. With this small set of variables, the researcher is a long shot away from the intuitive assessment of economic potential that is often made in personal contact. If the same researcher is asked to predict future economic success of his own students, friends or relatives, a whole series of indicators of skills, abilities and motivations will be used. The field between the economist's meagre list of variables and the wide ranging intuitive assessment is taken up by occupational and educational psychology, as a systematic investigation of individual heterogeneity in school and labor market performance. In this paper, we will seek to find out what economists can learn from that research.

In a very simple structure laid out in the next section, the chain from individual abilities to individual earnings will be discussed: the dimensions of ability in Section 3, their role within the model of human capital in Section 4, the production process within schools in Section 5, modelling the link to earnings in section 6. Section 7 considers what can be learned from the literature on personnel selection and section 8 pulls together what has been learned from the march

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through the empirical literature. Section 9 concludes and suggests directions for future research.

2. A Basic Structure

In the simplest possible framework, individuals are characterized by an ability vector a, which is transferred into a skill vector s through an educational production matrix E; skills are transferred into outputs q by a productivity matrix Q, and finally, with output prices p, productivities determine standard earnings or wages y:

$$s = Ea \tag{1}$$

$$q = Qs \tag{2}$$

$$y = pq \tag{3}$$

So by substitution:

$$y = pQEa \tag{4}$$

In most studies, *ability* and *skills* are left undefined, often even without bothering about any difference. Generally accepted sharp definitions would be useful. Lacking these, this paper will follow the practice of a rather loose understanding. Ability is an indication of the potential of an individual: mental and physical characteristics of an individual that determine potential proficiency in human performance. Skill is the actual proficiency in a specific mental or physical activity. Productivity is actual output of a commodity or a service. E and Q will be discussed extensively below.

The simple linear structure of equation (4) ignores all choice and all problems of information. But it provides an easy link with some of the (early) literature and it fits in smoothly with the standard neoclassical view of a market economy. Earnings follow from endowments and prices, with prices determined by scarcity. The equation can even refer to a simple general equilibrium structure. With fixed supply of labor by ability, and linear technologies, output supplies are fixed. Hence, equilibrium prices are determined by the demands for the outputs: consumer demand determines the value of workers' abilities and hence, the earnings distribution. The contribution of education to earnings inequality, at given output prices, production technology and covariance structure of abilities, depends on the deviation of the education production matrix E from an identity matrix. Schooling may widen or compress ability differences among pupils. Across schooling levels it is hard to imagine a reduction, but within schooling levels (or schools) this is a real policy choice, as will be further discussed below. Of course, education may also affect output prices, either through supply or through demand effects.[1]

[1]An obvious problem with ability and skill, and hence E, is the scale of measurement. If a and s were scaled by the relative market prices, E could in fact be deduced (if it is square). Note that we use "schooling" and "education" interchangeably, although schooling is a more restricted concept. The wider meanings of education are not analyzed in this paper.

With linear technologies, a multivariate normal distribution of a leads to a normal distribution of earnings. However, this clearly clashes with observed distributions. The clash was once known as Pigou's Puzzle: if abilities are normally distributed,[2] why is the earnings distribution skewed to the right? Pigou's answer was that within occupations, abilities are normally distributed; the overall skewness arises from aggregation of occupations as non-competing groups. Roy (1950) argued that output depends on a compound ability that results from multiplicative interaction of a number of elementary abilities. Champernowne (1953) and Rutherford (1955) started from Gibrat's Law of Proportionate Effect, where the change of income is a random proportion of income itself. Properties of the process of change then may generate lognormal or Paretian distributions of income (see Mincer (1970) and Pen (1971) for discussions; for an application see Fase (1969)). Hartog (1981) specifies a model where individuals choose to employ only a proportion of their earnings potential; if effort and earnings potential are independent lognormal, across individuals, the earnings distribution is also lognormal.

Some of the simplifications in equation (4) are harmless. If the fixed linear technologies Q and E were replaced by non-linear functional forms, nothing essential would change. More substantial changes result because individuals do not know their own abilities, because of uncertain technologies and because outputs are imperfectly observable. The ongoing revolution about the role of information in the economy may bring useful models here, but applications to the distribution of earnings have not yet been developed. Important qualitative differences also arise from allowing for individual self-selection and comparative advantage in education and production. These effects will be discussed below.

Schooling is taken to be the only link from ability to productivity. This ignores all other learning, such as learning from general life experience, learning in the home environment and learning in the work environment from on-the-job training and work experience. These are serious omissions, but including them would simply be too much for a single survey. The first category is routinely ignored in economic analyses, the second is implicitly covered in the effect of family background on later achievements and on the third there is a substantial literature (for reference to work by economists, see e.g. Lynch (1994) and to work by psychologists, see e.g. Ford (1997)). So far, we have ignored individual preferences, but they can easily be added (Hartog, 1981). Preferences are somewhat akin to attitudes and motivation, a set of variables also measured by occupational psychology.

3. About a

Focusing on IQ as the single relevant measure of ability seems unduly restrictive. Psychologists have used four main categories of variables to classify individuals: cognitive abilities, psychomotor abilities, personality variables and vocational preferences. Vocational preferences (individuals' preference ranking of

[2] For cardinally measured human traits, such as length and weight, the normal distribution is empirically established. But for ordinal variables, like IQ, normality is imposed by construction.

occupations) appear highly stable over age, they are reasonably effective predictors of future occupational classification of persons in broad occupational families and they have poor predictive value for performance within occupations (Peterson and Bownas, 1982, p. 83). These results fit the models designed by economists quite well: tastes are exogenously given, constant and independent from proficiencies.

As to cognitive ability, Spearman in 1894 introduced the idea of a single general ability factor g and many specific factors g_i. Thorndike later denied the existence of the g-factor and only recognized the specific factors. Thurstone's group factor theory claims that intelligence is made up of six to ten primary or group factors, such as "number," "verbal," "space," "word fluency," "reasoning," and "rote memory'. Later work has suggested that there may be some hierarchy in the sense that there is a common factor in these primary factors that is more primitive than these factors.[3] Carroll (1993) complicated the picture by arguing that a single general ability dominates at the top, that in the middle range ten broad factors are relevant, and at the bottom range some 50 specific factors. Herrnstein and Murray (1994) made the single dimensional g-factor the key variable in their much debated *The Bell Curve*, claiming that this factor is of overriding importance for social outcomes in the U.S., decisively more important than family background and mostly determined by heredity. These claims are not shared by economists (Goldberger and Manski, 1995; Heckman, 1995).[4] Heckman argues that g is an artifact of linear correlations and that in fact it is always possible to construct a scalar latent variable that can play the role of a single factor in factor analysis (Heckman, 1995, p. 1105). He claims that the low contribution of g in explaining test scores and wages implies a lot of room for factors not measured by psychometric testing. But as measured examples he only specifies education and experience.

