The Theory of "Screening," Education, and the Distribution of Income

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One of the most important kinds of information concerns the *qualities* of a factor or a commodity. We know that there are important differences among individuals, among bonds, among equities, among brands of automobiles. The identification of these qualities we call *screening*, and devices that sort our *commodities* (individuals) according to their qualities we call *screening devices* (for example, egg sorters).

This paper focuses on the labelling of individuals, on the economic costs and benefits of labelling, the institutions that provide it, and the determination of the equilibrium amount of screening under various institutional arrangements.

Economists have traditionally argued that because of the problem of appropriability in a market context, too few resources will be allocated to obtaining "information." This is not the case with the information provided by screening processes: individuals who can be labelled as "more productive" are able thereby to obtain a higher wage, partly, however, at the expense of others. Thus, by its very nature, screening information has important effects on the distribution of income.

The basic argument of this paper is that economies with imperfect information with respect to qualities of individuals differ in fundamental ways from economies with perfect information. There may be, for instance, multiple equilibria in which one of the equilibria is Pareto inferior to another; the Pareto inferior equilibrium may involve either too much or too little screening, or it may entail the wrong kind of screening. On the other hand, there may be situations where there exists no equilibrium.

The paper is divided into two parts. In

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The idea that education serves as a screening device and that as a result the allocation of resources to education may not be optimal is, of course, an old one. (See, for instance, Hull and Peters (1969) and Young (1958).) More recently, Thurow, Fields, Akerlof (1973), Spence, and Arrow (1973) have discussed education as a screening device. The first two papers assume a disequilibrium in the labor market (i.e., wages of any group of individuals need not equal the mean marginal product of the group); none of the papers, with the exception of Fields, appears to contain a completely articulated theory of the equilibrium of the system (the "supply" of education), and without a theory of the determination of the screening mechanism, it is difficult to make welfare economic evaluations of the system. For a more extensive discussion of this point, see Rothschild and Stiglitz (1973a). Several of the results are closely related to those obtained independently by Akerlof (1973), Spence, and Arrow (1973). As we show below, the presumption that these papers attempt to establish, that there is too much screening, is not necessarily valid. Various aspects of the theory of screening have recently been the subject of extensive discussion in other areas besides those of the capital market and education referred to earlier: in insurance markets (Rothschild and Stiglitz (1973a)), in labor markets (Salop and Salop (1972)), in discrimination (Arrow (1972), Phelps, Stiglitz (1973, 1974)), and in product markets (Salop (1973)). See also Akerlof's (1970) seminal work on the theory of lemons.

Section I, I develop, partly by means of a number of examples, the central aspects of the theory of screening. Section II is devoted to an analysis of the implications of screening for the allocation of resources to education.

I. The Theory of Screening

A. *The Benefits and Costs of Screening: Private Returns*

We begin with the simplest possible example involving screening. All our later examples (and the examples of George Akerlof (1973), Kenneth Arrow (1973), Michael Spence, J. K. Salop and S. C. Salop, and Michael Rothschild and the author (1973a)) can be thought of as elaborations—on the screening mechanism, the production technology, etc.—of this example.

Consider a population in which individuals can be described (at least for economic purposes) by a single characteristic, which we denote by θ, and which is proportional to the individual's productivity p:

$$p = m\theta$$

(That is, an individual of type θ_2 can do in an hour what a worker of type θ_1 can do in θ_1/θ_2 hours.) The variable p can be interpreted as the individual's marginal product. We choose our units so that $m=1$. The fraction of the population that is of type θ is given by $h(\theta)$.

Assume that the individual knows his ability but the market does not, and in the absence of any information treats all individuals identically. Firms are risk neutral, and act competitively. Assume moreover that the individual is assigned to an assembly line, and on that assembly line it is impossible to tell the productivity of any single individual without prohibitively costly examination. The output per man of the assembly line is proportional to the average value of θ for those working on the assembly line, and there are no other factors of production.

Under these assumptions, a worker will receive a wage equal to the mean value of those with whom he is grouped. If individuals with higher θ can be identified, they will receive a higher wage. They thus have an economic incentive to be identified.

Consider a case where there are only two groups, denoted by θ_1 and θ_2, $\theta_1 > \theta_2$, and which we refer to as the more able and less able, respectively. Assume there is a screening process which screens perfectly[1] and which costs c per individual screened, where

$$\theta_1 - \theta_2 > c > \theta_1 - \bar{\theta} \tag{1}$$

$$\bar{\theta} = \theta_1 h(\theta_1) + \theta_2(1 - h(\theta_1)) = \text{average value of } \theta \tag{2}$$

First we consider a case where the supply of labor by each individual is inelastic, so that with perfect knowledge, the first group would receive an income of θ_1 and the second an income of θ_2. These are best thought to be lifetime incomes, i.e., present discounted values of wage streams.

We now establish that there are two equilibria:

(a) *The no-screening equilibrium.* Since no differentiation is made among individuals, they will all receive the same income, equal to the mean productivity of the population, $\bar{\theta}$. To see that this is an equilibrium observe that it does not pay any individual, in particular, it does not pay the more able individual, to be screened. For with screening, he would obtain a gross income of θ_1, from which we must subtract the cost of screening to obtain net income, $\theta_1 - c$, and by (1), this is less than the income he would have received in the absence of screening, $\bar{\theta}$.

[1] Implicitly, we assume that the technology of screening is such that if less than c is spent, there is no screening, i.e., labels are assigned randomly.

(b) *The full-screening equilibrium.* The individuals of type θ_1 receive a gross income of θ_1, a net income of $\theta_1 - c$ (after paying for screening costs); individuals of type θ_2 receive an income of θ_2. Since these individuals know that they are the less able, they do not pay for any screening. Clearly, it pays individuals of type 1 to pay for screening: By our assumptions, all individuals who are not screened are "lumped" together and receive the same wage, so an individual of type 1 who is not screened would have received an income of θ_2, which by (1) is less than his net income with screening.

This simple example illustrates four propositions concerning economies with screening:

1) *There may be multiple equilibria.*[2]

2) *Some of the equilibria are unambiguously Pareto inferior to other equilibria.* Note that in the full-screening equilibrium, both groups have lower net incomes than in the no-screening equilibrium: the first group has an income of $\theta_1 - c$, which by (1) is less than $\bar{\theta}$; the second group an income of θ_2 which is obviously less than $\bar{\theta}$.

