INFORMATION, SCREENING, AND WELFARE*

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There is a widespread belief that, in their attempt to have their abilities identified, individuals spend (directly or indirectly) an excessive amount of resources; these attempts to garner ability rents do not lead to an increase in national product, and hence are socially unproductive.[1]

This argument for the inefficiency of the market is, however, not completely persuasive: Pareto inefficiency requires that there exist an alternative resource allocation in which someone could be made better off without making anyone worse off. Though the gains of the able may be at the expense of the less able-- and resources may be used in the process of identifying the able-- if the market allocation is indeed Pareto inefficient, the alternative resource allocation must be such that even the most able must be better off. Certainly, in the complete absence of screening, it is possible that the most able will be worse off than he is in the market allocation. (Cf. Stiglitz (1975).)

Moreover, the models in which this alleged inefficiency have been discussed have employed at least two very restrictive assumptions: all individuals are assumed to be perfectly informed concerning their own abilities and ability is described by a single-dimensional variable: there is no comparative advantage, only absolute advantage.[2]

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1. Such views are, for instance, implicit or explicit in the work of Spence [1974], Hirschleifer [1971], and Akerlof [1970].

2. This is not meant to be an exhaustive list of the restrictive assumptions of the traditional screening (signaling) model. Another important assumption, for instance, is the absence of noise in the tests (signals).

The object of this paper is to establish that the market equilibrium is indeed Pareto inefficient, and to ascertain some of the major determinants of the nature of the bias. We do this in the context of a set of models in which the limitations noted above have been removed. In particular, we assume that there is, initially, no asymmetry of information. Any asymmetry of information is endogenous.

We show that there exists a set of taxes/subsidies which can make everyone better off. Similarly, we show that a reduction in the costs of information may lead to an equilibrium in which everyone is worse off: more information may lead to Pareto inferior equilibria. On the other hand, the presumption that there is too much expenditure on screening (signaling) is shown not to be valid; if individuals differ in their comparative advantages, there may be too little, rather than too much screening.

There is often confusion about the appropriate definition of Pareto optimality in markets with imperfect and costly information. Typically, individuals are not as well off as they would be were information costless, but this in itself does not mean very much. Costs of obtaining information are as much a fact of life as are costs of producing commodities. Hence, the practice of referring to welfare optima in which costs of information are taken into account as "second best" seems, at best, misleading. In the models which we formulate here, there is a simple and unambiguous welfare criterion: since everyone will be assumed to have the same utility function and, ex ante, to have the same

prior probability distribution concerning their abilities, welfare is simply measured in terms of ex ante expected utility. We can rank all equilibria in terms of this simple criterion.[1]

Although we couch our discussion in terms of individuals having their abilities identified, it should be clear that our analysis is equally applicable to any of a wide variety of screening problems, e.g., firms having differences in their product identified, or entrepreneurs having differences in their companies identified.

Thus, it is sometimes asserted that disclosure regulations are unnecessary, because the private market provides appropriate incentives for firms to reveal all relevant information[2]--high quality firms can sell their products at a higher price if they disclose this information, and the failure to disclose product quality is tantamount to admitting that one has an inferior product. We show that this argument is not, in general, correct.

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1. In contrast, we cannot, in general, rank alternative possible equilibria in terms of the ex post income distributions to which they give rise. For instance, in one of the models to be described below, there are multiple equilibria. In the screening equilibrium, the more able may obtain a higher income than in the no-screening equilibrium, while the less able obtain a lower income. In some special circumstances, there are multiple equilibria, with one dominating the other, i.e., both the more able and the less able are better off in the no-screening equilibrium than in the screening equilibrium. See Stiglitz (1975).

2. Clearly, of course, there must be laws concerning the provision of fraudulent and untruthful information. Throughout this paper, whenever information is disclosed, we shall assume it is truthful (that is, although all statements are "nothing but the truth," they need not be the "whole truth").

There are two specific questions to which we address our-
selves:

1.   If individuals cannot acquire information about their
own abilities, will they still seek to be screened?

We shall argue that even when there are social returns to
being screened, there may not be any demand for screening. This
failure is related to the inability to purchase "ability insurance";
this in turn is related to the problem of moral hazard.

2. If individuals can acquire information about their own
abilities, will they do so? How are the social returns to the
acquisition related to the private returns?

We show that the same kinds of biases noticed earlier
(Stiglitz (1975)) in economic incentives to have certification
(i.e., for individuals to make public their information about
their own abilities) appear in the economic incentives to acquire
information about one's abilities. Thus, the result obtained
earlier about the existence of inefficient equilibrium with in-
formed individuals extends to environments where initially indi-
viduals are uninformed.

Section 2 is addressed to screening with uninformed indivi-
duals, where those who attempt to pass the screening test (to be
identified as one of the more able) but fail can hide that infor-
mation, while in Section 3, we analyze the equilibrium with unin-
formed individuals where they can obtain information about their
own abilities but not without at the same time disclosing that
information publicly. Finally, Section 4 considers perhaps the

most interesting case, where there are two separate information
activities: the first concerned with the individual obtaining
information about his own abilities; the second with the indi-
vidual transmitting information to others. In Section 5, we
show how the value of information may easily be calculated.
Finally, in Section 6 of the paper we discuss briefly some of
its policy implications for disclosure laws.

2. Equilibrium With Uninformed Individuals

In this section, we take up the first question, the nature
of the equilibrium when individuals are uninformed about their
abilities and cannot obtain information about them. We assume
there are two groups in the population; the more able have
ability A_1 , the less able A_2 . (The more able can do in one
hour what the less able take A_1/A_2 hours to do.) Except for
this difference in ability, individuals are identical. A com-
pletely uninformed individual is one who believes that his proba-
bility of being able is identical to the proportion of able indi-
viduals in the population. In an ex ante sense, it is clear that
with risk averse individuals, everyone is better off with no
screening, even with zero screening costs (with risk neutral in-
dividuals, everyone is better off with no screening, if screening
costs are positive). Yet, there may still exist a screening
equilibrium. Whether there does depends on (a) the degree of
risk aversion of the individual, and (b) how individuals who are
not screened are treated, i.e., whether individuals who are not

screened are treated the same as those who are screened but are labeled "less able," or whether they are treated as a separate group. The answer to this depends in turn on whether a failed attempt to obtain accreditation as more able can be kept secret.

In less abstract terms, this is equivalent, for instance, to asking whether the market distinguishes between those who drop out of school (fail to seek accreditation) and those who fail (those who seek accreditation but fail to obtain it); or, in another context, whether individuals who quit their jobs can be distinguished from those who are fired.

If individuals are able to keep information about failed attempts to obtain accreditation secret, then individuals who fail to obtain accreditation and those who fail to seek it are treated the same. This we assume for the remainder of this section. It is easy to show that there may be two equilibria, a no-screening equilibrium and a full screening equilibrium.

Consider first the full screening equilibrium. Individuals who do not obtain an accreditation are regarded as less able, and receive a wage of A_2. The more able who are "certified" receive a wage of A_1. Now, however, everyone is uninformed. Hence, being screened is a risky investment. If one is more able, the return is $A_1 - A_2 - c$, the difference in wages less the cost of accreditation; if one is less able, the return is $- c$, since the wage one receives is still A_2. If λ is the proportion of the more able, the expected return to this investment is

$$\lambda(A_1 - A_2) - c \qquad ,$$

where we assume that, since the individual has no information concerning his abilities, prior to being screened, he assigns a probability to being more able equal to the proportion of more able in the population. Thus, if c is small enough, and individuals are not very risk averse, then they will undertake the gamble.

Such is the case illustrated in Figure 1. There are two "states of nature": the individual may be able (of type 1) or unable (of type 2). His choice is between the point S, the safe income of A_2 in both states of nature, or the gamble, which leaves him with $A_2 - c$, or $A_1 - c$. If $u(w)$ is the individual's utility function, his expected utility if he is screened is

$$u(A_1 - c)\lambda + u(A_2 - c)(1 - \lambda)$$

and if he is not screened, it is

$$u(A_2) \qquad .$$

His indifference curve is drawn in the figure, and it is clear that in this case he will undertake the gamble.[1]

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1. It should be clear that nothing in the analysis depends on assuming that the individual is an expected utility maximizer. More generally, we could represent his preferences by a utility function of the form

$$u = u(Y_1, Y_2, \lambda)$$

where Y_i = income if labeled a type i, and λ is the probability of being labeled a type 1.

If the costs of information are sufficiently high and/or individuals are sufficiently risk averse, there will be another equilibrium involving no screening. Clearly, when no one is screened, everyone obtains an income equal to $\overline{A}$, the average productivity of workers in the economy; for someone to undertake screening entails a risk. He may receive income of $A_1 - c > \overline{A}$, or, if he is of low ability, an income of $\overline{A} - c < \overline{A}$ (since the market fails to distinguish between those who did not seek a credential and those who could not obtain one).

If the proportion of those who are of high ability in the population is λ, and the individual again takes λ to be the probability that he is more able, then the expected return to this gamble is

$$\lambda A_1 + (1 - \lambda)\overline{A} - c - \overline{A}$$

$$= \lambda(A_1 - \overline{A}) - c$$

$$= \lambda(1 - \lambda)(A_1 - A_2) - c$$

where we have made use of the fact that

$$\overline{A} = \lambda A_1 + (1 - \lambda)A_2 .$$

Thus, if c is large enough,

$$c > \lambda(1 - \lambda)(A_1 - A_2)$$

no risk averse person will undertake the gamble, i.e., there exists a no-screening equilibrium. If

$$c < \lambda(1 - \lambda)(A_1 - A_2)$$

an individual with a sufficiently small degree of risk aversion
will undertake the gamble, so the only possible equilibria entail
screening.