With respect to psychomotor abilities and physical proficiencies, Peterson and Bownas (1982) conclude from assessing empirical research that for the labor market allocation problem, some 18 abilities are relevant. These are various types of physical strength, flexibility, reaction time, dexterity and control.

Personality variables are used to describe an individual's interpersonal orientation, that is, perceptions and behavior among other individuals. Peterson and Bownas concluded that a list of 15 variables, such as sociability, impulsiveness and persistence, appears most useful. In the last decade, consensus has emerged "that there are five robust factors of personality which can serve as a meaningful taxonomy for classifying personality attributes" (Barrick and Mount, 1991, p. 2). Their "Big Five" have names that may fluctuate a little; Barrick and Mount call them Extraversion, Emotional Stability, Agreeableness, Conscientiousness and Openness to Experience. Conscientiousness is also called Dependability or Conformity, or Will to Achieve. Openness to Experience associates with being imaginative, curious, broad-minded. Interestingly, Barrick and Mount mention that

[3]In practice, this is established from factor analysis in two stages. In the first stage, primary factors are found from raw test scores. In the second stage, the general "g-factor" is found from factor analysis on the primary factor score correlations. See Welland (1976, p. 12).

[4]For extensive reviews, see Devlin *et al.* (1997) and Arrow *et al.* (2000).

these personality dimensions are relatively independent of measures of cognitive ability.

A good example of applied work on cognitive and psychomotor abilities is the GATB: the General Aptitude Test Battery developed by the U.S. Employment Agency. It consists of six tests for cognitive ability (from Thurstone's primary factors) and three for psychomotor ability, and it was used to set scoring norms for occupations. The information is collected in the Dictionary of Occupational Titles. Its usefulness has been shown in many applications (e.g. Bishop, 1989; Hartog, 1980, 1981, see Section 6.2 for results). The empirical relevance of other ability measures than just standard IQ scores for explaining earnings variance has been demonstrated by Welland (1976) and by Thurow and Lucas (1972, cited in Welland, 1976, p. 18); the relevance of ability and personality for job performance, as demonstrated by occupational psychologists, will be discussed below.

4. Human Capital Theory

4.1. *Internal Consistency*

In the framework of equation (4), human capital theory is a bold shortcut, focusing only on years of schooling. But there is a price to boldness. If human capital is homogenous and can be measured in efficiency units, firms are indifferent on the size distribution of human capital. The assumption is necessary to apply a single rental rate of human capital. It makes the firm's demand function for any particular level of human capital (a particular level of schooling) horizontal, at the relative wage rate reflecting efficiency units. The size distribution of human capital (the distribution of workers by schooling levels) should then be determined by supply. But if suppliers maximize net present value, and if these are equalized in a perfect market, suppliers are indifferent about the investment volume in human capital. This is inconsistent as, in the words of Sattinger (1980, p. 20), horizontal supply curves and horizontal demand curves in general do not meet. The distribution of schooling is thus left unspecified (cf Griliches, 1977, Section 7). Other considerations should be invoked to explain it, such as rationing, ability constraints and financial constraints for individuals who want to invest. Human capitalists commonly refer to Becker's Woitinsky lecture for this purpose (Becker, 1967). While this model has been revived by Card (1995) for properly estimating the rate of return to schooling, the failure of human capital theory as an articulate theory of the joint distribution of schooling and earnings remains.[5]

4.2. *Vertical Sorting*

What is the role of individual ability in the human capital model? Consider the standard model (e.g. Polachek and Siebert, 1993). An individual, facing the

[5]Mincer (1958) studied the shape of the distribution of earnings, but he did so for a given distribution of schooling length. Chiswick and Mincer (1972) apply the human capital model to understand inequality in observed earnings distributions and the changes over time.

choice of schooling length, is assumed to maximize lifetime wealth associated with schooling length d, V_d, defined by:

(5)
$$V_d = -\int_0^d K e^{-rt}\, dt + \int_d^T W_d e^{-rt}\, dt$$

where K is out-of-pocket expenses per schooling period, r is the discount rate, W_d is earnings obtained after d years of schooling and T is the number of years in the labor force (i.e. until retirement). Solving the integral, maximizing with respect to d and assuming T sufficiently large to ignore $\exp[-r(T-d)]$, we get:

(6)
$$N \equiv \frac{\partial W_d}{\partial d} - r(K + W_d) = 0$$

Optimum schooling length d^* is determined from equating marginal cost (outlays and earnings forgone, valued at capital cost) and marginal benefits (increased earnings). With decreasing marginal benefits and increasing marginal (opportunity) cost, the optimum is determined at the intersection of the two curves.

Following Becker (1967), the marginal cost and marginal benefit curves (and hence optimum schooling) may vary with ability and with "opportunity" (such as family background). Let ability **a** affect earnings[6]:

(7)
$$W_d = f(d, a)$$

Then, assuming $\partial W_d/\partial a > 0$, abler individuals have higher opportunity costs which works towards lower d^*. Abler individuals will only choose longer schooling if there is some compensation somewhere. From differentiating the optimum schooling condition we get:

(8)
$$\text{sign}\left(\frac{\partial d^*}{\partial a}\right) = \text{sign}\left(\frac{\partial N}{\partial a}\right)$$

(9)
$$\frac{\partial N}{\partial a} = \frac{\partial^2 W_d}{\partial d\, \partial a} - (K + W_d)\frac{\partial r}{\partial a} - r\left(\frac{\partial K}{\partial a} + \frac{\partial W_d}{\partial a}\right)$$

With a perfect capital market ($\partial r/\partial a = 0$), a separable wage function ($\partial^2 W_d/\partial d\,\partial a = 0$) and direct cost independent of ability ($\partial K/\partial a = 0$), abler individuals invest less in schooling than the less able, because it would be more costly for them.

The purest model of human capital yields the so called Mincerian earnings equation[7]:

(10)
$$W_d = W_0 e^{rd} + K(e^{rd} - 1)$$

If we let ability affect initial earnings, $W_0 = W_0(a)$, we have

(11)
$$\frac{\partial N}{\partial a} = r e^{rd}\frac{\partial W_0}{\partial a} - r e^{rd}\frac{\partial W_0}{\partial a} = 0$$

[6]Note that W_d is still wages for education d, not a derivative.
[7]It follows by equating V_d as in (5) with V_0: equal present values for d and 0 years of schooling.

In this case, ability has no effect on schooling. Everyone chooses the same amount, because marginal cost and marginal benefit increase in the same proportion if ability increases. An earnings function loglinear in years of schooling and an ability measure like IQ, as is commonly estimated, also implies that ability has no effect on the demand for education (unless r is affected).