3) In both equilibria, *the presence of the less able individuals lowers the net income of the more able;* in the absence of the second group the first group would have received a wage of θ_1; in the full-screening equilibrium, net income is $\theta_1 - c$, in the no-screening equilibrium it is $\bar{\theta}$. *Conversely, the presence of the more able may increase the income of the less able* (in the no-screening equilibrium, they receive an income of $\bar{\theta}$ rather than an income of θ_2), *but need not* (as in the full-screening equilibrium).

[2] The multiplicity of equilibria noted here is different from the kind observed by Spence, which arises from an incomplete specification of the equilibrium conditions (or, alternatively, from a different notion of equilibrium than that employed here). (See Rothschild and the author.)

4) *If one of the functions of education is to screen individuals*, as we shall argue later, *social returns* (ignoring distributional effects) *differ from private returns.* The gross social return, in this example, is zero (since the only effects of screening are distributional), the net returns are negative (since there is a cost). But the private rate of return (in the screening equilibrium) to screening, for the more able, is clearly positive:

$$\frac{\theta_1 - \theta_2}{c} - 1$$

Many screening equilibria have the characteristic that some individuals are better off than they would be in the absence of screening, some individuals are worse off, but total net national output is lower. One might be inclined to conclude that such a screening equilibrium is not Pareto optimal, but one must be careful. Assume instead of (1),

$$(1') \qquad \theta_1 - \bar{\theta} > c$$

Then there would not exist a no-screening equilibrium, but the losses from screening to group 2 exceed the gains to group 1. Clearly, if we forbade screening, we could compensate the upper group and divide the costs of screening among the population to make everyone better off. Such an argument misses, however, the essential nature of screening: neither the government nor the private producing sector knows who are the more able without screening; hence, in this example, even though with screening net national output is lower than without it, the screening equilibrium is Pareto optimal in the sense that the redistributions which would be required to make "someone better off without making anyone worse off" than they were in the screening equilibrium, are not feasible in the absence of the screening itself.

On the other hand, since the screening does lower net national output and increase the inequality of income, *under any quasi-concave* (equality preferring) *social welfare function the screening equilibrium just described is socially undesirable* (see Anthony Atkinson, Rothschild and the author (1973b)).

These examples illuminate the nature of the private returns to screening: the individual's capturing of his "ability rents" which in the absence of screening he shares with others. It has several special characteristics which are essential for the results: (i) The more able are better in every relevant sense than the less able. Since there is an unambiguous ranking of abilities, we call such screening *hierarchical*. (ii) Labor is inelastically supplied and there are no increases in production from sorting individuals. (iii) Individuals have perfect information about their own abilities. (iv) There is no method of on-the-job screening. (v) The screening is perfectly accurate. (vi) The information acquired is "general" information. General information is information about characteristics of an individual which affect his productivity in a wide variety of jobs; specific information concerns characteristics which affect his productivity in a specific firm, for example, his ability to operate a particular machine. (The distinction corresponds to Gary Becker's distinction between general and specific training. These are clearly polar cases; as with training, there is a continuum of degrees of specificity/generality of information.) In subsequent sections I shall show the results are dependent on these characteristics.

In the remainder of this section I consider the private returns to the acquisition of general hierarchical screening information by an individual who is fully informed of his own abilities. I shall argue that in a private economy, as a first approximation, the benefits of such information would accrue to and the costs of information would be borne by the individual as opposed to the firm.

To see this, consider an economy in which individuals did not provide information about themselves. The wage in competitive equilibrium would be equal to the mean marginal product of the workers, and all workers would receive the same wage. Now assume that some firm did research which detected which workers (or groups of workers) were more productive. If it were able to keep that information secret, it would be able to earn, as a return to obtaining that information, the difference between the marginal productivity of these workers and the average of the population as a whole. Thus, it would pay firms to do research to obtain this information, provided, of course, that the costs of obtaining the information were sufficiently low. If the information were to become *public*, however, the worker would receive the benefits of the information: other firms would bid for his service, until his wage rose to his marginal productivity.

There are thus two conflicts of interest: the worker wishes to have all such information public, the firm private; and to the extent that some of the return is captured by the worker, the firm will not allocate as much resources to obtaining information about the quality of the individual as the more able individuals would have liked.

We have so far established that the most able individuals have an economic interest in providing information about their capabilities. But the gain of the more productive workers may be at least partially at the expense of the less productive workers. It may be in the interests of the poorer workers for the information about who is the best worker not to be known. I shall now argue that if information were relatively costless, in a competitive economy everyone except the poorest (least capable) individual would have an economic interest in providing such information. For, assume the most able is able to provide information certifying to his abilities. The market would then, in equilibrium, pay the remaining workers their (now lower) mean marginal productivity. It would clearly pay, then, for the most able person of this group to have his ability certified. And the analysis proceeds, until information about the capabilities of all individuals except for the least capable is provided: but if we have sorted out all except for the least capable, we have also sorted out the least capable. This may be called the Walras Law of screening information.

Our basic argument can be summarized as follows: *since individuals are able to capture the returns to general information about their skills themselves, they are willing to spend resources to provide this information*—indeed, this is the only way they can fully capture their "ability rents"; and in a competitive economy, firms that allocate resources to obtaining general screening information about individuals will be unable to appropriate (most of) the returns.

There are some conditions under which even the most able may not be willing to pay for "general screening." (a) If there are self-employment opportunities where they can realize the same returns that they would have realized had they been accurately screened, any "underrated" individual would be self-employed. For most individuals, this is not a relevant possibility. (b) If individuals are perfectly certain of their ability, and if it is possible for their ability to be costlessly observed "on the job" then the individual would offer to absorb all the risk involved in hiring and training costs. There are obviously instances of this sort, individuals who persuade the employer to hire them at low wages until they can "prove themselves." But for many jobs, ascertaining abilities (productivities) on the job may be relatively costly; most individuals are not perfectly certain of their abilities, and the screening is far from perfectly accurate. (c) If individuals are very risk averse and not perfectly certain of their abilities, then they may prefer to be treated simply as average rather than to undertake the chance of being screened and labelled below average. Indeed, in the examples given above, screening increases the variance of the individual's income and reduces the mean (since there is a cost to screening) and so, in such a situation, a "completely uninformed" individual, that is, one who took as the subjective probability distribution of his abilities the distribution of abilities in the population, would never screen. But even if there is a social return to screening, uninformed individuals may not undertake it (see Section ID below).