Figure 1a illustrates a full screening equilibrium, where

$$u(A_1 - c)\lambda + u(A_2 - c)(1 - \lambda) \geq u(A_2)$$

the expected utility of the gamble of being screened (point R)
lies above the certain utility one obtains if one is not screened.
While Figure 1a illustrates a case where there is both a full
screening and a no-screening equilibrium, Figure 1b illustrates
a situation where there is only a full screening equilibrium,
although the welfare obtained at the full screening equilibrium
is below that which would have obtained if no one were screen-
ing. (However, there is not a "no-screening" equilibrium.)

For contrast, Figure 1c illustrates a case where there is
a no-screening equilibrium, but not a full screening equilibrium.

Figures 1c through 1e illustrate the roles of the magnitude
of the screening costs and the degree of risk aversion in deter-
mining the nature of the equilibrium. Greater risk aversion, not
surprisingly, makes a no-screening equilibrium more likely, and
a full screening equilibrium less likely, since to be screened
is always a risky investment. Similarly, the greater the screen-
ing costs, the more likely a no-screening equilibrium, and the
less likely a full screening equilibrium.
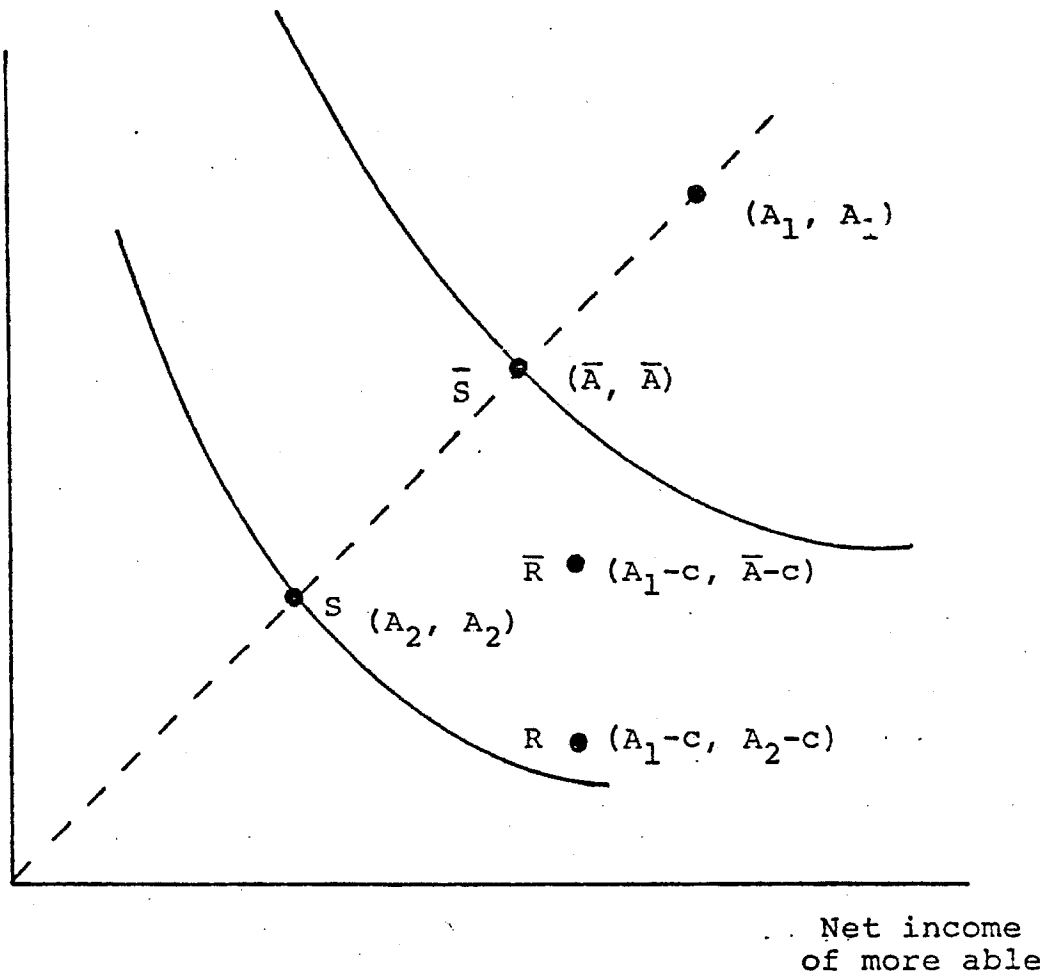
Net income
of less able

(A_1, A_2)

$\overline{S}$ / $(\overline{A}, \overline{A})$

$\overline{R}$ ● $(A_1-c, \overline{A}-c)$

S (A_2, A_2)

R ● (A_1-c, A_2-c)

Net income
of more able

Figure 1a

Multiple Equilibria

(i)   Since R lies above indifference curve through
      S , there is a full screening equilibrium.

(ii) Since $\overline{R}$ lies below indifference curve through
      $\overline{S}$, there is a no-screening equilibrium.

(iii) Since R lies below the indifference curve
      through $\overline{S}$, the full screening equilibrium is
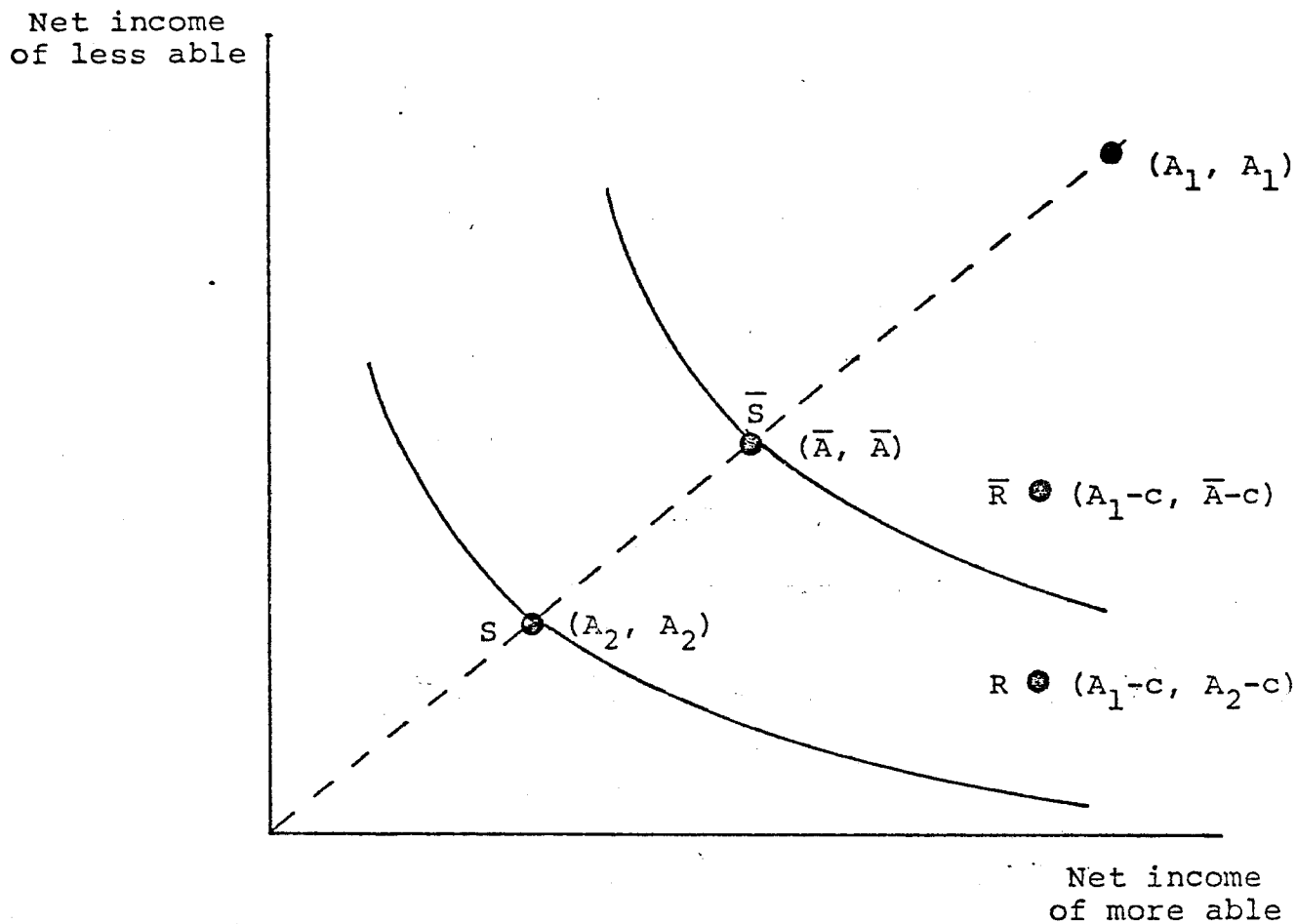   Pareto inferior to the no-screening equilibrium.

Figure 1b

Full screening equilibrium Pareto inferior
to no screening, but no screening is not
an equilibrium.

(R lies below indifference curve through
$\overline{S}$, but since $\overline{R}$ lies above indifference
curve through $\overline{S}$, $\overline{R}$ is not an equilibrium.)