Vertical sorting, where individuals of higher ability opt for longer schooling,[8] will not necessarily occur. It may depend on the type of ability. It may very well be that those with higher levels of manual or social ability choose less schooling. Students with commercial or artistic talent may find advanced schooling a rather poor investment. Many successful entrepreneurs are school drop-outs (the recent wave of new ICT entrepreneurs provides striking examples). Unfortunately, there is no more than anecdotal evidence of such cases. There is, however, substantial evidence of a positive correlation between length of schooling and general cognitive ability as measured by IQ scores (Taubman, 1975, p. 180; Hartog, 1992, p. 189; Kodde, 1985, p. 199). Given the model as we developed it, this is only compatible with a lower discount rate for abler individuals or a positive cross-derivative in the earnings function.

The effect of ability on the discount rate is probably not very large, although there may be some indirect effect through the correlation between ability and family background (poorer family background is associated with lower ability and higher discount rates). There may be rationing however, with the less able simply denied access to funds such as grants, scholarships and bank loans.

A positive cross-derivative in the earnings function may arise because with higher ability a year at school produces more human capital or because ability has a positive cross-effect on the labor market value of human capital produced in school. The former is implicit in the commonly adopted Ben-Porath model (Ben-Porath, 1967, Polachek and Siebert, 1993, p. 25):

$$I_t = (\theta_t H_t)^a \tag{12}$$

where I_t is the output of produced human capital, θ_t, is the fraction of the human capital stock devoted to human capital production, H_t is the stock of human capital and a is an efficiency parameter reflecting ability. Ability and schooling interact (abler individuals produce more with a given capital stock, hence get more out of a year of schooling). To get students out of school for other reasons than finite working life, we must have $a < 1$. But that implies a declining rate of growth for human capital with additional years spent in school and is incompatible with the standard Mincer earnings function (requiring constant growth of human capital for years spent in school).

Abler individuals may indeed need less time to produce a given output of human capital. But there is very little empirical evidence to test this hypothesis. Oosterbeek (1992b) finds that in The Netherlands students of lower ability take more time to obtain a degree in economics than abler students.[9] But he also finds that longer duration (for a given degree) raises earnings (at a rate of return of 8

[8] Horizontal sorting, by type of ability, will be discussed later.

[9] Siegfried and Fels (1979, p. 955) report that in an introductory economics course, an elasticity of achievement with respect to ability of 0.89 was found. The elasticity for effort was 0.25.

percent!); one may speculate that these individuals have spent their time producing valuable human capital in other ways, such as work experience or other extracurricular activities. First year students of higher ability tend to supply more effort (though not significantly so) while second year students of higher ability supply significantly less effort (Oosterbeek 1992b, p. 75; Oosterbeek, 1993).

The evidence of the effect of general cognitive ability on the earnings–schooling slope is conflicting, as also noted in surveys by Blaug (1976), Fägerlind (1987) and Cawley, Heckman, and Vytlacil (2000). Positive interaction is found by Lillard (1977), Oosterbeek (1993), Fägerlind (1987), Hause (1972), Welland (1976), and Blackburn and Neumark (1993). Independence is reported by Taubman (1975), Taubman and Wales (1973), Griliches (1976), Cawley *et al.* (2000), and Ashenfelter and Rouse (2000). Hanushek (1986) summarizes his readings of the literature: "In most studies, however, years of schooling and measures of cognitive ability exhibit independent effects on earnings." The conclusion should be that the evidence is mixed. Certainly there is no unqualified support for increasing marginal benefits for individuals of higher intellectual ability (IQ).[10]

From the perspective of an extended human capital theory, these are rather unsettling results. Neither increasing marginal benefits nor decreasing marginal cost for individuals of higher ability has convincingly been established. It may very well be that the effect of ability materializes through a much cruder mechanism of restricted access to schools based on perceived ability levels, rather than through unrestricted individual choice of investment. In fact, this calls for better modeling of investment opportunities facing individuals.

5. About E

5.1. *The Literature*

Conceptually, it is easy to think of the school as a production process, but empirical implementation is complicated. We need measures of output, measures of input and a perception of the transformation process. Educational psychology has not yet been able to establish a general theory of learning. There are many learning theories, all specific to particular situations, but there is no core theory to flesh out (or replace) the matrix E in equation (1). Outputs are commonly measured with tests for educational performance. At the primary and to a lesser extent the secondary level, tests can focus on achievement in a few key areas, such as reading, writing and arithmetic in primary education. Of course, schools may produce a lot more than what is measured in these tests. At the more advanced schooling levels, heterogeneity in curricula, and hence output increases rapidly, and the production function approach to achievement scores is seldom used (Hanushek, 1986, p. 1155). The exception, understandably, is a large literature on teaching college economics using tests for economics apprehension (Siegfried and Fels, 1979). On the input side, distinguishing the role of individual ability in the school's contribution to student achievement is hardly feasible, as ability cannot easily be measured other than through test scores on school related items. Indeed, the problems of defining exactly what and how to measure has led

[10]We note in Section 8 that the ability effect on wages may be sensitive to age (experience).

to surveys in which laments on the state of the art take up a large share of the story (e.g., Hanushek, 1986; Wood, 1987).

Hanushek (1986) draws conclusions from the results of 147 studies of educational production functions.[11] Teachers and schools appear to be dramatically different in their effectiveness for the educational performance of students: they have strong fixed effects. But it proves very difficult to find out what it is that makes the difference. Hanushek concludes that teacher/student ratios and teacher education have no effect on student achievement. Teacher experience only has a significant (positive) effect in one-third of the 109 studies. "There appears to be no strong or systematic relationship between school expenditures and student performance." Family background, on the other hand, is very important in explaining differences in achievement (for The Netherlands, see Faasse *et al.* 1987).

Hanushek's conclusions were received wisdom until Krueger (2000) reanalyzed his data and concluded that reducing class size significantly increases test scores. His main adjustment is a focus on studies rather than on estimates. Hanushek counts every selected estimate as an observation. He has 17 observations from single-estimate studies, but 123 observations stem from a set of only nine studies. On the effect of class size, the Tennessee STAR experiment has generated the methodologically most convincing approach (see Krueger, 1999). Kindergarten children and their teachers were randomly assigned to classes that substantially differed in size, either 13–17 students or 22–25; the class assignments were maintained throughout the first three years of elementary school. The results show a persistent 5–7 percentile increase in test scores for children in the small classes, about a fifth to a quarter of the standard deviation of the average percentile score.

While our conceptual framework separates the school effect on skills from the skill effect on earnings, there are also shortcuts: estimates of school quality on earnings. In 1996, Moffitt noted that school inputs apparently had little effect on test scores, whereas they did significantly affect earnings. Card and Krueger (1992) estimate the school quality effect at aggregate state level. They relate rates of return estimated for three birth cohorts by state of birth on school input variables in the state of birth: pupil/teacher ratio, teacher salary relative to the state mean wage, and term length. The former two inputs have statistically and economically significant effects, the latter has not. In the 1996 REStat symposium (Moffitt, 1996), these conclusions are challenged on several grounds. Evidence is presented that aggregation to state level may be responsible for a good deal of the results, suggesting an effect of state-level omitted variable bias. Heckman, Layne-Farrar, and Todd (1996) argue that returns to education are not uniform across the U.S. and that migration follows individuals' comparative advantage. They reject models with a separable uniform effect of school quality, favoring models where region-of-birth interacts with region-of-residence through selective migration. In particular labor markets for the unskilled are sensitive to regional shocks. They only find evidence of school quality effects at the college level.