B. *The Social Benefits from Screening*

The examples of the previous section explicitly assumed that there was no social return to screening; i.e., screening did not increase output, it just redistributed it. Here we discuss the two major categories of social returns.

1. *Tradeoffs*. In the absence of information, individuals receive a wage which differs from their true marginal product. Imperfect information acts just like a wage tax on the more able, a wage subsidy on the less able. Like all taxes, the "information wage tax" is distortionary in its effect on the consumption-leisure decision. If screening costs are small enough, so long as labor is elastically supplied, everyone can be made better off as a result of screening (provided we have the appropriate tax instruments).

(Often, however, the requisite redistributive taxes may not exist; in that case, some of the gains of the more able may be at the expense of the less able.)

Similarly, in choosing a job, an individual must trade off nonpecuniary returns with monetary returns, and if his wage does not correspond to his marginal productivity, he will not make the socially correct decision.

2. *Matching*. Even in the absence of nonpecuniary differences among firms, there is a "matching problem" in the individual's choice of jobs. It is widely recognized that individuals differ in the comparative skills with which they can perform different tasks (jobs) and the ease with which they learn different skills. If the typist has a comparative advantage in plumbing and the plumber a comparative advantage in typing, we can have both more typing and more plumbing if they "switch" jobs.

Educators often talk of the importance of matching an "educational program" to the needs and abilities of our students. The efficiency losses in attempting to train a moron to be an engineer are obvious; other kinds of education mismatching while not as obvious may in the aggregate be quite important.

Even within a given occupation, there are further matching problems. In many economic activities, individuals act together. What is easy to observe is the net output of the group, but this in turn is a complicated function of the different qualities of the individuals of the group. In the previous section, for instance, we considered an assembly line, the speed (output) of which depended simply on the average of the "productivities" of the individuals working on the line. It would perhaps have been more accurate to assume that it is a weighted average, with the individuals who are below average slowing the line down by more than those who are above average speed it up. In that case, total output would be greater if we had two assembly lines, one with slow workers, the other with fast workers, than if the workers were randomly mixed together. Although this example is based on the assumption that there are returns to group homogeneity, the argument that there exist social returns only requires that output depend in part on how individuals of different characteristics are grouped together.

A similar argument can be made with respect to man-machine interactions. Assume that there are different kinds of machines for producing a given level of output. There is a large training cost associated with the operation of each machine; training for one machine does not equip one for operating another. Each machine is optimally designed for an individual of a given ability (value of θ). Clearly there are social returns to knowing the individual's ability (θ). (If there were no training costs, we could quickly observe the output of the machine with any individual, and infer his ability from this.)

C. *Is There Too Little Screening?*

The previous two sections should make it clear that there is no clear correspondence between social and private returns to screening; in the absence of screening individuals are "grouped" together and so may either be subsidized by or be subsidizing other members of the group. Individuals capture the direct increase in their own productivity as a result of screening; but if, as a result of screening, individuals can be "better organized" (for example, by using more homogeneous assembly lines) then there is a kind of externality provided by the availability of information. Moreover, screening eliminates the subsidy which the individual will have been receiving (or extending to others with whom he is grouped). This is a private cost (return) which is not social. As a result of these two factors, there may be too little or too much screening. The following two examples illustrate important situations in which there is too little screening.

1. *Job-Matching Screening: Screening for Comparative Advantage.* Assume a type 1 worker has a productivity of θ_{1s} when assigned to a skilled job but a productivity of θ_{1u} when assigned to an unskilled job. Type 2 workers have a zero productivity on the skilled job. We assume that type 2 workers are actually more productive at the unskilled job than the type 1 workers:

$$\theta_{1s} > \theta_2 > \theta_{1u} \tag{3a}$$

The productivity differentials are such, however, that with no screening, all workers are assigned to unskilled jobs. Let $\bar{\theta}_u$ be the mean wage with no screening in the unskilled jobs,

$$\bar{\theta}_u = h(\theta_1)\theta_{1u} + h(\theta_2)\theta_2$$

Then

$$\bar{\theta}_u > h(\theta_1)\theta_{1s} \tag{3b}$$

If screening costs are such that

$$\max(\theta_{1s} - \bar{\theta}_u, \theta_2 - \bar{\theta}_u) < c < \theta_{1s} - \theta_{1u} \tag{3c}$$

then equilibrium entails no screening; for if an individual of type 1 is screened, his net income is $\theta_{1s}-c$ which is less than his income on the unskilled job, and if an individual of type 2 is screened his net income is $\theta_2-c<\bar{\theta}$ (again by (3c)). On the other hand, if

$$\max(\theta_2 - \bar{\theta}_u, \theta_{1s} - \theta_2) < c < \theta_{1s} - \bar{\theta}_u < \theta_{1s} - \theta_{1u} \tag{3d}$$

then equilibrium entails a fraction γ of type 1 individuals being screened, where

$$\frac{\theta_2 h(\theta_2) + (1-\gamma)\theta_{1u}h(\theta_1)}{h(\theta_2) + (1-\gamma)h(\theta_1)} = \theta_{1s} - c \tag{4}$$

It is clear that $0<\gamma<1$ (at $\gamma=0$, the right-hand side of (4) exceeds the left-hand side; at $\gamma=1$, the left-hand side of (4) exceeds the right-hand side). In both cases, net national income maximization entails $\gamma=1$. Using (3c) and (3d) one can show that by having a subsidy for screening so the cost of screening is lowered to $\theta_{1s}-\theta_2$, financed by a lump sum tax, everyone can be made better off. *If type 1 workers are less productive in unskilled jobs than type 2 workers, there is too little screening.* The reason for this is that in the alternative occupation, the potentially skilled workers are in effect subsidized by the unskilled.

These results do not depend on the lack of complementarity between the two kinds of jobs. For instance, if

$$Q = F(\theta_{1s}\gamma, \theta_2 + (1-\gamma)\theta_{1u})$$

where Q is output and F is a constant return to scale production function, maximization of Q may entail less than full screening but the equilibrium level of screening will still be smaller than the optimal level.