Net income
of less able

(A_1, A_1)

$\overline{S}$ $(\overline{A}_1, \overline{A})$

$\overline{R}$ $(A_1-c, \overline{A}-c)$

S

(A_2, A_2)

R (A_1-c, A_2-c)
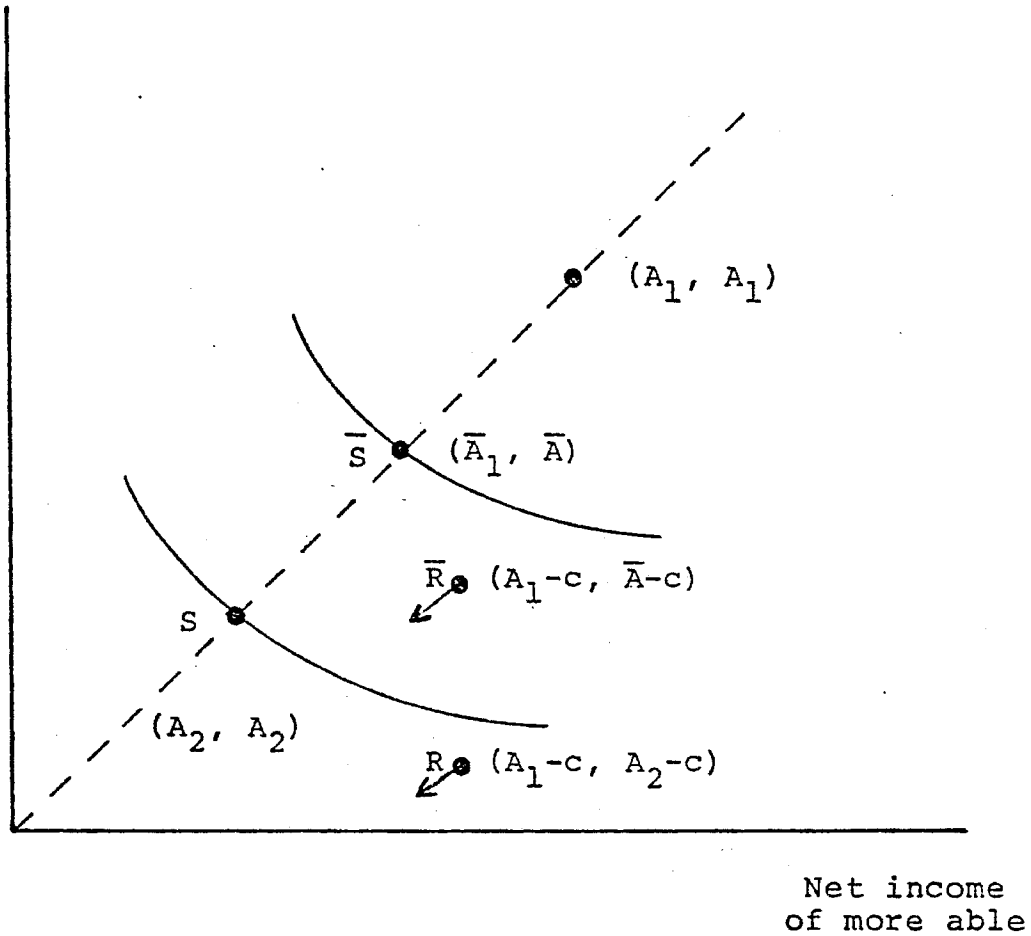
Net income
of more able

Figure 1c

No-Screening Equilibrium

An increase in c , screening costs, moves R and
$\overline{R}$ down in direction of arrows, and makes a no-
screening equilibrium more likely ($\overline{R}$ is more likely
to lie below indifference curve through $\overline{S}$) and a
screening equilibrium less likely (R is more likely
to lie below indifference curve through S).

Net income
of less able

$\overline{S}$ $(\overline{A},\ \overline{A})$

more risk averse

$\overline{R}$ $(A_1-c,\ \overline{A}-c)$
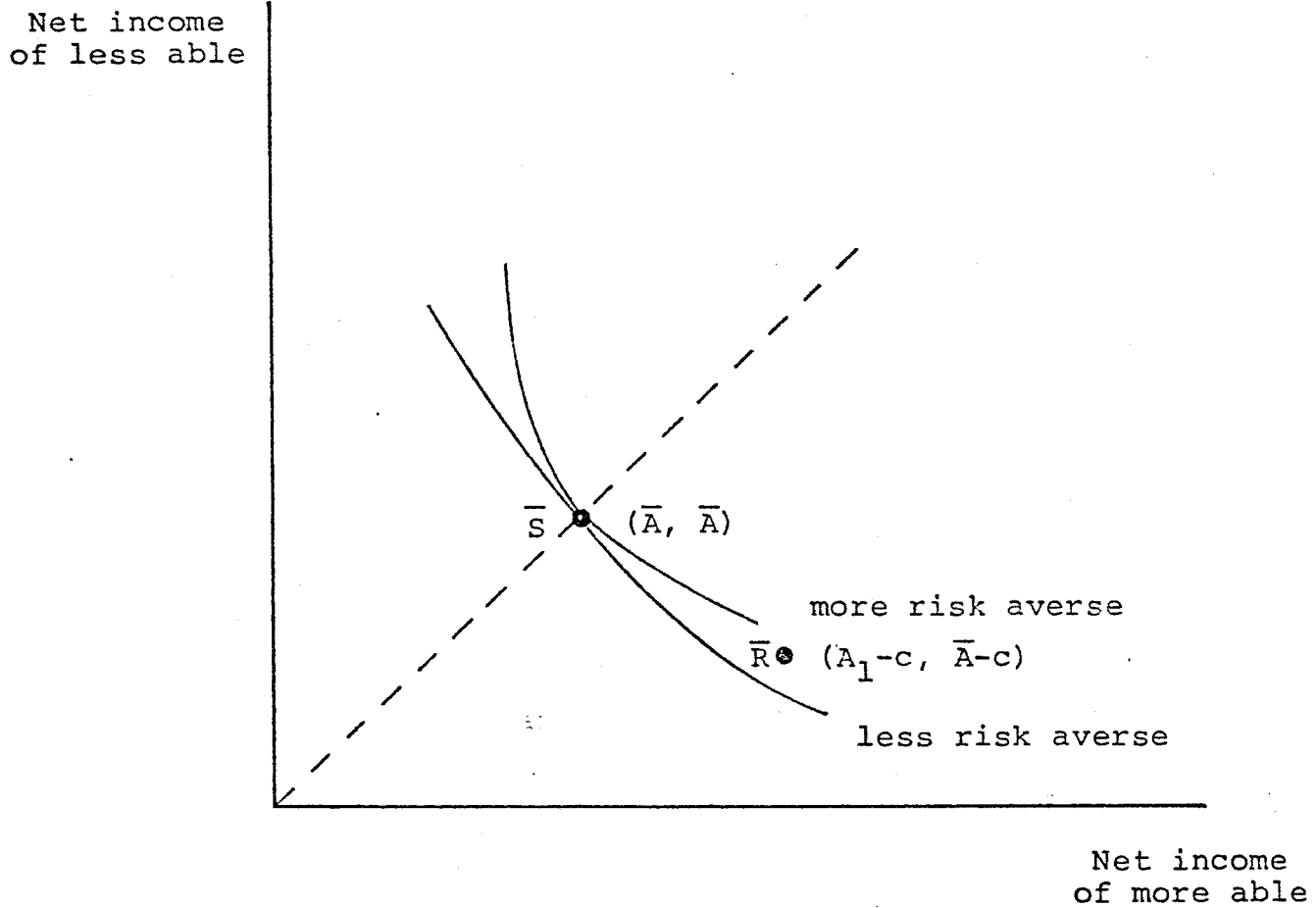
less risk averse

Net income
of more able

Figure 1d

The greater the degree of risk aversion, the more
likely a no-screening equilibrium. (There is a
no-screening equilibrium for more risk averse
individual, since $\overline{R}$ lies above the indifference
curve through $\overline{S}$, but not for the less risk averse
individual.)

Income of
less able

S ● (A_2, A_2)

more risk averse

R ● (A_1-c, A_2-c)

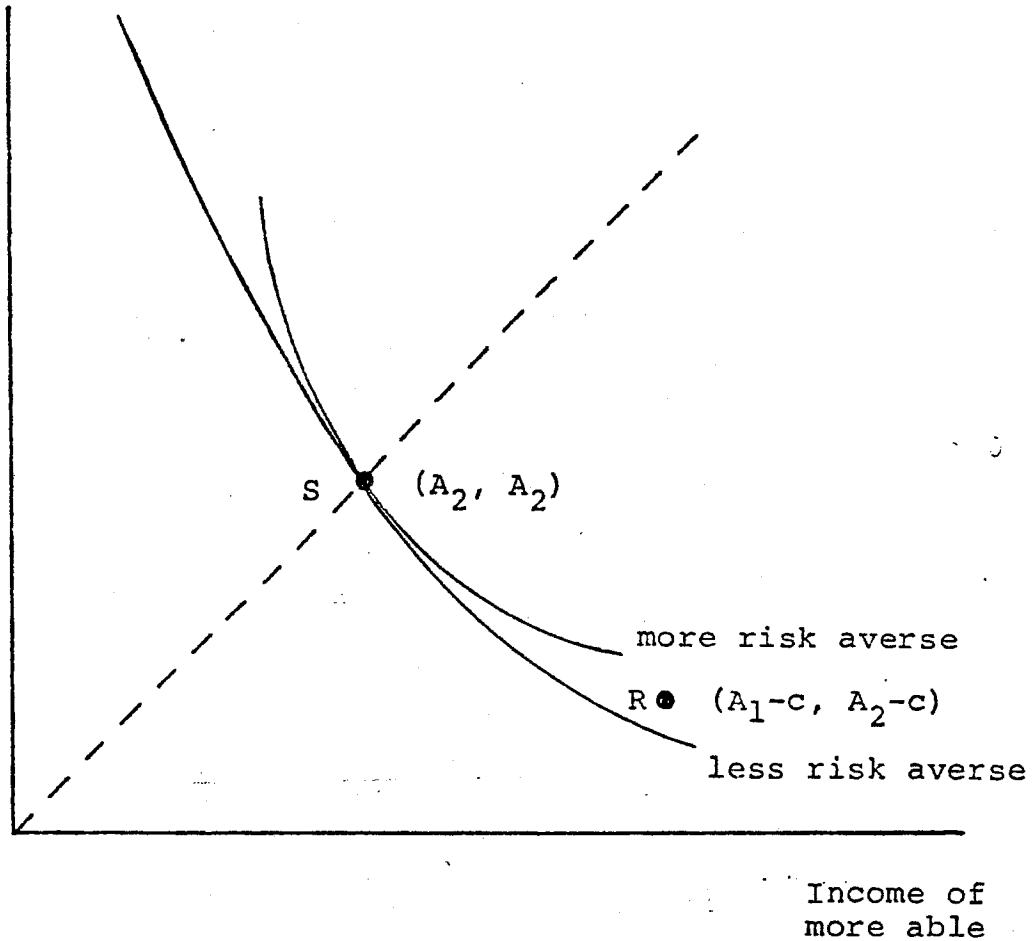less risk averse

Income of
more able

Figure 1e

The smaller the degree of risk aversion the more
likely there is a full screening equilibrium.
(While for the less risk averse individuals there
is a full screening equilibrium, since R lies
above the indifference curve through S, there does
not exist a full screening equilibrium for the
more risk averse.)