[11] They apply to elementary and secondary public education in the U.S.

Differences in length of schooling of course increase differences among individuals in levels of skill, and hence, in earnings.[12] But what about inequality for a given school level or type—are differences at entry magnified or reduced when the individuals leave with their diploma? Hartog, Pfann, and Ridder (1989) group individuals by the realized exit level from the school system (seven levels) and for each group predict what they would have earned had they chosen any of the other exit levels. The interesting conclusion is that when simulating identical exit levels for the different groups, earnings differentials increase with exit level. Had they all chosen higher education, the earnings differences would be greater than if they all had chosen basic education only. In other words, *at given reward structure* on the labor market, earnings differentials increase with schooling levels. The plausibility of this result is easily illustrated. If randomly selected women compete in a race over 800 meters, there will be differences at the finish. The more we train the women, the more the initial differences will be enlarged. If we give most training to the most gifted runners, this holds even stronger. And this is just what appears to happen in education.

Brown and Saks (1975), however, argue that there is a choice in the relation of training intensity to initial ability. They find clear evidence (in Michigan school districts) that the average experience of instructional staff reduces the dispersion and weak evidence that level and dispersion of students' backgrounds[13] increase achievement dispersion. Schools may differ in their policies toward students: "levellers" versus "elitists." When estimating an educational production function this may bias the effect of technology with that of unknown preferences. Brown and Saks (1987) empirically separate technology and teacher tastes. The learning technology of diminishing marginal returns (smaller advances for pupils who start out at a higher level) favors a compensation strategy of teachers.

The state of affairs in measuring education has generally been recognized as unsatisfactory. "Frankly, I find it hard to conceive of a poorer measure of the marketable skills a person acquires in school than the number of years he has been able to endure a classroom-environment. My only justification for such a crude measure is that I can find nothing better" (Welch, 1975, p. 67; cf also Griliches, 1977, p. 3). Against this background, the effort made by the OECD, jointly with Statistics Canada, to measure skills directly in the IALS project is particularly laudable (OECD, 1995). The International Adult Literacy Survey measures three different skills of information procesing, Prose, Document and Quantitative Literacy, by the same method for seven countries. The results can be used, for example, to compare the effects of schooling in different countries. One of the interesting conclusions is that the mean skill levels do not differ very much between developed countries, but the dispersion of skills within the population differs widely. This is related to the result that the skill level of graduates of a given schooling level differs markedly between countries. A low education

[12]Ram (1990) analyzes the relation between mean and standard deviation of schooling years in about 100 countries and finds a parabolic pattern: with increasing mean years of schooling in the labor force, dispersion first increases and then, after a mean of about 7 years, decreases. Dispersion in schooling years of course translates in earnings dispersion, but Ram has no observations on this relation.

[13]This is measured by average and standard deviation of student's socio-economic status and by percent white students in the district.

level in the United States comes with much lower levels of skills than the same schooling level in Europe. This can explain the wider wage dispersion in the U.S., as a given difference in schooling simply corresponds with a greater difference in skills (Leuven, Oosterbeek, and Van Ophem, 1997).

5.2. *Horizontal Sorting*

We have discussed vertical sorting as emerging from individual choice. But there is also an important normative question: does it make sense to stratify schools by ability level, separate schools for the dumb and for the smart? Most countries have basic education in undifferentiated schools, while at some point schools start to differentiate, at different ages in different countries. Optimum conditions will not be developed in this paper, but it is clear that both learning technology and interaction effects between students play a role. Also, the reliability of information about individual ability will be relevant.

With more than one type of ability and skill, it makes sense to consider horizontal sorting: will individuals specialize in developing the ability they are most gifted with, how much "ability-type" differentiation should there be in the school system? The answer hinges on the existence of comparative advantage. A mathematically gifted individual will get a mathematically oriented education, and a verbally gifted individual an education in languages or humanities, if each has a comparative advantage in the direction that matches ability endowments. This is easily demonstrated in a simple model.[14]

Suppose we have two types of ability, A and B say. Individual α is strongly endowed with ability A, individual β is strongly endowed with ability B, as in Figure 1. Wages depend simply and linearly on abilities, and if we draw an iso-wage function, individuals α and β have the same earnings: their endowments, prior to schooling, are on the same iso-wage function. There are two schools, or two curriculums: one exclusively develops ability A, the other one exclusively develops B. The dashed line indicates how far they would develop ability A in an A-school or ability B in a B-school. The slope of the lines E indicates the ratio of ability (or skill) development in the two school types, for individual α and individual β. We assume comparative advantage: if you score high on ability A, you benefit more from the A-education. Now, we get horizontal sorting if for each individual, developing her "best ability" is most rewarding. It is straightforward to show that this requires:

$$E^{\beta} \equiv \frac{\partial a_A^{\beta}}{\partial a_B^{\beta}} < \frac{\partial w/\partial a_B}{\partial w/\partial a_A} < \frac{\partial a_A^{\alpha}}{\partial a_B^{\alpha}} \equiv E^{\alpha} \tag{13}$$

The condition is feasible because by assumption $E^{\beta} < E^{\alpha}$. Horizontal sorting occurs if the wage slope, the ratio of marginal wage effects of the abilities, lies between the two educational development ratios. With equal cost for both school types, this is also the condition that supports the differentiation of the school system into these two types. In this particular case, the individuals reach the same wage level after schooling. Hence, their rate of return to schooling is identical.

[14]The analysis draws on Hartog (1992, Chapter 4).

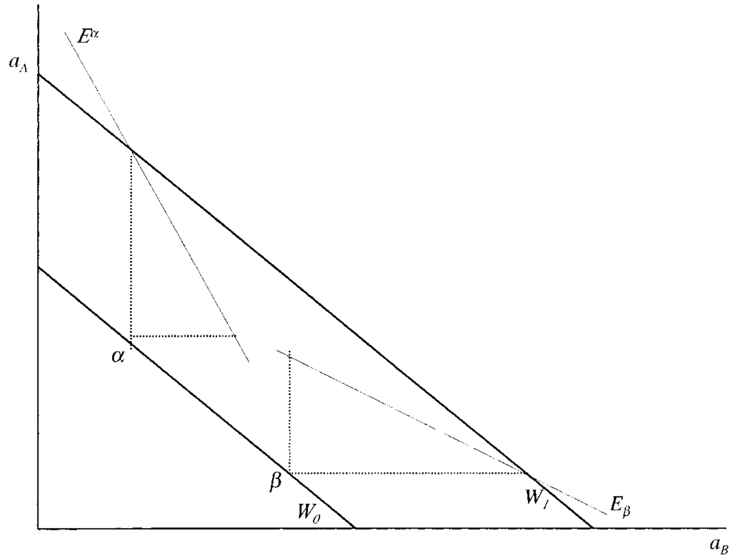

Figure 1. Horizontal Sorting

But they take different educations, and if they were to switch to the other schooling type, they would both lose. Of course many alternatives and generalizations are conceivable, with different rates of return to different individuals and with less than complete specialization by school types, but they will not be developed here (details are given in Hartog, 1992).