2. *Information Externalities: Returns to Homogeneity.* Assume that the output per worker of the assembly line is of the form

$$\bar{\theta} - \beta\sigma^2 \tag{5}$$

where σ^2 is the variance of abilities on the assembly line. Moreover, assume that there is a fixed, large number of individuals working on the assembly line. Equation (5) embodies the notion that homogeneous work forces work more efficiently. Let σ_θ^2 be the expected variance on the assembly line drawn from an unscreened population, and assume

$$\theta_1 - \bar{\theta} < \theta_1 - \theta_2 < c < \theta_1 - \bar{\theta} + \beta\sigma_\theta^2 \tag{6}$$

Then the (unique) equilibrium involves no screening: with no screening, everyone receives $\bar{\theta}-\beta\sigma_\theta^2$. If a single individual were to buy screening, his income would be (approximately) $\theta_1-\beta\sigma_\theta^2-c$ (since the degree of heterogeneity of the labor force would be unaffected, we assume that the costs of heterogeneity are allocated uniformly over all individuals) which by (6) is less than $\bar{\theta}-\beta\sigma_\theta^2$. On the other hand, with full screening everyone is better off: the lower group receives $\theta_2>\bar{\theta}-\beta\sigma_\theta^2$ (again by (6)) and the upper group receives $\theta_1-c>\bar{\theta}-\beta\sigma^2$. *Although Pareto optimality requires full screening, the market equilibrium entails no screening*. To see that the full-screening situation cannot be sustained by a competitive market (assuming individuals have to pay for their own screening), observe that with full screening the net income of the first group is $\theta_1-c<\theta_2$, the net income of the lower group.

One might have thought that if $c<\beta\sigma_\theta^2$, it would pay firms to screen their workers if they do not screen themselves, since they would then obtain an average output of $\bar{\theta}$ rather than $\bar{\theta}-\beta\sigma_\theta^2$. But if the information about the outcome of screening could not be kept secret (for example, if the two types of assembly lines are different), then type 1 individuals would all be bid away, and so screening would be unprofitable. We assume the firm is aware of this and therefore would do no screening.

D. *Uninformed Individuals*

There is another reason besides the two presented in the previous section why there may not be screening even when it might be possible for everyone to be better off with screening: individuals are uninformed about their abilities and are risk averse. Assume, for instance, that labor is elastically supplied. Then it is possible to show that with the appropriate set of taxes, if the costs of screening are sufficiently small, everyone can be made better off both *ex ante* (expected utility before screening) and *ex post* than in the no-screening equilibrium, but if individuals are sufficiently risk averse, the only equilibrium will entail no screening. The source of "market failure" here is different from those discussed earlier: now the problem is the unobtainability of "ability" insurance, presumably largely because of difficulties with moral hazard.

In such a situation, there is still an incentive for the firm to obtain information about individuals; for if the firm can find individuals whose market wage is below their marginal productivity it can capture the difference between the two, if it can keep the information secret. If, as is often the case, this information cannot easily be kept secret, for example, if individuals of different abilities are assigned to different jobs (kinds of machines), then it would not pay any firm to do screening even if the firm were risk neutral. For other firms would bid away the more productive workers. The firm doing the research would not be able to capture the returns.

There is another problem in competitive economies with uninformed individuals: if two competing firms "discover" that a given individual's marginal product is greater than his wage, then they compete against each other; the individual's wage is bid up until it equals his marginal product, and neither firm is able to capture the returns from doing the research. For a more extended discussion of this point, see the author (1974c).

E. *On-the-Job Screening*

The previous analysis assumed that the screening and production activities were completely separated and there was no on-the-job screening. This is important for two reasons. First, with binding contracts (for the firm not to fire the unproductive, for the productive individuals not to quit), the equilibrium will always be Pareto optimal. For if it were not, any firm, by integrating the screening and production processes could make a pure profit: in effect there is nothing the government could do in these circumstances that an intelligent entrepreneur could not do. In fact, even though there is some on-the-job screening, considerable screening does occur in the educational system, and as long as that is the case, the problems we have detailed above remain. Secondly, on-the-job screening is likely to screen for somewhat different characteristics than, say, educational screening; the return to on-the-job screening is likely to depend on the amount of educational screening and conversely. In the absence of coordination of screening and production, *the equilibrium screening may well be Pareto inefficient*, as the following example illustrates.

Assume individuals are characterized by two characteristics, θ and ϕ, and their productivity is a function of θ and ϕ. (θ may be viewed as a characteristic screened for by the education system, ϕ is a characteristic screened for on the job.) For simplicity, we let $p=p(\theta,\phi)=\theta\phi$. We consider a population with four groups $(\theta_1\phi_1)$, $(\theta_2\phi_1)$, $(\theta_1\phi_2)$, $(\theta_2\phi_2)$, with $\phi_1>\phi_2$, $\theta_1>\theta_2$. Let $h(\theta_i,\theta_j)$ be the proportion of the population with characteristics θ_i and ϕ_j. Define

$$\bar{\theta}(\phi_i) \equiv \frac{\theta_1 h(\theta_1,\phi_i)+\theta_2 h(\theta_2,\phi_i)}{h(\theta_1,\phi_i)+h(\theta_2,\phi_i)}$$

and similarly define $\bar{\phi}(\theta_i)$. Let

$$\text{(7)}\quad \max\left[\phi_i(\theta_1-\bar{\theta}(\phi_i)),\ \theta_i(\phi_1-\bar{\phi}(\theta_i))\right] < c_\theta < c_\phi < \theta_1\phi_1 - \sum_i\sum_j \theta_i\phi_j h(\theta_i,\phi_j)$$

where c_θ and c_ϕ represent the costs of screening for θ and ϕ, respectively. Costs are assumed to be such that it always pays to screen for one and only one characteristic. It immediately follows from (7) that there may be two equilibria, one in which θ is to be used as the "screen," the other in which ϕ is used. When ϕ is being used as a screening device, it does not pay to use θ, and when θ is used, it does not pay to use ϕ. Clearly national income is higher if the former is used rather than the latter. Indeed, it is even possible to construct examples[3] in which everyone is worse off in the former equilibrium rather than the latter! *An attempt to eliminate educational screening may just shift the focus of screening, and make everyone worse off.*

F. *Accurate Screening and Fines*

Another important implication of the possibility of on-the-job screening at any finite cost is that if it is perfectly accurate and individuals are perfectly informed, *the market equilibrium will be characterized by full screening without spending any resources on screening.* The individual agrees to pay the firm a large fine if it turns out he has overstated his ability. The firm announces it will undertake screening of individuals on an assembly line if the output of that assembly line differs from what it should be, given the ability levels which the individuals have declared. Clearly, for a sufficiently high fine, only individuals of ability level θ_1 will declare themselves to be of ability θ_1, and hence no screening need actually be undertaken.