We can easily relate the nature of the equilibrium to the two parameters, λ and c , for the case of risk neutral individuals. There exists a screening equilibrium if, when everybody is screened, the expected return to being screened is positive, i.e.,

$$(A_1 - c)\lambda + (1 - \lambda)(A_2 - c) \geq A_2$$

or

$$c \leq \lambda(A_1 - A_2) \quad .$$

There exists a no-screening equilibrium when the expected return to being screened then is negative, i.e.,

$$\bar{A} \equiv \lambda A_1 + (1 - \lambda)A_2 \geq (A_1 - c)\lambda + (1 - \lambda)(\bar{A} - c)$$

$$= \lambda(2 - \lambda)(A_1 - c) + (1 - \lambda)^2(A_2 - c)$$

which upon rearrangement we can write as

$$c \geq \lambda(1 - \lambda)(A_1 - A_2)$$

There two loci are drawn in Figure 2. It is clear that there is a large area of overlap, in which there are multiple equilibria.[1]

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1. We have limited our discussion to this point to equilibria
   with no-screening or full screening. A more general formu-
   lation, entailing the possibility of partial screening, is
   discussed below. There, we show that whenever there is both
   full screening and no-screening equilibria, there also exists
   a partial screening equilibrium, but it is, under a reason-
   able dynamic postulate, unstable.

Since, in the simple model postulated so far, ex ante (before screening) all individuals have the same probability of being more able, and since there are no productivity returns to screening, even when individuals are risk neutral, whenever there is screening, ex ante expected utility is reduced; a fortiori, when individuals are risk averse, screening unambiguously lowers individuals' ex ante expected utility. The market equilibrium clearly may not be Pareto efficient.

Once we introduce the possibility that screening has some productivity effects, it still remains true that the market may not be Pareto efficient; but the nature of the bias is no longer obvious. There are important instances where there exists a no-screening equilibrium, when everyone might be better off with at least some screening. Indeed, we can show that if screening allows individuals to be better matched to their jobs, then a screening subsidy may lead to a Pareto improvement.

Partial Screening Equilibria

To see this, we shall focus on a partial screening equilibrium, where some individuals become screened and others do not. Thus, if a fraction s of the population is screened $(0 \leq s \leq 1)$ we let

$w(s)$ = wage (mean productivity) of those who are not certified as in group 1 (this includes, then, both those who are not screened, and those who are, but have "failed"); and

w_1 = wage of those who are identified as type 1.

w(s) is a function of the fraction of the population screened. In the pure hierarchical model (i.e., the model with on comparative advantage) described earlier

$$w'(s) < 0$$

since·as more individuals become screened, the proportion of the less able in the unscreened increases: those who are identified as more able (pass the exam) are selected out, but those who fail the exam (are identified as A_2) are thrown back into the "pool." On the other hand, whenever there is an element of job-matching (sorting), ·it is possible that $w'(s) > 0$. (See Stiglitz (forthcoming) and the discussion below.)

In the pure hierarchical model presented earlier, w_1 is fixed and independent of s , but in more general models w_1 could depend on s . For most of the analysis, we assume w_1 is fixed, indicating how the analysis is altered if w_1 is a function of s in footnotes.

a. Patterns of Equilibria

In equilibrium, the individual who becomes screened must be indifferent between remaining unscreened, and receiving w(s) , and becoming screened, with a probability λ of being type 1 and a probability $1 - \lambda$ of being type 2. Thus we require for an interior equilibrium

(1) $\qquad u(w(s)) = u(w_1 - c)\lambda + u(w(s) - c)(1 - \lambda) \equiv v(s)$

while there are boundary equilibria at

$$s = 0 \qquad \text{if} \qquad u(w(0)) \geq v(0)$$

and at

$$s = 1 \qquad \text{if} \qquad u(w(1)) \leq v(1)$$

The market equilibrium is depicted in Figures 2 through 5.

The slope of the LHS is $u'(w(s))w'(s)$ while that of the RHS is[1] $u'(w(s) - c))(1 - \lambda)w'(s)$. Since $u'(w(s) - c) > u'(w(s))$, the slope of the LHS may be greater or smaller than that of the RHS depending on the value of λ (if $c > $ and $\lambda = 0$, the RHS is always steeper than the left) and c (if $c = 0$, $\lambda > 0$ the LHS is always steeper than the right). But if $u'(w(s)) = u'(w(s) - c)(1 - \lambda) \equiv v'(s)/w'(s)$

$$\frac{u''(w(s))}{u'(w(s))} \gtrless \frac{u''(w(s) - c)}{u'(w(s) - c)} \qquad \text{as}$$

there is decreasing or increasing <u>absolute</u> risk aversion. Thus, under the hypothesis of decreasing absolute risk aversion, there are, at most, three equilibria.[2] The possible patterns are de-

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1. If w_1 is a function of s, the slope of the RHS is
   $$\lambda u'(w_1(s) - c)w_1'(s) + u'(w(s) - c)(1 - \lambda)w'(s) \qquad .$$

2. The two curves, $u(w(s))$ and $v(s)$, can intersect at most twice; if they intersected three times, there would have to be two values of s at which the slopes of $u(w(s))$ and $v(s)$ were the same. But under the assumption of decreasing absolute risk aversion, the slopes can be equal only once (assuming $w'(s)$ does not change sign). If the two curves intersect once, there can be, at most, two boundary and one interior equilibria. If the curves intersect twice, there can be, at most, one boundary and two interior equilibria. The boundary equilibria require $u(w(0)) \geq v(0)$ and $u(w(1)) \leq v(1)$. With two intersections one, and only one, of these inequalities holds.
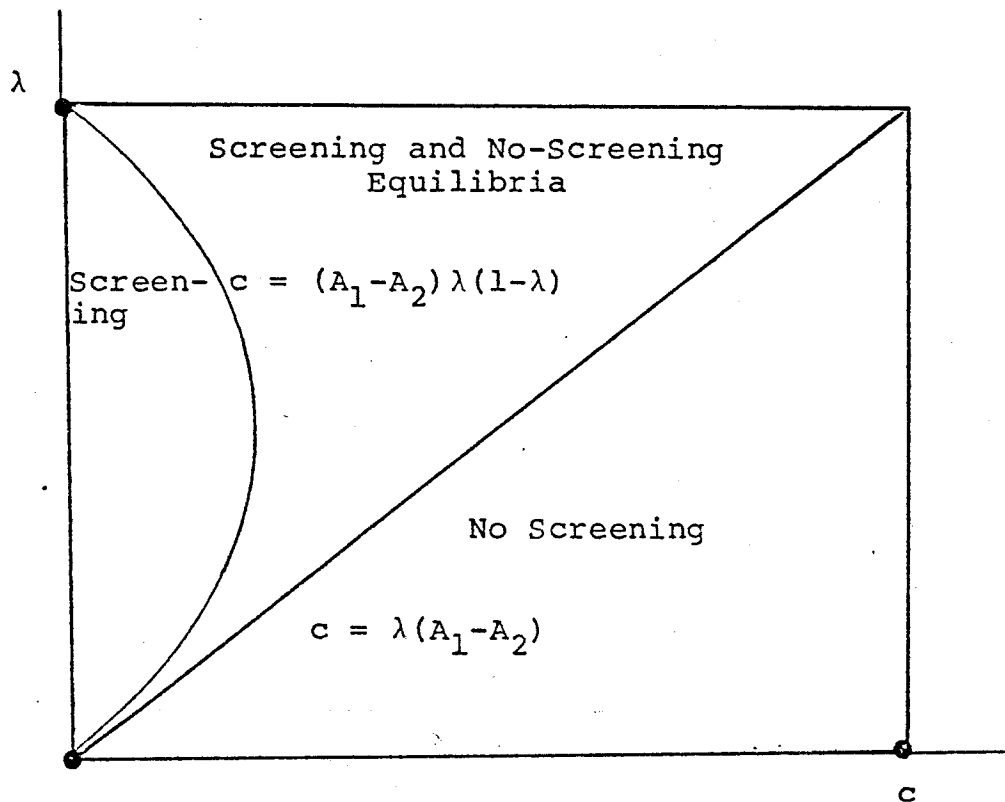
Figure 2

No Information (risk neutrality)

No Screening: $\lambda A_1 + (1-\lambda) A_2 \geq (A_1 - c)\lambda + (1-\lambda)(\overline{A} - c)$