In practice, the extent of differentiation in the school system differs between countries. If we include curriculum variation among school type variation this yields a bewildering array of choice. For example, in The Netherlands, individuals at one time could choose from at least 130 types of higher education (Kodde and Theunissen, 1984, p. 118). The present analysis may be very relevant for the choice between academic and vocational training, a topic that draws attention also for its importance in organizing schooling in developing countries. Neuman and Ziderman (1991) report that the international literature suggests that vocational secondary education is not cost-effective relative to academic training. However, recent U.S. studies would suggest that this changes if one allows for proper matching between type of curriculum and type of job (e.g., those with "electricity" courses working as electricians). Neuman and Ziderman find similar results for Israel. In matched occupations, vocational school graduates earn substantially more than academic school graduates. Lack of data prohibits control for background and ability, but it would certainly be interesting to attempt such controls.

Evidence on horizontal sorting seems to be scarce, since the question has barely been researched. A Dutch study reports that students in secondary school choose Latin and Greek significantly more often if in elementary school they scored high at language, and they choose sciences significantly more often if in elementary school they scored high at mathematics. Similar results hold for type of secondary school chosen (Kodde and Theunissen, 1984). Oosterbeek, Van Ophem, and Hartog (1993) distinguish secondary and higher education into three types, α (language and arts), β (health, science, engineering, agriculture) and γ (humanities, law, economics). The results clearly support vertical and horizontal sorting.

6. About y

6.1. *The Human Capital Model*

In an earnings function, individual earnings can be related to innate abilities, to augmented abilities or skills, or to schooling. In the simple framework of equations (1) to (4), these are just different ways of combining the elements. The basic Mincerian human capital specification only uses years of schooling, and assumes uniform marginal returns to additional schooling years. This requires very strong assumptions. The demand side is smoothed away by the assumption of homogeneity of human capital, and the coefficient on schooling years (the "price") only reflects the supply side: the reservation price for postponing earnings. Becker (1967) allowed for the marginal cost and marginal benefit curves in equation (6) to vary with individual abilities and family background. Card (1995) revived this model as a tool to discuss (and assess) econometric issues of endogeneity, omitted variables and measurement errors (see his survey in Card, 1999). In this approach both the schooling function and the earnings function are random coefficient models. Omitted variables, such as abilities, can be hidden in these random coefficients. In Card's specification, a positive endogeneity-omitted ability bias in the OLS-estimate of the rate of return is quite plausible.[15] The upward bias can be countered however, by a negative bias from measurement error in the schooling variable. Card assesses the latter bias at some 10 percent of the estimated mean returns to schooling, and the former somewhat larger. Hence, on balance, the OLS estimate of the average return to education would have a slight upward bias. By contrast, estimates with Instrumental Variables suggest a serious underestimate by OLS. One explanation that has been put forward is that IV estimates pick out the returns for groups with low schooling, handicapped by high marginal cost and hence, high marginal returns. For example, the instrument may be changes in the minimum school leaving age or geographical distance to a college. Another explanation is publication bias. If estimation results are more likely to be published if the estimated coefficient is significant, an estimate with a high standard error only passes the gatekeeping referees and editors if the coefficient is high enough for the threshold t-value. Correcting for publication bias indeed reduces the gap between IV and OLS estimates, but does not eliminate it (Ashenfelter, Harmon, and Oosterbeek, 1999).

[15]Sufficient conditions are: a positive covariance between the ability effect on earnings and the marginal returns from schooling ($\mathrm{cov}(b, a) > 0$, in Card's terms), a negative covariance between the ability effect on earnings and the marginal cost of schooling ($\mathrm{cov}(r, a) < 0$) and a negative covariance between marginal cost and marginal benefits of schooling ($\mathrm{cov}(b, r) < 0$).

6.2. *The Hedonic Model*

The general infeasibility of a single unit price for characteristics is a core result in the class of hedonic models (Rosen, 1974), where equilibrium matches between workers and jobs (firms) are tangency points between an iso-profit function and an iso-utility function.[16] The market valuation of a characteristic is the envelope that connects the common tangency points of the realized matches. The curvature of the envelope will depend on the distributions of supply and demand. This essential insight was the core of Tinbergen (1956) and it is elegantly set in the frame of an Edgeworth Box by Heckman and Scheinkman (1987), who empirically reject the hypothesis of equal prices. The absence of unit prices in the labor market was also demonstrated in a series of papers that use job level as a demand side characteristic. Job level is a variable that measures the complexity of a job, often expressed as the required ability level of a worker and sometimes as required education (Hartog, 1985, 1986a, 1986b; Bierens and Hartog, 1988; Hartog and Bierens, 1988). Hartog (1988) shows how the marginal return to IQ depends on job level; also, the probability of reaching a higher job level appears highest for individuals whose earnings gain across job levels is greatest: assignment follows comparative advantage.

It is not easy to estimate a full structural hedonic model (Arguea and Hsiao, 1993). Still, some structural information has been uncovered for The Netherlands, again using job level as an important demand side variable (Van Ophem and Hartog, 1993a, 1993b; Van Ophem, Hartog, and Vijverberg, 1993). Separability of capabilities and job level in the wage function is decisively rejected. The marginal rate of substitution between job level and wages is increasing in both. The higher the job level, the more individuals want to be compensated for further increasing complexity. Similarly, at higher wage levels, individuals are more reluctant to take on more demanding jobs. Hence, "leisure-on-the-job," obtained by choosing a less demanding job level, is a normal good, with a positive income elasticity.

Teulings (1995) manages to estimate a structural model by reducing the matching problem to a problem of matching two one-dimensional variables, as in Sattinger (1975), by grouping variables into a skill index and a job complexity index. He emphasizes that wages can be related to the complexity index or to the skill index, but the indexes should not appear simultaneously in the wage function, since in equilibrium they match one-to-one. According to the results for The Netherlands, wage differentials in the lower tail of the wage distribution are mainly due to differences in worker skills, while in the upper tail they are mainly due to assignment of workers to different levels of job complexity (the skill distribution is skewed to the left, the high end of the wage distribution shows the elongation of the upper part of the skill distribution to fit the upper part of the job complexity distribution). The model has also been estimated for Portugal (Teulings and Vieira, 1998).