This type of screening often occurs, although in a slightly modified form. Individuals accept low wages while they prove themselves; the low wages today are compensated for by high wages later if they do prove themselves. If they do not, the difference between the low wages and what they could have obtained elsewhere acts as a fine (see Section IIB below and Salop

[3] Let $\theta_1=\phi_1=2$, $\theta_2=\phi_2=1$; $h(\theta_1,\phi_1)=h(\theta_2,\phi_1)=1/3$, $h(\theta_1,\phi_2)=h(\theta_2,\phi_2)=1/6$. Let Y_{ij} be gross income of someone with characteristics (θ_i,ϕ_j). Then with screening for θ: $Y_{11}=Y_{12}=10/3$, $Y_{21}=Y_{22}=5/3$; with screening for ϕ: $Y_{11}=Y_{21}=3$, $Y_{12}=Y_{22}=3/2$. If $C_\theta-1/3\leq C_\phi$, $C_\theta\leq 11/6$, and $C_\phi\geq 4/3$, all individuals are better off under θ screening than under ϕ screening. For these to be equilibria, we require in addition, $1\leq C_\theta\leq 5/3$, and $C_\phi<3/2$. With the further restriction that $C_\theta+C_\phi>9/4$, it can be shown that there are no other equilibria.

and Salop). Lack of knowledge about one's own abilities and imperfectly accurate screening, combined with risk aversion, places a limit on the efficacy of this kind of screening; if screening is to occur, there will have to be some expenditures for examination. (See the author (1974c).)

G. *Nonexistence of Equilibrium*

We have exhibited examples of too much screening, too little screening, the wrong kind of screening, and multiple equilibria. But another striking aspect of screening models is that *there may be no competitive equilibrium* where individuals take the action of others as well as the wages paid to an individual of any label as given.

The simplest example involves a slight modification of the one given in Section IE. For simplicity we present only a numerical version: Let $p(\theta_1, \phi_1)=4$, $p(\theta_2, \phi_2)=2$, $p(\theta_2, \phi_1)=p(\theta_1, \phi_2)=0$, $h(\theta_i, \phi_j)=\frac{1}{4}$, all i, j; let $c_\phi=c_\theta=1.5$. Clearly, there exists no no-screening equilibrium $(4-1.5>1.5)$.

Let us consider alternative possible screenings. Assume $(\theta_1\phi_1)$ screens for θ only. It then pays a fraction (approximately .7) of $(\theta_1\phi_2)$ to screen for θ_1. But this cannot be an equilibrium, for the average wage (after paying for screening) of those screened for θ_1 is then .9; clearly, it pays $(\theta_1\phi_1)$ to screen for ϕ as well. (His net income would then be 1.) But if $(\theta_1\phi_1)$ screens for both θ and ϕ, it does not pay $(\theta_1\phi_2)$ to screen for θ. But if $(\theta_1\phi_2)$ does not screen, it does not pay $(\theta_1\phi_1)$ to screen for both θ and ϕ. Other possibilities (for example, $(\theta_1\phi_1)$ screening for ϕ, partial screening, etc.) may be checked, to see that there in fact exists no equilibrium. (This is similar to the result of Rothschild and the author (1973a).)

II. Screening and Education

Section I established some general characteristics of screening equilibria. We now focus in more detail on screening in educational institutions. Educational institutions are not the only institutions which do screening in our economy. Employment agencies and the College Entrance Examination Board both screen; there is considerable on-the-job screening; how an individual dresses, his accent, his socioeconomic background, his race or ethnic group may all provide bases for screening. The fact that there are other bases for screening does not detract from the importance of educational screening; indeed the screening done by educational institutions provides the primary determinant of one's initial job opportunities and hence of what screening can occur subseqeuntly. In this section we enquire into why educational institutions are important for screening (Section IIA), the mechanisms used for screening (Section IIB), and the implications this has for the structure of the educational system (Sections IIC–E).

A. *Why Educational Institutions?*

Educational institutions provide information about individuals' abilities for a number of reasons: (a) The efficient allocation of scarce educational resources requires the identification of different individuals' abilities, i.e., some individuals would gain little from a Ph.D. program in economics, but would clearly benefit greatly from a course in automobile mechanics, and conversely for other individuals. (b) Most educators would argue that even within a given educational level there are returns from recognizing that some individuals learn certain skills faster than others. (c) Part of the social marginal product of educational institutions is finding each individual's comparative advantage (as educators are wont to say, "helping the individual find out about himself") and information about absolute advantages is almost an inevitable byproduct of obtaining information about comparative advantages. (d) In the interchange between teacher and student which is common to many (but not all) educational processes, the teacher obtains a great deal of information about his student. The fact that there are a large number of teachers making those "observations," makes the information more valuable than the judgment of a single individual (for example, an employer).

In short, it is hard to imagine an educational system which did not obtain some information about individuals. Not all educational *processes* involve screening; that is, large lectures may impart a great deal of information, but the teacher need never ascertain how much of the information the student has absorbed. Some students have even argued that screening diverts them from "real" education to the acquisition of the particular skills and pieces of information which will be tested. Our analysis is predicated on the fact that for the reasons mentioned above, all educational *systems* do some screening.

B. *The Provision of Screening Information: The Screening Mechanisms*

As discussions of grading systems make clear, there is, however, an important difference between obtaining information and making it public. There are several mechanisms by which such information about the individual's capabilities become public:

1) If the education system does any sorting for its own purposes (as it must), the groups into which an individual has been sorted will convey some information to the firm about the individual.

2) Another mechanism is performance tests: individuals have been confronted with roughly similar learning experiences (say geometry). Some individuals "learn" geometry better than others: this fact may be ascertained by a "grade" from the teacher, or by "standardized" objective examination. Failure to pass a course in college, or failure to pass a grade in elementary and secondary schools, conveys a great deal of information, which adversely affects the wages received by those individuals. As long as the school system does any grading, if only on a pass-fail basis, it is providing some information; and even when it does not do the grading itself, others can do the grading for it (Graduate Record Examination, etc.).

3) A great deal of information is provided, however, by *self-selection:*[4] a self-selection mechanism works as follows. Consider any characteristic of an individual about which the individual has more information than the firm. (We do not require that the individual have perfect information, only that on average he be better informed than the firm.) Some individuals have "more" of the given characteristic than others, for example, more brains, more mechanical ability, a higher turnover rate. We construct two (or more) reward-penalty structures such that on average individuals with more of the given characteristics will do better under one reward-penalty structure than under the other, and conversely. If individuals are asked to choose among these reward-penalty structures, and if they are rational, they will sort *themselves* out into those who have more of the characteristic and those who have less. (The better the information of the individuals and the greater the differential rewards, the better the sorting will be.)