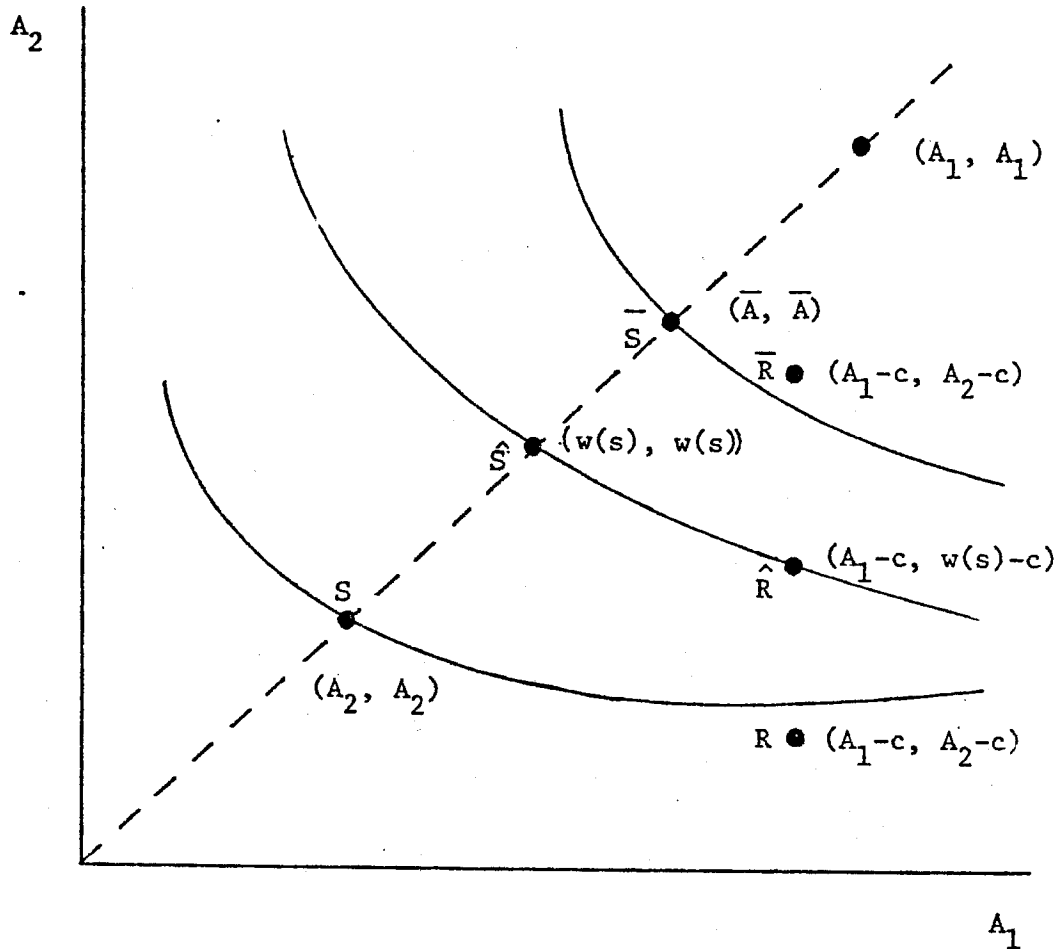Screening Equilibrium: $A_2 \leq (A_1 - c)\lambda + (1-\lambda)(A_2 - c)$

Figure 3

Partial Screening Equilibrium

$$w(s) \equiv \frac{(1-s)\lambda A_1 + (1-\lambda)A_2}{(1-s)\lambda + (1-\lambda)}$$

Full screening equilibrium Pareto inferior to partial screening equilibrium (which is Pareto inferior to no-screening situation, which is not an equilibrium).
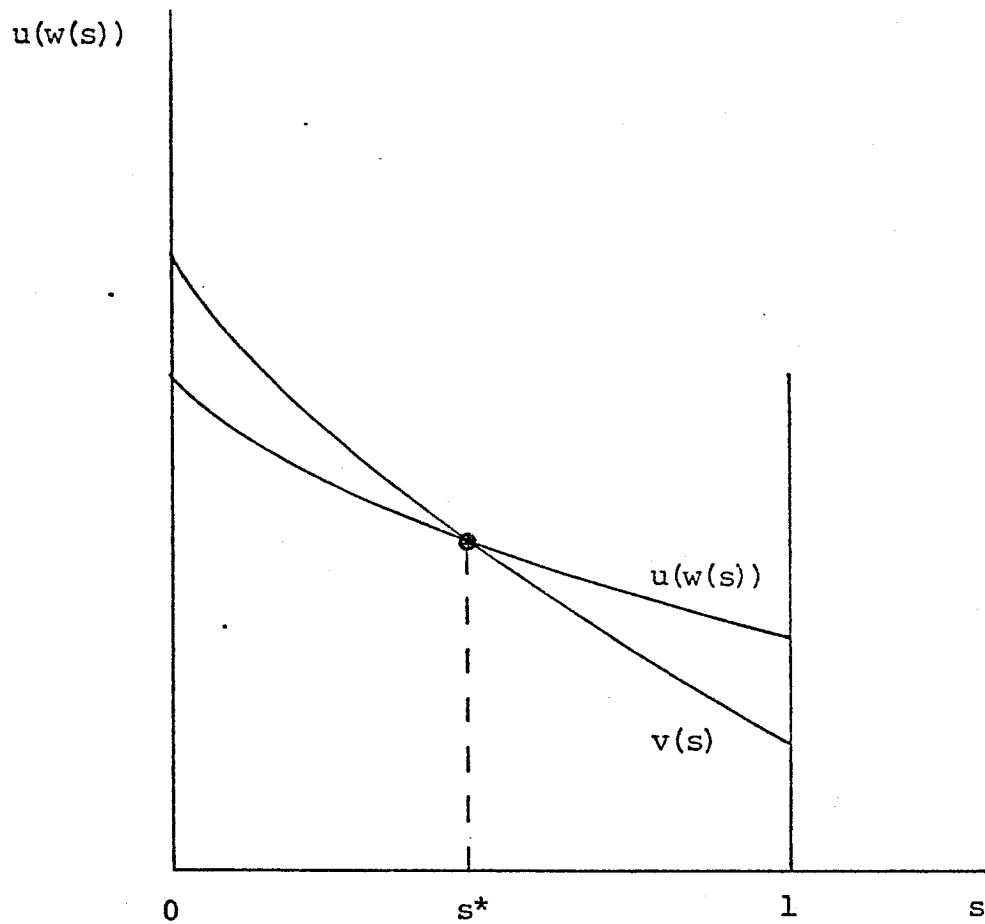
Figure 4a

Unique equilibrium (at s = s*) stable, but
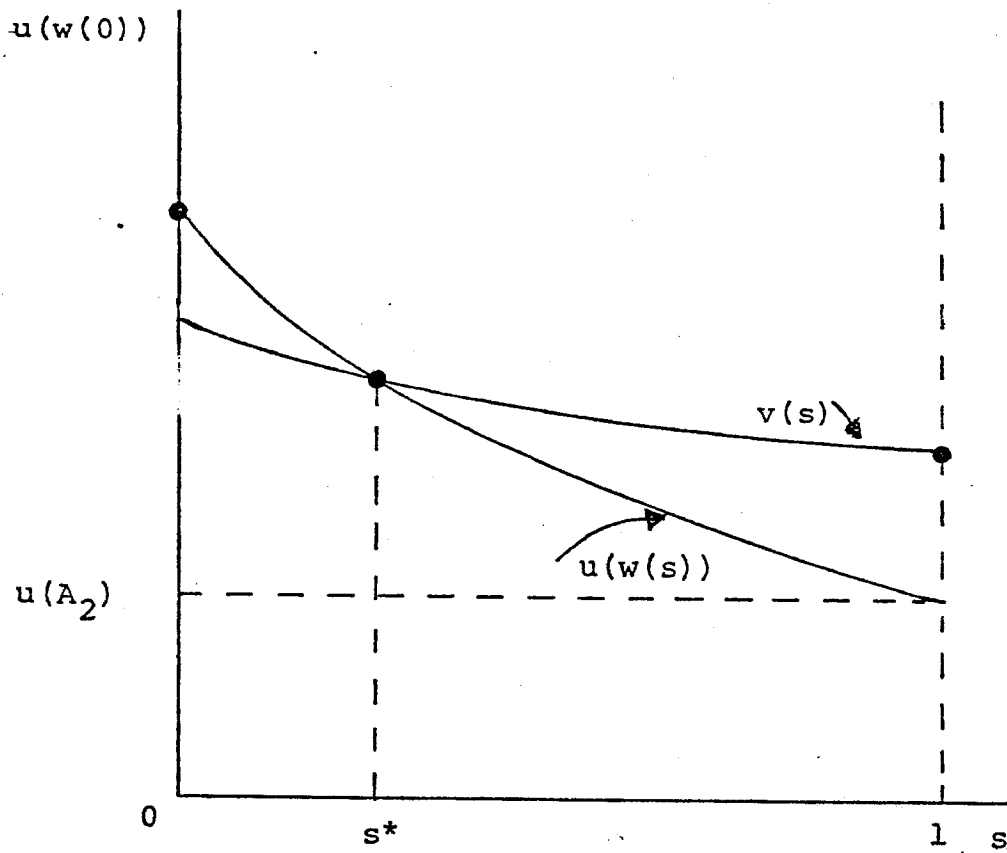Pareto inferior to s = 0 (which is not
an equilibrium)