Hartog (1980, 1981) estimates an earnings function following from Tinbergen (1956), with earnings related to job requirements, using earnings by job from

[16] The hedonic model is set out in standard labor economics texts like Ehrenberg and Smith (1996) and Filer, Hamermesh, and Rees (1996).

the Census (1950, 1960 and 1970) and job requirements for each job from the Dictionary of Occupational Titles. On a standardized scale, intellectual ability had the highest implicit price, followed by social-commercial ability, with manual ability having the lowest price. Between 1949 and 1959, relative prices changed, with the intellectual price lagging behind, the social-commercial ability price increasing a little, and the manual ability price rising substantially. Comparisons of the earnings function with a human capital specification proved the latter to be inferior. Also, evidence was found that the earnings function was indeed non-linear: a number of interaction levels got significant coefficients. Hartog (1998) and Vieira (1999) use the Tinbergen model to analyze changes in the wage structure in Portugal

Different, but related, is the earnings function allowing for under- and over-education (Duncan and Hoffman, 1981). Based on information about the required education for an individual's job, the gap between actual and required years of education is included in the earnings function, separately for positive values ("over-education") and negative values ("under-education"). The data favor such an extended earnings function, implying that returns to education depend on where in the labor market the individual ends up. A proper match gives the highest return, over-education years are valued less and under-education generates a penalty. The standard human capital specification, in attained education only, is rejected. Hartog (1998, 2000) surveys the international literature and also points out that there is kinship between the over-education earnings function and the hedonic model, but that the specification does not directly follow from it.

The theoretical analysis of the hedonic model has been married to the econometric model of self-selection, where individual choices are highly dependent on variables that the researcher does not observe. As a model of choice in the labor market, it goes back to Roy (1951),[17] who presented it as a choice between hunting and fishing.[18] Because of individuals' earnings maximizing choice, we only observe particular chunks of the joint distribution of potential productivities, where the selection of those chunks is determined by relative sector output prices, differences in individual mean sector outputs and by the variances and covariances of outputs. The model has been analyzed extensively by Heckman and Sedlacek (1985), Heckman and Honoré (1990) and Sattinger (1993). Analytical results depend critically on variances and covariances of performance in the two sectors. For empirical work, the key lesson is the selective observation of individuals in jobs and sectors, and hence, the incomplete view on structural parameters.

With a sufficient number of observations, one can probably show earnings functions to have statistically significant different parameters in almost any sector decomposition (industry, public/private, union/non-union, primary/secondary,

[17]Mandelbrot (1962) has developed a similar model to derive a Pareto distribution of earnings from a multivariate Paretian distribution of abilities. Earnings result from rewards for abilities at given prices. The ability prices differ by occupation and individuals select the occupation that pays best.

[18]Roy presented his model verbally, but apparently based himself on a fully developed statistical model. See Sattinger (1993, note 21).

level of education, etc).[19] The key issue is however, whether the difference is sufficiently large to be economically significant. We know, for example, that wages differ substantially between industries, in a pattern that is remarkably stable over time and across countries (Teulings and Hartog, 1998). An interesting question is then whether the industry effect is a multiplicative constant or varies by ability, schooling and personality (as Heckman and Scheinkman (1987) found). It seems also useful to make a distinction between initial entry decisions and (potential) switches during the career. Any sector choice will tend to imply lock-in effects, in the sense that potential experience in other sectors is lost. Modeling experience related switching cost seems a worthwhile exercise.[20]

So far, the literature has not produced a fully satisfactory earnings model that is based on a rich theory of heterogeneous individuals facing heterogeneous jobs and that can be estimated without insurmountable difficulties. The Becker–Card model, while fully allowing for individual heterogeneity in costs and benefits, is only a partial reduced-form model. It does not specify why individual costs of schooling differ and it is even less informative about the reasons for differences in individual returns. With benefits restricted to earnings, the individual's earnings simply follow from integrating marginal benefits up to optimal schooling but applied work usually does not obey this consistency requirement (see e.g., Blackburn and Neumark, 1995). In fact, the Becker–Card model is never used for structural identification. The full hedonic and the Tinbergen model are more structural, by explicitly including labor demand and labor market equilibrium, and stressing the strong implications of the impossibility of unbundling. Individual choice (self selection) in a structurally specified labor market is more easily envisaged in such a model, even though parameter estimation is not easily accomplished. It seems then, that econometric specification and economic modelling have not yet successfully been matched.

7. Abilities and Personnel Selection

Job applicants are often screened by administering paper-and-pencil tests to predict their productivity on the job. There is a large volume of empirical work on the predictive value of such tests. For example, Schmidt *et al.* (1979) refer to a study on the relation between subtests of the GATB and job performance that is based on 367 studies published between 1950 and 1966. In fact, personnel psychologists have developed a pragmatic approach to study the relation of output q with abilities a and skills s in our simple model. As Schmidt *et al.* (1979) point out, the approach goes back to work by Brogden published in 1949 (the formulae are also presented in Cascio, 2000). Starting point is the standard linear regression model:

$$Y_s = \beta Z_s + \mu_y + e \tag{14}$$

[19]In Hartog and Van Ophem (1986) we did not find meaningful results for separate earnings functions by job level, in a specification that included selectivity bias correction from a multinomial logit model for job level allocation. But the number of observations within job levels was not very large.

[20]Magnac (1991) distinguishes between testing for comparative advantage and for free entry to a sector. Both hypotheses are not rejected.

where Y is job performance measured in dollar value, Z_s is the test performance in standard score form in the applicant group, μ_y is the mean job performance in dollar value of randomly selected employees and e is the error term. If the test performance is normalized to unit variance, expected job performance for a selected group s is, using the formula for the regression slope:

$$\bar{Y}_s = r_{xy}\sigma_y \bar{Z}_{xs} + \mu_y \tag{15}$$

where r_{xy} is the correlation between dollar performance and test score where employees are randomly selected, and σ_y is the standard deviation of Y. Hence, the gain from selection equals the productivity advantage of the selected group over random selection:

$$\bar{Y}_s - \mu_y = r_{xy}\sigma_y \bar{Z}_{xs} \tag{16}$$

If the test scores are normally distributed, the proportion of applicants selected is p and F is the ordinate in the $N(0, 1)$ distribution corresponding to p, mean test score of those selected, Z , is F/p and we can write[21]:

$$\bar{Y}_s - \mu_y = r_{xy}\sigma_y F/p \tag{17}$$

Schmidt *et al.* (1979) discuss the validity of the assumptions (linearity of the model, normal distribution of dollar performance) at some length, drawing from extensive empirical work. Correlation coefficients are well documented (e.g. Ghiselli, 1966). Schmidt *et al.*'s innovation is the method they present for estimating the dispersion of output value σ_y. They survey supervisors to present estimates for the dollar value of performance of three employees: one with average performance, one performing at the top 15th percentile and one at the bottom 15th percentile. Taking differences, they have two estimates of σ_y and they can test for equality as required under the normal distribution assumption.[22]

Schmidt and Hunter (1983) report estimates of σ_y as a percentage of salary to range from 42 percent to 60 percent and advocate 40 percent as a rule of thumb. They also present estimates of the standard deviation of output from published research using physical counts of employee output. It turns out that the standard deviation of output is about 15 to 22 percent of mean output, and the estimated values are concentrated in a fairly narrow range.[23] The authors conclude that a standard deviation in output of 20 percent of mean output is a safe rule of thumb to apply their formula (equation (17)) to assess the value of selection methods in terms of output. The result can then be compared with the cost of the selection method, to assess the net effect.[24]

Bishop (1989) shows output variability to be different by occupation. The coefficient of variation of output among workers in a job, assessed over a period

[21] Note that F/p is the Heckman correction term in selectivity corrected regression models. It's the expected score conditional on scoring above the threshold set for accepting a proportion p of applicants (cf. e.g. Sattinger, 1993).