Assume that wages are a function of the number of grades completed, and the length of time to complete a grade is a function of the individual's ability. Then if the two functions have the appropriate

[4] This is related to Akerlof's theory of lemons (1970). Akerlof argues that the used car market is a self-selection mechanism in which the worst cars become traded. Self-selection mechanisms provide what Spence has called "signals" to the market.

shape, individuals with lesser ability will quit at a lower grade level than persons with a higher ability. Grade completed is a complete surrogate for ability (see Spence).

Alternatively, assume we have a hierarchy of schools, from those for the most able to those for the least able. Assume that the schools only use a pass-fail system. Assume that the schools for the more able are more expensive. If individuals had perfect information about their capabilities (and ignoring motivation, emotional, and other problems) in fact no one need ever fail. Students would apply to the school of the appropriate ability.

It should be noted that all these self-selection devices are based on *performance tests;* that is, although the employer is using information from self-selection, self-selection only works because of the performance tests. If there were no *possibility* of failures, everyone would attempt to go to the best school (and then screening would have to be done by admissions committees) and everyone would pass on from grade to grade at the same rate.[5]

C. *The Structuring of Educational Systems*

Although we have argued that an educational system inevitably provides some information about the capabilities of individuals, there are a number of characteristics of the school system which determine how much and what kind of information is provided either by performance test or by self-selection. The school system can decide on the fineness or coarseness of screening. The structure of payments for education and the differences in "levels of education" provided by different schools are also important determinants of the effectiveness of self-screening.

Earlier, we noted that the reason that the school system is the major screening institution in our society is that this information is a natural by-product of its principal activity of providing knowledge (skills) and guiding individuals into the right occupations. In most of the ensuing analysis, we shall employ a stronger hypothesis: the more educational institutions perform their principal functions, the more screening that is produced as a by-product.[6] The more accurately it is able to place individuals into the right "slots," i.e., ascertain their comparative abilities, the more accurately it must ascertain the individuals' absolute abilities. The more knowledge it attempts to impart, the more it is able to "separate the men from the boys." At the extreme, if it tried to teach nothing, there would be no basis for performance testing, and there would similarly be no basis on which the self-screening mechanisms could be based.

There is thus the possibility that in imparting more skills to the abler students, we will simultaneously increase the inequality of income. This has made the organization of the educational system, and the method by which the levels of screening and skill acquisition are determined, an intensely political question.

Many of the social issues involving education arise because of differences in the wealth of parents. It is important, however, to observe that this parental distributional question can at least partly be separated from the questions of educational organization on which we are focusing. Thus the government could provide

[5] This is, of course, not true of other self-selection mechanisms, e.g., those discussed by Salop and Salop. The absence of performance tests plays a crucial role in the economics of self-selection devices discussed by Akerlof (1973), and Rothschild and the author (1973b).

[6] That is, for most of the analysis we shall assume that they are joint products, and that the mix between screening and "skill formation" is technologically determined. We could generalize the model to allow for the determination of this mix. In this paper we will not enquire in detail how the skill acquisition and screening take place (e.g. the nature of the grading system). We shall employ a general formulation which is consistent with a number of alternative microstructures.

its support for education in the form of vouchers, allowing individuals to use these in private schools. Even if there were no inequality in parental ability to pay for education, there would be, as we have argued above, important distributional consequences to alternative methods of organizing the educational system. To isolate our attention on these, we shall assume in the subsequent discussion that an individual's attitude towards education is determined completely by the own private monetary returns.[7]

D. *The Comprehensive School Systems with Majority Voting and Fairly Accurate Screening*

In this section, we shall show that *with majority voting a comprehensive school system will under reasonable assumptions allocate too many or too few resources to education (screening), relative to the amount which would maximize net national output depending on whether individuals are informed or uninformed about their abilities.*

The model is a slight extension of that presented in Section 1. Individuals are described by a single characteristic θ; the distribution of θ over the population is given by $h(\theta)$. We let λ denote the "intensity" of education.[8] More intensive education (a) costs more, (b) screens better, and (c) increases the productivity of the group educated, either because of skill acquisition or better matching of individuals and jobs.

The Productivity Effect. Let $p(\theta, \lambda)$ be the productivity of an individual of ability θ who has received an education of intensity λ. For simplicity, we shall let p take on the special form (upon appropriate choice of units)[9]

$$p(\theta, \lambda) = m(\lambda)\theta, \quad m' \geq 0, \quad m'' \leq 0 \tag{8}$$

Screening. The educational system places labels on individuals; it gives a point estimate of the individual's ability. Let $e(\theta, \hat{\theta}, \lambda)$ be the probability that an individual of type θ be labelled $\hat{\theta}$, in an educational system of intensity λ. As λ increases, the probability of error decreases, i.e.,

$$\left.\frac{\partial e(\theta, \hat{\theta}, \lambda)}{\partial \lambda}\right|_{\hat{\theta}=\theta} \geq 0 \tag{9}$$

Costs of Education. Finally, we assume that the cost of education per pupil $c(\lambda)$ is an increasing function of λ and that the marginal cost also increases with λ.

$$c' > 0 \quad \text{and} \quad c'' > 0 \tag{10}$$

In a comprehensive educational system all schools have the same value of λ. The model includes as special cases the traditional model of pure skill acquisition ($\partial e/\partial\lambda = 0$) and the pure screening model ($m' = 0$).

Wage Determination. Workers whose ability is estimated to be $\hat{\theta}$ receive a wage equal to their mean marginal product

$$w(\hat{\theta}) = m(\lambda) \int \theta e(\theta, \hat{\theta}, \lambda) h(\theta) d\theta \div \int e(\theta, \hat{\theta}, \lambda) h(\theta) d\theta \tag{11}$$

[7] This would be the case for instance even without government redistribution if (a) there were a perfect capital market, (b) education were not a consumption good, and (c) there were no tax distortions in the allocation of capital between human and physical capital.

[8] Throughout the discussion we make the extreme assumption that all information about individuals' abilities is obtained through the educational system, and hence the individuals' wages are determined by the label imposed by the schools. Obviously, there is some information obtained on the job. The qualitative results of our analysis will, however, be unaffected so long as (a) firms cannot obtain information on the job instantaneously, and/or (b) there are any fixed costs of hiring and training. Intensity can be thought of as either "length" (number of years of schooling) or "quality" within a program of fixed length.