Figure 4b

Equilibria at s = 0, s = s*, s = 1

s = 0 Pareto efficient and stable
s = 1 Stable

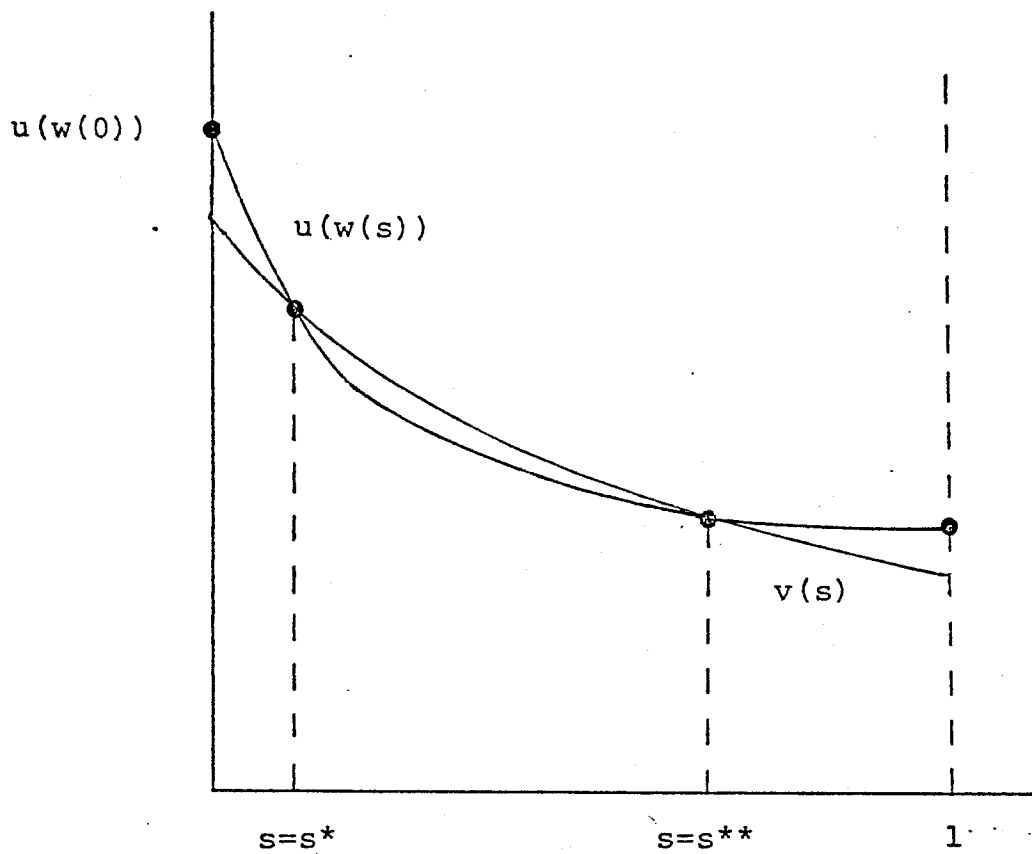Figure 4c

Equilibria   at   s = 0,   s = s*,   s = s**

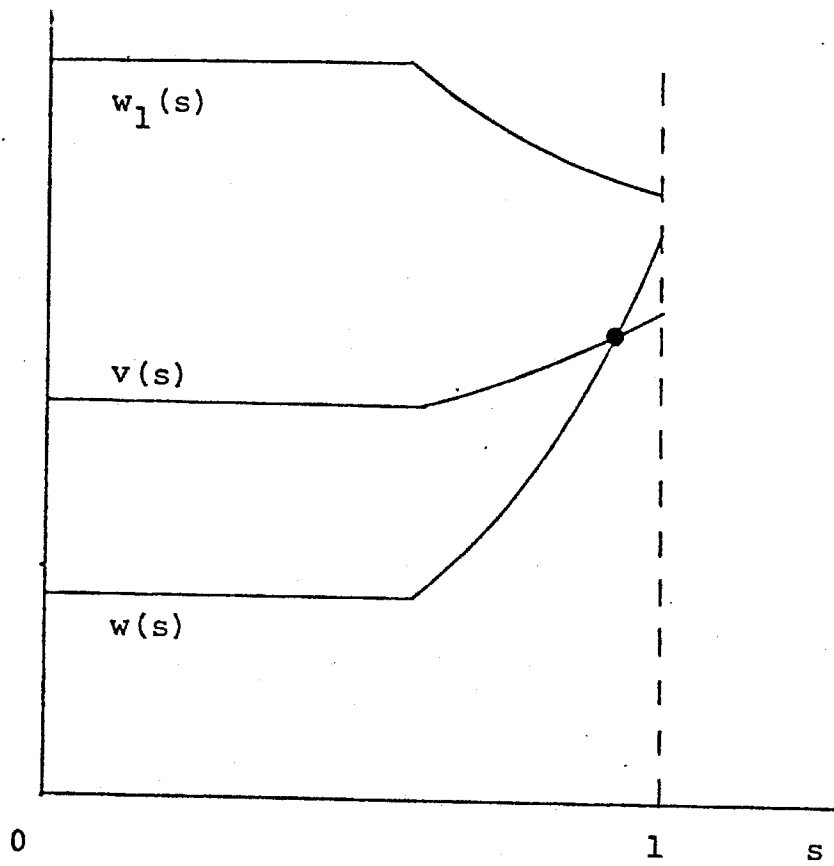s = 0   Pareto efficient
s = 0,   s = s**   Stable

Figure 5a
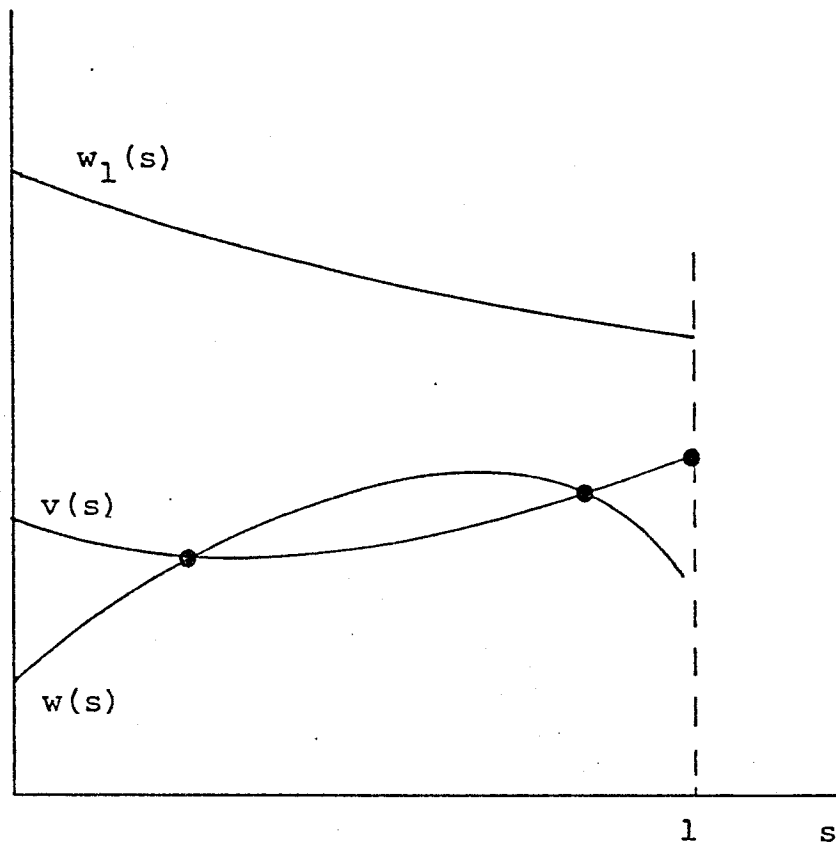
Interior Equilibrium with $w'(s) > 0$

Figure 5b

Multiple Equilibria

Stable Interior Equilibrium at Point where $w'(s) > 0$

picted in Figure 4 for the case of $w'(s) < 0$. The figure makes clear that there may be multiple equilibria, some of which may be Pareto inferior to others (and all of which may be Pareto inferior to allocations in which no one is screened, even when those allocations are not "sustainable" within a market).

In Figure 5, we illustrate some alternative patterns, with $w'(s) > 0$ for at least some values of s. ($w(s)$ functions of this shape are generated by Examples 2 and 3 below.)

b.   Stability

In those cases where there are multiple equilibria, not all of the equilibria are stable, in the natural sense to be defined below. Assume $s*$ is an equilibrium, and assume that, by chance, a fraction $s* + \Delta$ happen to get screened. If the equilibrium $s = s*$ is stable, it must now be the case that the wages of those screened are less than those not screened. More formally, stability of an interior equilibrium (with $0 < s < 1$) requires[1]

(2) $u'(w(s))w'(s) > u'(w(s) - c)(1 - \lambda)w'(s)$

c.   Effects of Subsidies

Now, let us impose an _ad valorem_ subsidy on screening, reducing screening cost to

$c(1 - \tau)$

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1. If w_1 is a function of s, we require

$u'(w(s))w'(s) > u'(w(s) - c)(1 - \lambda) w'(s) +$
$u'(w_1(s) - c)\lambda w_1'(s)$

The subsidy is paid for by a uniform lump sum tax of τcs. The equilibrium condition now becomes

(3) $\quad u(w(s) - \tau cs) = \lambda u(w_1 - c(1 - \tau(1 - s))) + (1 - \lambda)u(w(s)$
$\quad\quad - c(1 - \tau(1 - s)))$

Implicit differentiation of (3) then yields

$$\left.\frac{ds}{d\tau}\right|_{\tau=0} = \frac{c[u_0' s + (\lambda u_1' + (1 - \lambda)u_2')(1 - s)]}{[u_0' - (1 - \lambda)u_2']\, w'(s)} > 0$$

where

$$u_0' = u'(w(s) - \tau cs)$$

$$u_1' = u'(w_1 - c(1 - \tau(1 - s)))$$

$$u_2' = u'(w(s) - c(1 - \tau(1 - s)))$$

and where we have made use of the stability condition (2).