[22] Their original application was to computer programmers hired for the U.S. government, for which they received a response from 105 supervisors. The two σ_y estimates were not significantly different. The standard errors for the estimates from the 105 supervisors were 16 and 10 percent.

[23] As an interesting aside, they find that piece rate compensation systems yield a smaller dispersion: 15 percent of the mean, on average over the studies, compared to 18.5 percent for non-piece rate compensation.

[24] For more detailed discussion and recent developments, see Cascio (2000).

of a year or more, is 14 percent for laborers and operatives, 29.8 percent for sales clerks, 33.8 percent for technicians, and 16.7 percent for routine clerical jobs. "Standard deviation of output is substantially higher in the more cognitively complex and better paid jobs." (Bishop, 1989, p. 18). Correlations with test scores also vary across occupations, but not for all predictors of job performance. Information on GATB test scores is combined into three measures, Academic Achievement, Perceptual Speed and Psychomotor Ability. The effect of Academic Achievement is quite similar in six out of eight occupations[25]: a difference of one standard deviation in achievement has an effect of 25 to 30 percent of the standardized supervisor performance rating. It is lower for operatives and laborers (19 percent) and much lower for sales workers, at 12 percent, where it is not even statistically significant. The variation in the effect of psychomotor skills is modest on average, but the extremes are far apart: 8 percent for craft workers, 17 percent for sales clerks. The effect of Perceptual Speed covers a range from 2 percent for technicians (not significant) to 11 percent for plant operators. Bishop calculates that if the workers in these eight occupations had been assigned randomly, the productivity loss would have been 8 percent of mean compensation. Assignment based on test performance would raise output by 6.9 percent of mean compensation. The magnitude of the benefits from test based job assignment is subject to debate (Hartigan and Wigdor, 1989; Levin, 1989, 1991, 1993; Mueser and Maloney, 1991).

8. Ability and Personality: Does it Matter?

Almost from the beginning of empirical work on the human capital model, there has been much interest in the potential bias in the schooling coefficient due to omitted ability variables. Most of this literature suggests that the schooling coefficient would be reduced by not more than a third if ability variables such as IQ test scores are included. The central tendency is perhaps in the order of 10 to 15 percent reduction (Welch, 1975, p. 66; Griliches, 1976, p. S78). Ashenfelter and Rouse (2000) conclude from their data on identical twins that the ability bias is about 25 percent (but their reported results show wide variation). Taubman, also using observations on siblings and twins, claims that the bias of ability and family background combined may be much larger, perhaps up to 70 percent (Taubman, 1975, p. 297). Two points are noteworthy in this literature. First, while the emphasis has been on estimating the upward bias in the schooling coefficient when ability is omitted, it has been pointed out that the presence of measurement errors could very well have the opposite effect (Welch, 1975, p. 67; Griliches, 1977, p. 12). Second, Hause (1972) shows that while the ability bias may be negligible in the first years of work experience, it may be substantial after 15 to 20 years of experience. Taubman (1975) also finds that ability effects are more pronounced for individuals in their late 40s than in their mid-30s. This is also relevant for the discussion in Section 4.2 on vertical sorting. If ability only pays off later in the career, the opportunity cost of the more able students is not higher than for the less able. Ashenfelter *et al.* (1999) survey studies from the

[25] Plant operators, technicians, craft workers, high skill, low skill clerical and service workers.

1990s dealing with ability bias, schooling endogeneity and measurement error. In a meta-analysis, allowing for publication bias (“only significant results are published”), they find that estimated returns do not differ by estimation method, such as OLS or Instrumental Variables. Remarkably, they find that adding ability controls reduces estimated returns in the U.S. and increases them elsewhere.[26]

Welland (1976), using scores on 17 tests (relating to verbal, mathematical, memory and visual abilities) finds that restriction to one or two composites only, like an IQ measure, is statistically rejected. The effect of ability scores varies across six occupational groups; “There does not appear to be one specific skill, or set of skills, which suffices to characterize cognitive earnings capacity for all occupations at a given level” (Welland, 1976, p. 102). Taubman and Wales (1974) identify four main factors in the NBER/Thorndike–Hagen dataset: mathematical ability, psychomotor coordination, reading/mechanical principles and spatial–visual perception. But in their earnings equation, only mathematical ability has a significant effect.[27]

Most authors conclude that the contribution of IQ, while significant, is not very large. Griliches and Mason (1972) report that if schooling and family background are accounted for, adding an IQ measure does not raise R^2 by more than 2 percentage points. Hause (1972), studying four different data sets, also concluded that the contribution of measured ability to explaining differences in earnings is modest. Welland (1976) finds that his 17 ability measures jointly reduce the standard error of estimate in an earnings equation by 1.7 percent. Within separate schooling groups, this increases to a maximum of 6.9 percent, within separate cells for education and occupation it reaches a maximum reduction of 9.9 percent. Cawley *et al.* (1996) construct a single ability variable (“Spearman’s g”) from principal components on a set of test scores and conclude that there is a modest contribution to explaining wages.

The results for economic relevance tend to be somewhat stronger. Griliches and Mason (1972), in their sample of men under 35, find that an increase in IQ score which improves an individual’s position by 1 percentile increases earnings by about 0.1 percent, given schooling, age and family background. Hause (1972) reports that for low levels of schooling, ability differentials have negligible effects, but at high levels, one standard deviation of within-sample-schooling-class measured ability raises earnings by 10–13 percent for males aged 35–40. Taubman and Wales (1973) report the earnings differential for scoring on mathematical ability in the highest or the lowest fifth (again given schooling, age and family background): 17 percent when individuals are 33 years old on average, 25 percent when they average 47 years. In Welland’s (1976) results, the change in the predicted income, for a 1 standard deviation increase in IQ or the Quantitative Ability composite, within education groups, is 8 percent at most. If an individual is 1 standard deviation above the mean on all 17 tests, predicted income within occupations, for given education, may rise by as much as 20 percent (Welland, 1976, pp. 99–100).

[26]See the Special issue of *Labour Economics*, 6(4), 1999 for IV estimates for several countries.

[27]Taubman and Wales call the third factor IQ, while Thorndike has indicated his belief that the first factor would correlate much stronger with IQ (see Taubman, 1975, p. 224).