[9] It should be noted that the model may be considerably generalized without affecting its qualitative properties. In particular, the restriction embodied in equation (8) may be dropped, and an additional kind of education which increases skills without screening may be introduced. See the author (1972b).

The expected wage which a person whose true ability is θ will receive is then given by

$$(12) \qquad W(\theta) = \int w(\hat{\theta})e(\theta, \hat{\theta}, \lambda)d\hat{\theta}$$

We shall consider the special case of a fairly accurate grading system in which $e(\theta, \hat{\theta}, \lambda)$ takes on the form

$$(13) \quad e(\theta, \hat{\theta}, \lambda) = f(\theta - \hat{\theta}, \lambda) = f(\epsilon, \lambda)$$

where $\epsilon = \theta - \hat{\theta}$ is the error. We thus assume that the distribution of error is independent of the value of θ. Moreover, we assume $E\epsilon = 0$ and $E\epsilon^2 = g(\lambda)$, $g'(\lambda) \leq 0$. Thus from (11)

$$(14) \; w(\hat{\theta}) = m(\lambda)\hat{\theta} + \frac{m(\lambda)\int \epsilon f(\epsilon, \lambda)h(\hat{\theta} + \epsilon)d\epsilon}{\int f(\epsilon, \lambda)h(\hat{\theta} + \epsilon)d\epsilon}$$

$$\simeq m(\lambda)\left[\frac{h'(\hat{\theta})g}{h(\hat{\theta})} + \hat{\theta}\right]$$

(15)

$$W(\theta) \simeq m(\lambda)\int\left[\hat{\theta} + \frac{h'(\hat{\theta})}{h(\hat{\theta})}g\right]f(\theta - \hat{\theta}, \lambda)d\hat{\theta}$$

$$= \int\left[m(\lambda)(\theta - \epsilon) + m(\lambda)\frac{h'(\theta - \epsilon)}{h(\theta - \epsilon)}g\right]f(\epsilon, \lambda)d\epsilon$$

$$\simeq m(\lambda\left[\theta + \frac{h'(\theta)}{h}g\right] \gtrless m(\lambda)\theta \text{ as } h' \gtrless 0$$

Thus in an unimodal distribution, individuals below the mode get more than they would under perfect screening, individuals above the mode get less than they would. The reason for this is that individuals are being averaged with some individuals who are better than they are, but have been underrated, and some who are worse, but who are overrated; if there are more who are worse (within a given range of error) than who are better, the individual will receive less than his true marginal productivity (on average).

Output Maximizing Educational Intensity. If we wish to maximize national output less educational expenditures, i.e.,

$$(16) \qquad \max\left\{m(\lambda)\int \theta h(\theta)d\theta - c(\lambda)\right\}$$

we set

$$(17) \qquad c'(\lambda) = \bar{\theta}m'(\lambda)$$

where $\bar{\theta}$ is the mean level of ability in the economy. The solution to (17) we shall call the "optimal level of education," bearing in mind that we are using the term in a very restricted sense.

Majority Voting. We now come to the choice of an educational intensity (and the associated degree of screening) in a majority voting political system. We assume the educational system is paid for by proportional wage taxes. Then if τ is the tax rate,

$$(18) \qquad \tau m(\lambda)\bar{\theta} = c(\lambda)$$

and the net expected wage of someone at ability θ (using (15) and (18)) is

$$(19) \quad W(\theta)(1 - \tau)$$

$$\simeq m(\lambda)\left[\theta + \frac{h'}{h}g\right]\left(1 - \frac{c(\lambda)}{m(\lambda)\bar{\theta}}\right)$$

$$= \left(\theta + \frac{h'}{h}g\right)\left(m(\lambda) - \frac{c(\lambda)}{\bar{\theta}}\right)$$

Taking the derivative of (19), we can see how varying educational intensity affects different groups

$$\frac{dW(1 - \tau)}{d\lambda} = \frac{W}{m}\left(m' - \frac{c'}{\bar{\theta}}\right) + (1 - \tau)m\frac{h'}{h}g'$$

This depends on both θ and λ. Consider the optimal level of education. Note then that the first term drops out, and we are left with only the second term: individuals above the mode will want more than the optimal level of education, individuals

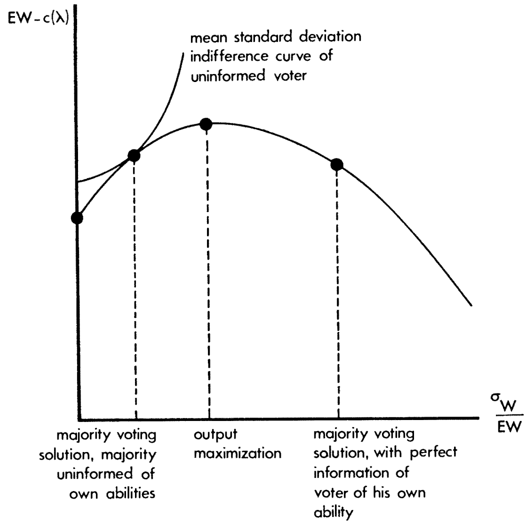

FIGURE 1

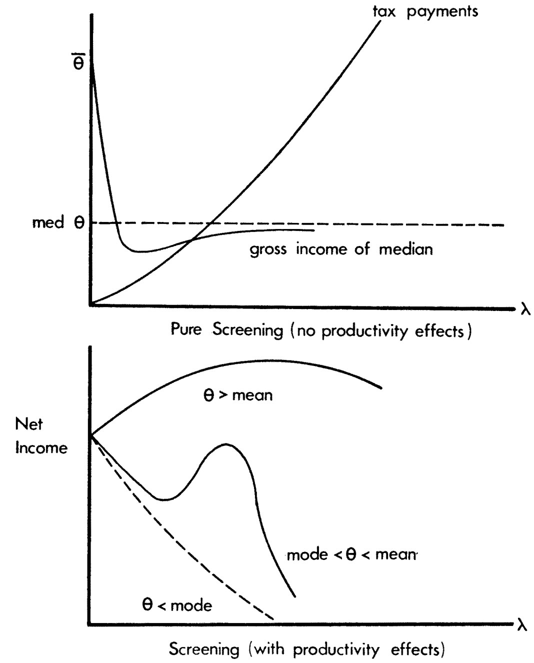

FIGURE 2

below the mode will want less. It is possible to show that if c'', $g''\geq 0$, and $m''<0$, preferences will be single peaked. Thus, the majority decision will be determined on the basis of the median value of h'/h. It is clear that if the mode lies below the median as it does for the income distribution, there will be an excess of investment in education over the optimum amount.