We can now calculate the effect of the subsidy on the welfare of everyone:

$$\left.\frac{du}{d\tau}\right|_{\tau=0} = u_0'[w'(s)\frac{ds}{d\tau} - cs]$$

$$= \frac{u_0' c}{[u_0' - (1 - \lambda)u_2']}\, [\lambda u_1'(1 - s) + (1 - \lambda)u_2']$$

It is thus apparent that if the equilibrium is stable (using (3)), everyone is better off if $w'(s) > 0$, and worse off if $w'(s) < 0$.[1,2]

In Figure 6, we illustrate the effect of a screening subsidy on the equilibrium. In Figure 6a, $w'(s) < 0$ so everyone is worse off at the (stable) interior equilibrium, while in Figure 6b, $w'(s) > 0$, while $w_1'(s) > 0$, so the screening subsidy makes everyone better off. Finally, Figure 6c shows a case with $w'(s) > 0$, $w_1' < 0$, where the results of a subsidy are ambiguous. (In any particular case, however, the effect can easily be ascertained.)

d. The Effects of Lowering Screening Costs

An immediate implication of our previous analysis is that, although an increase in costs of screening, i, will normally lead to less screening (in the case of an interior stable

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1. A more general theorem on the inefficiency of the market equilibrium with adverse selection (screening or signaling) is contained in Greenwald and Stiglitz (1982)).

2. If w_1 is a function of s, then

$$\left.\frac{ds}{d\tau}\right|_{\tau=0} = \frac{c[u_0's + (\lambda u_1' + (1-\lambda)u_2')(1-s)]}{[u_0' - (1-\lambda)u_2']w'(s) - \lambda u_1'w_1'(s)}$$

and

$$(4) \quad \left.\frac{du}{d\tau}\right|_{\tau=0} = \frac{u_0'c\{w'(s)(\lambda u_1'(1-s) + (1-\lambda)u_2') + sw_1'(s)\lambda u_1'\}}{(u_0' - (1-\lambda)u_2')w'(s) - \lambda u_1'w_1'(s)}$$

Thus, whether welfare is increased or decreased depends on the magnitude of w_1' as well as w'. If λ is small, the results remain essentially unchanged.

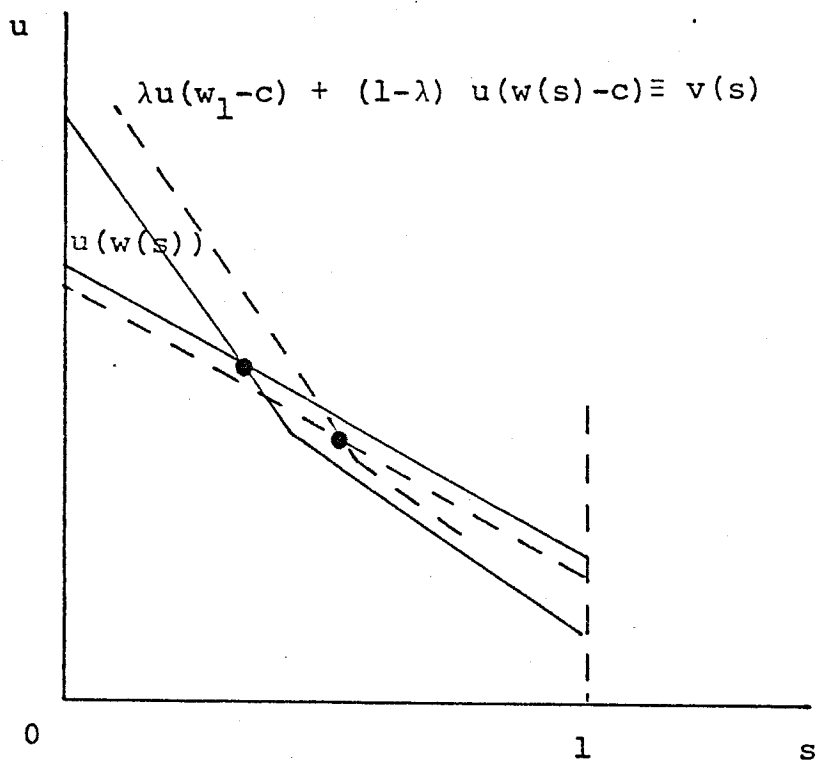$$\lambda u(w_1-c) + (1-\lambda)\, u(w(s)-c) \equiv v(s)$$

$u(w(s))$

Figure 6a

A Screening Subsidy Leads to a Pareto Inferior Equilibrium
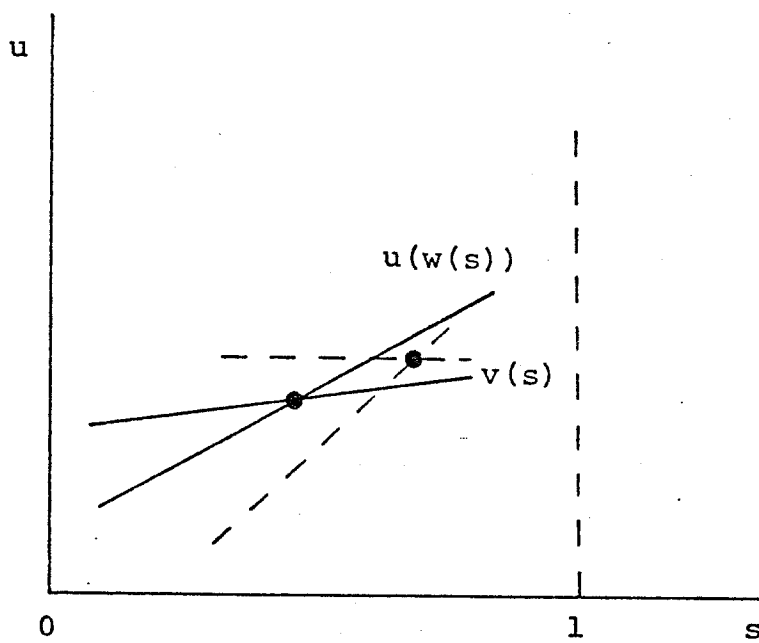

$u(w(s))$

$v(s)$

Figure 6b

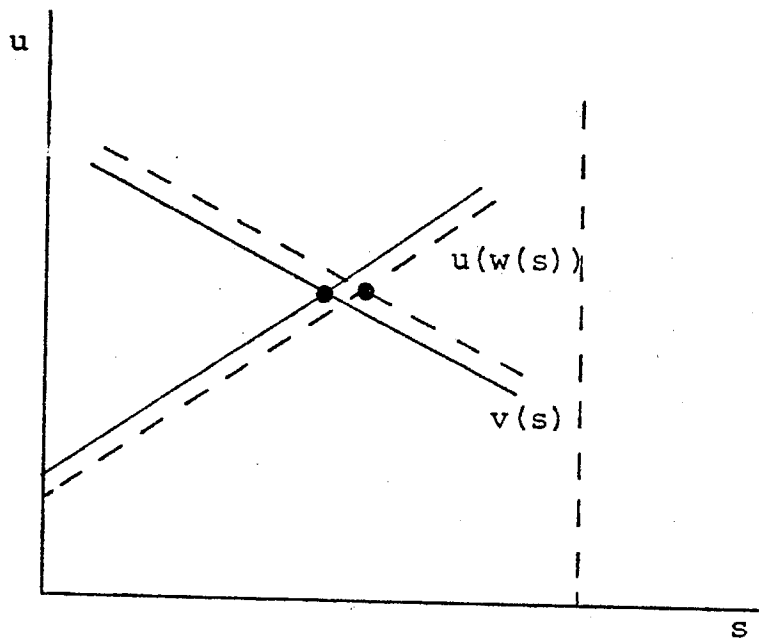A Screening Subsidy Leads to a Pareto Improvement

Figure 6c

Effects of Screening Subsidy Ambiguous

equilibrium), its welfare effects are ambiguous. In particular, for the case of hierarchical screening, it leads to an increase in the wage of the unscreened. It is apparent that such a tax would be a Pareto improvement. <u>Reducing the cost of information reduces everyone's welfare</u>.

e. <u>The Derivation of w(s): Three Examples</u>

In the preceding discussion, we have seen the crucial role played by the sign of w'(s) . We now provide three simple examples showing that w(s) may in fact be either an increasing or decreasing function of s .