As mentioned above, personnel psychologists have collected a large amount of empirical information on the validity of their methods. Based on these studies, meta-analyses are applied to draw conclusions on true correlations, measurement error, effects of "range restriction" (observations restricted to a selected group) etc. Van der Maesen de Sombreff (1992) tabulates results from several meta-analyses. Mean correlation coefficients with performance are highest for cognitive abilities, biographical inventories, mini-courses plus test, and structured evaluations of training and experience, all at about 0.50. Lowest predictive values relate to non-structured evaluations.

Some meta-analyses evaluate the contribution of personality measures to predict job performance (Barrick and Mount, 1991; Tett, Jackson, and Rotstein, 1991). Barrick and Mount claim progress from focusing on the "Big Five" mentioned above. Still the correlation coefficients with performance (corrected for unreliability in the predictor and the criterion) are not impressive: 0.10 for Extraversion, 0.07 for Emotional Stability, 0.06 for Agreeableness and even –0.03 for Openness to Experience; Conscientiousness is an exception, with 0.23. For training proficiency, the coefficients are never lower, and in some cases substantially higher.[28] They also report correlation coefficients separately for occupational groups, although, unfortunately they average over predicted variables (job proficiency, training proficiency and personnel data, such as tenure, turnover and salary). This differential impact hints at comparative advantage Extraversion correlates much higher for managers and sales personnel than for skilled and semi-skilled workers (0.18; 0.15 versus 0.01). Agreeableness correlates much better for police and managers than for professionals and (semi-)skilled (0.10 and 0.10 versus 0.02 and 0.00). But Conscientiousness correlates about equally for all five occupational groups.[29] This suggests, as Barrick and Mount initially hypothesized, that some personality traits are relevant for all occupations and some are specially relevant for a subset of occupations. Tett, Jackson, and Rothstein (1991) report an average correlation coefficient for personality variables that is about double the value reported by Barrick and Mount (0.24 versus 0.11). An important reason is their use of absolute values of correlation coefficients, prohibiting the unwarranted cancelling of positive and negative values. They have limited their study to job proficiency only. They find correlations for the "Big Five" that are certainly not negligible: 0.16 for Extraversion, 0.18 for Conscientiousness, 0.23 for Emotional Stability,[30] 0.27 for Openness, and 0.32 for Agreeableness (Tett *et al.*, 1991, Table 5, p. 726). Clearly then, personality makes some difference.

9. Conclusions

This review started from a very simplistic framework to discuss the link between individual abilities, skills, schooling and earnings, and tried to flesh it out with evidence from economics and psychology. It turns out that there are important complementarities that might be exploited for mutual benefit. The

[28] 0.26; 0.07; 0.10; 0.25; 0.23 respectively. Results taken from Barrick and Mount (1991, Table 3, p. 15).

[29] Barrick and Mount (1991, Table 2, p. 13).

[30] Actually, they report –0.23 for Neuroticism.

pragmatic approach of occupational psychologists to measure relevant variables and relations should be stimulating to economists. Focusing on the empirical relevance of abilities and personality variables the following conclusions can be drawn:

1. The contribution of ability to earnings differentials is significant; there is evidence that the monopoly position given by economists to IQ is unwarranted: not all relevant information on ability is covered with just one summary measure.
2. Although the contribution of abilities to earnings variance is statistically significant, the increase in explained variance is modest. However, it increases with the age of individuals, and samples of young workers give an underestimate of the contribution.
3. The economic significance of abilities, in terms of their effect on predicted earnings, is certainly not negligible.
4. Personality variables contribute to explaining output variance among individuals in given jobs, but the contribution is modest.
5. There is clear evidence of interlocking heterogeneity: the relevance of abilities and personality measures differs by type of occupation. This is in line with economists' emphasis on selection processes and comparative advantage.

The results indicate that there is certainly scope for a richer theory of earnings differentials between individuals. The theory may start from individual choices made in schools, in a differentiated school system, allowing for comparative advantage by type of ability and personality and with stable individual preferences. It would be useful to add lock-in effects, where sector choice reversal becomes increasingly costly with growing experience in the sector. More work can be done on the differentiation of schools, on horizontal sorting and on optimal differentiation of the schooling system. School systems differ sometimes substantially between countries; an evaluation of the consequences on the basis of international comparative analyses would be quite informative.[31]

A important gap is the absence of a good theory of learning. We know very little about the connection between the school and the labor market and how school output transforms into labor market input. What is it that is learned in school that makes more educated workers more productive? Can we get a better understanding of the process that turns test score achievement into productivity in jobs? Krueger (1999) indeed applied the link of our basic model to assess the benefits of reducing class size (estimated at a rate of return of 6 percent), by using estimated effect of class size on basic math and reading test scores in conjunction with test score effects on wages. But that is just an example, not an articulate theory of the link between school and productivity. The labor market may very well reward other characteristics than test scores, with test scores just correlated with these characteristics.

Continued attention is needed for the role of imperfect information and the gradual unfolding of knowledge about individuals' capabilities as revealed in their work experience, building on earlier work in the controversy between human

[31]Interest in the topic seems to be growing; see Meier (2000).

capital and screening models. There are convincing arguments why individuals reach their labor market destination only after a considerable lapse of time: in essence, they are continually being tested and it would be remarkable indeed if a simple battery of psychological tests could accurately predict their ultimate destination. The older literature assigned a dominant role to stochastic processes. That seems overdone: success in the labor market is certainly more than just "luck." But no doubt, the stochastic component is important, as underlined by the modest explanatory power of the measured variables. The challenge is in finding the proper mix of stochastic events, imperfect information and rational choice. Essentially that requires a combination of analyses at different levels. The work that has been outlined here focuses on the individual, on a deterministic chain from pupil and worker characteristics to individual earnings, conditioned by the operation of the labor market. To move ahead, it seems most promising to consider system characteristics of labor markets. Market imperfections due to problems of incomplete information, specificity of skills, cost of transition between jobs are more substantial and more consequential in some market segments than in others. These features could be analyzed to predict differences in earnings variance between worker and job categories. That is, it would generate a theory to predict differences in earnings variances from differences in underlying variables that could then be combined with the deterministic models of earnings determination surveyed here. It would make residual variance a target rather than a measure of ignorance. Indeed, unavoidably incomplete information intrinsically limits the precision of earnings prediction at individual levels, as this is precisely the problem that the labor market itself also has to solve. A focus on system determinants is then inevitable. We do not have to go back to the stochastic models of the past. It seems much more fruitful to marry the static individual deterministic models to search models. Postel-Vinay and Robin (2000) estimate a search model on French data and decompose the variance of log earnings in a firm effect, a person effect and a search friction effect. The search friction component is smallest for the category of "executives, managers and engineers": 22 percent of the variance. For the other six categories, the contribution ranges between 44 and 52 percent. Thus, system characteristics rather than individual variables explain almost half the variance of wages! Viewed in that light we should not be surprised that observable variables explain only a modest proportion of individual wage variation.

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