Indeed, it is easy to establish that not only is output lower, but the coefficient of variation in after tax expected wage income is greater, as illustrated in Figure 1.

It is worth noting at this point a major difference between fairly accurate screening systems and those which, for low values of λ, are very inaccurate. Take as an extreme case a system in which with "no information" and no education everyone receives the average value of the marginal product, as discussed earlier. Assume education only screens and that the distribution of abilities is lognormal. With no screening, the median receives the average, with perfect screening, he receives the median. As screening increases, his gross income initially declines. The cost of education increases with screening. Thus, there are two "peaks" to his net income, and accordingly there may not exist a majority voting equilibrium.[10] (See Figure 2.)

The above analysis assumed that everyone knew perfectly his own ability. The other polar case is where at least a majority of individuals are completely uninformed as to their abilities, i.e., their subjective probability distribution of their abilities is identical to the frequency distribution of abilities in the population. It is clear then that the median voter will vote for a level of education which is below that which maximizes net national output.

E. *Noncomprehensive School Systems*[11]

Although there is an institutional and analytical simplicity to a comprehensive

[10] I am indebted to John Chant for discussions on these points.

[11] For a more extensive discussion of the issues discussed here as well as the development of a formal model, the reader is referred to the author (1972b, 1974).

school system, it is easy to establish that in general net national output is not as high as in a system in which different individuals receive a different education. Indeed, if by greater ability we mean in part the ability to learn more easily, then it is more efficient (if our objective is maximizing net national output) to spend more resources on the more able.[12] This will be a characteristic of most noncomprehensive school systems. The allocation, however, will differ between a governmentally organized system attempting to maximize net national output, a private educational system, and a mixed public-private system. A full analysis would take us beyond the scope of this paper, but what we wish to do here is to characterize the major reasons that the equilibrium in pure private as well as mixed public-private systems does not maximize net national income.

For simplicity, it is best to return to the special case of Section IA, where there are only two ability groups in the population. The school system will consist of two schools, one run for the more able, one for the less able. In the mixed public-private school system, the school for the more able is private, for the less able, public. Private schools charge a tuition equal to per pupil expenditure; public schools raise revenue by general proportional taxation. We assume that the less able are in the majority. Each school system will have some of both kinds of individuals, the upper school will contain some individuals of lower ability who are attempting the "gamble" of being able to pass through the system and hence be grouped with the more able, and those of lower ability who overestimate their ability. Conversely for the lower school.

We shall now argue that there is some presumption for excessive expenditure even in a private school system. Consider the three effects of an increase in educational expenditure in the upper school. First, there is the direct productivity effect. Since the upper school focuses its attention on those who will "succeed," it spends more on this account than a government-run school which is also concerned with those who do not succeed in the upper school. Secondly, there is the direct screening effect, which, as we argued above, is simply redistributive in character, and again leads to "too much" spending on education. Thirdly, there is the "self-selection effect." By increasing educational expenditure and the quality of screening, the upper school discourages those of lower ability from attempting to go to the upper school. There is some social return to this, since the amount of education which is optimal for the less able is less than that which is optimal for the more able. The private return, how ever, is derived not from the increased "efficiency" of the educational system, but from the ability of the more able to capture more of their "ability rents." The private return to self-selection may be more or less than the social return. Thus, only if the social return to self-selection exceeds the private return by just the right amount to compensate for the excess of the private productivity and direct screening returns over the social returns will the level of expenditure be at the output maximizing level; normally we would expect there to be too much expenditure in the upper school.

A similar analysis applies to the lower school. It is obviously not in interests of those of lower ability to have extensive screening. Although the social return to self-selection is positive, the private return to those of lower ability is negative. By increasing the level of educational

[12] Although the precise quantitative relationship clearly depends on the specific technological assumption embedded in equation (8) so long as some are able to learn more quickly and easily than others, the result remains valid.

expenditures they are, however, able to attract those of higher ability who are less sure of their abilities and more risk averse.

This again leads to some presumption of excess spending even in the lower school. When the lower school is publicly financed, there is a further incentive for excess spending, since now the costs for the lower school are borne by the population as a whole.

F. *Concluding Comments*

In recent years economists have shown an increasing awareness of "market failures" and have increasingly called upon government intervention to correct these failures. But to turn over an allocation process to the public sector is to make it subject to "political laws" which may be no less forceful—and even less efficient—than the "economic laws" which previously governed the allocation process. The fact that these political laws are less well understood, perhaps more amorphous, than the corresponding economic laws is not an excuse for relying on the mythical "benevolent despot" who plays the central role in most economists' models of the public sector.

The educational sector provides an important point of comparison between the two allocation processes. If, as we have suggested, education provides information as well as skills, then it is providing a "commodity" for which it is well known that the market "fails"; we have shown how social returns differ from private returns and have examined in detail the market allocation of resources to education as well as the structure of the educational system which would emerge from a simplified political process in a highly idealized setting. Some important results emerge. Screening has productivity returns, but tends to increase inequality. There will thus be a tradeoff between efficiency and distributional considerations; but beyond a certain point, further increases in educational expenditure may both increase inequality and decrease net national income. We noted a tendency for all the school systems examined—public, private, and mixed—to operate at these levels even when all citizens are simply concerned with their own income maximization. One of the reasons for this—found in all of the systems—is that some of the returns to higher levels of education (those returns derived from the increased accuracy of labelling individuals' abilities), are private but not social returns; we argued that if abilities are distributed skewly to the right, for the median voter these private returns were positive. A further reason, in publicly supported systems, is that the median voter pays for less than his proportionate share in marginal costs. As a result, the tendency for excessive spending on education may be greater in the publicly financed schools.

On the other hand, it should be emphasized, that whether there is "too much" or "too little" screening in a competitive economy depends on a number of assumptions concerning the screening technology, how well-informed individuals are concerning their own abilities, the nature of the production process, and whether screening is primarily hierarchical or "job-matching."

Finally, we note that attempts to curtail educational screening may simply shift the focus of screening (for example, to on-the-job screening), with the possibility of a lowering of net national output without any commensurate gain in equality.

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