<u>Example 1: Hierarchical Screening</u>. The first entails the hierarchical screening model employed earlier. Type 1 workers have a higher productivity than type 2 workers regardless of how they are assigned; screening thus has no productivity effects. When a fraction s of the workers are screened, λs will have "passed" and been certified as being more able. (Recall, we are assuming that one cannot distinguish between those who have not been screened, and those who have attempted to be screened, and turn out to be less able.) Thus,

$$w(s) = \frac{A_1(1-s)\lambda + A_2(1-\lambda)}{(1-s)\lambda + (1-\lambda)} = \frac{A_1(1-s)\lambda + A_2(1-\lambda)}{1-\lambda s}$$

$$w(0) = \overline{A}, \quad w(1) = A_2$$

$$w'(s) < 0 \quad .$$

Example 2: Assume the aggregate production function is of the form

$$Q = N_1^{\alpha} N_2^{1-\alpha}$$

where Q is output and N_i is the effective labor supply in job i. A type 1 worker has productivity ν when assigned to job 1,[1] one otherwise, while a type 2 worker has productivity of (just less than)[2] unity when assigned to a job of type 2, but zero otherwise. In the absence of screening, workers will be assigned to equate the (average value of the) marginal productivity on the two jobs, i.e.,

$$(5) \qquad \nu \alpha \lambda \left(\frac{N_1}{N_2} \right)^{\alpha-1} = (1-\alpha) \left(\frac{N_2}{N_1} \right)^{-\alpha}$$

where

$$(6a) \qquad N_1 = \nu z \lambda L$$

$$(6b) \qquad N_2 = (1-z) L$$

where L is the labor force, z is the fraction (of the unscreened) assigned to job 1. Hence,

---

1. That is, he embodies ν effective labor units.

2. The proviso is made to ensure that type 2 individuals would not wish to reveal their ability.

$$\frac{N_1}{N_2} = \frac{\nu\alpha\lambda}{1-\alpha} = \frac{\nu z\lambda}{1-z}$$

or

$$z = \alpha \quad .$$

When s workers are screened, clearly all will be assigned to type 1 jobs, provided s is sufficiently small, and

(7a) $$N_1 = [\lambda s\nu + \nu z[1-s + (1-\lambda)s]]L$$

(7b) $$N_2 = [(1-\lambda)s + (1-s)]L(1-z)$$

It is immediate from (5) that N_1/N_2 remains unchanged (at $\nu\alpha\lambda/1-\alpha$) as s increases, until $z = 0$, i.e., until

(8) $$\alpha[(1-\lambda)s + (1-s)] = (1-\alpha)s$$

i.e.,

$$s = \frac{\alpha}{1-\alpha + \lambda\alpha} \equiv s^* \quad .$$

Thereafter,

$$N_1 = \nu\lambda sL$$

$$N_2 = [(1-\lambda)s + (1-s)]L$$

Accordingly, we can calculate

$$w_1(s) = \begin{cases} \nu\alpha \left(\dfrac{1-\alpha}{\nu\alpha\lambda}\right)^{1-\alpha} & \text{for } s < s^* \\[4mm] \nu\alpha \left(\dfrac{(1-\lambda)s + (1-s)}{\nu\lambda s}\right)^{1-\alpha} & \text{for } s > s^* \end{cases}$$

$$w(s) = \begin{cases} (1-\alpha)\left(\dfrac{\nu\alpha\lambda}{1-\alpha}\right)^{\alpha} & \text{for} \quad s < s^* \\[2ex] (1-\alpha)\left(\dfrac{\nu\lambda s}{1-\lambda s}\right)^{\alpha} & \text{for} \quad s > s^* \end{cases}$$

Thus, $w' = 0 \quad s < s^*$

$ > 0 \quad s > s^*$

The condition for a screening subsidy to lead to a Pareto improvement becomes (using (4)),

$$\frac{1}{1-s\lambda}[\lambda u_1'(1-s) + (1-\lambda)u_2'] > u_1' \quad .$$

If individuals are risk averse, this is always satisfied for $\lambda < 1$.

Example 3: Assume there is a range of machines available. On a type α machine $(0 \leq \alpha \leq 1)$ a worker of type 1 has a productivity $\nu(\alpha)$, while a worker of type 2 has a productivity of $m(\alpha) < 1 < \nu(\alpha)$. Thus, if the fraction of type 1 workers in an unscreened pool is δ, the mean productivity is $\delta\nu(\alpha) + m(\alpha)(1-\delta)$.

There is an alternative technology, β , in which a type 1 worker has a productivity of $\hat{\nu}$ and a type 2 worker a productivity of 1. We assume $\hat{\nu} < \nu(\alpha)$, so all screened workers of type 1 are assigned to machines of type α. Moreover, we assume when no one is screened

$$(1-\delta)m(\alpha) + \delta\nu(\alpha) < \delta\hat{\nu} + (1-\delta)$$

Clearly, this inequality must then hold for all $\delta < \lambda$; hence, type α machines are the least productive for unscreened workers.

Finally, we assume there is a fixed supply of β type machines;
if L is the total population, N_β the number of β type machines,
N_α the number of α type machines, we assume

$$N_\alpha + N_\beta = L$$

$$N_\alpha < \lambda L$$

(where each machine can employ one worker).

We assume, moreover, that $\nu'(\alpha) < 0$, $m'(\alpha) > 0$, with

$$\delta\nu'(\alpha) + (1-\delta)m'(\alpha) > 0 \qquad \text{for} \quad \delta \leq \lambda$$

These assumptions are made to ensure (a) of the unscreened
workers, as many as possible are assigned to type β machines,
the remainder to type α machines; and (b) the screened workers
are assigned to type α machines, the low "α" machines being
assigned first.

Thus, if $F(\hat\alpha)$ is the number of machines with $\alpha \leq \hat\alpha$
$[F(1) = N_\alpha, F(0) = 0]$

$$w(s) = \begin{cases} \delta\nu(\hat\alpha) + (1-\delta)m(\hat\alpha) & \text{for} \quad s < s^* \\ \delta\hat\nu + (1-\delta) & \text{for} \quad s \geq s^* \end{cases}$$

and

$$w_1(s) = \begin{cases} \nu(\hat\alpha) & \text{for} \quad s < s^* \\ \hat\nu & \text{for} \quad s \geq s^* \end{cases}$$

where

$$\delta(s) \equiv \frac{\lambda(1-s)}{\lambda(1-s) + (1-\lambda)}$$

and

$$F(\hat{\alpha}) = sL, \quad F(1) = s*L$$

When $s < s*$, the "marginal" machine to which a certified type 1 individual is assigned is a type α; if $s > s*$, it is β. Thus, for $s < s*$ (letting $f \equiv F'$)

$$w'(s) = \frac{(\delta v' + (1-\delta)m')}{f} L - \frac{(v-m)\lambda(1-\lambda)}{(1-s\lambda)^2}$$

$$w_1'(s) = \frac{v'L}{f} < 0 .$$

If λ and $|v'|$ are small, then $w'(s) > 0$ while $w_1'(s) \simeq 0$, and a subsidy on screening may be beneficial.

The Inefficiency of the Market

Earlier, we showed that it was possible for there to be an efficient no-screening equilibrium (Figures 1a and 1c). In the no-screening equilibrium there is 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. The crucial question is the ability of the firm to appropriate the returns to acquiring information about individuals. Implicitly, here and in the subsequent discussion, we assume the firm cannot appropriate the returns to acquiring information.

The individual who is being screened can, of course, appropriate his ability rents, but screening is a very risky investment, and he cannot obtain ability insurance, presumably largely because of difficulties with moral hazard.[1] If the more able can do the same job as the less able with less effort, then if their income were independent of their ability, they would have an incentive to pretend that they were less able. Thus, even when screening is productive, it may not be undertaken.

There is a second source of market failure in our model: when some individuals are uninformed and some are informed concerning their abilities, and the market cannot distinguish between them, then those who know they are less productive will not disclose this information, even were it socially productive to do so. Rather, they pretend to be one of the uninformed. This source of market failure may be particularly important in product markets, as we shall note in Section 6 below.

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1. The issues are somewhat more complicated than the above simplified discussion might lead one to believe; for if there is a moral hazard problem here, why is there not a similar moral hazard problem whenever effort is variable? The following provides a context in which a meaningful distinction can be made. Assume that the output of the individual can be observed; that the less able and the more able perform different tasks; and that there are training costs to the performance of those tasks. Then, since output is observable, once on a job individuals have no incentive to slough on the job. But the more able may have an incentive to pretend to be less able, if the less able receive more than their marginal productivity, enough more to have effective insurance against being less able.

Summary

The results of this section are summarized in:

Proposition 1. If individuals are uninformed concerning their abilities, and "failures" are not publicly disclosed:

(1) If there exists a unique interior (partial screening) equilibrium, it is inefficient, in the sense that there exists a tax or subsidy on screening which will result in a Pareto improvement.

(2) There may exist multiple equilibria, in one of which everyone is worse off than in the other.

(3) Increasing the cost of information may reduce the amount of information purchased and increase everyone's welfare.

3. Public Failures

If those who fail screening cannot hide the fact, then there are (potentially) three distinct groups within the population: those who have obtained the credential (type 1); those who have attempted to obtain the credential and failed; and those who have not even attempted to obtain the credential.

In the simple models with which we are concerned in this paper, the productivity of an unscreened individual (the value of his marginal product) is independent of the number of individuals screened.[1] (In Stiglitz (forthcoming) I consider several

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1. This should be contrasted with our earlier analysis where those who were not screened and those who "failed" were mixed together. Then, the productivity of this group is, in general, a function of the fraction screened.

examples where this would not be true, either because of comple-
mentarity relationships in production or because of changes in
the prices of outputs as a result of screening. See also Examples
2 and 3 above.) Hence, the wage of an unscreened individual is
independent of the number of individuals screened. We denote
this wage by $\hat{w}$. There exists a full screening equilibrium if
(and only if)

$$u(\hat{w}) \leq \lambda u(w_1-c) + (1-\lambda) u(w_2-c)$$

where w_i = the productivity of a type i individual.
There exists a no-screening equilibrium if and only if

$$u(\hat{w}) \geq \lambda u(w_1-c) + (1-\lambda) u(w_2-c) \qquad .$$

It immediately follows that there either exists a no-screening
equilibrium or a full screening equilibrium, but not both.[1]

In particular, it should be noted that with pure hierarchical
screening (i.e., a model with no comparative advantages, where

$$\hat{w} = \bar{w} \equiv \lambda w_1 + (1-\lambda) w_2$$

if individuals are risk averse, the unique equilibrium is the
no-screening equilibrium, and this is Pareto optimal. More
generally, with "public failures" and productivities (wages) not
dependent on the number of individuals screened, the market

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1. Except for the singular case where
$$u(\hat{w}) = \lambda u(w_1-c) + (1-\lambda) u(w_2-c) \qquad .$$

equilibrium is Pareto optimal. The market equilibrium does not, of course, necessarily maximize net national output, for screening is a risky activity for which there are no insurance markets.

These results are, however, not general. The wage of the screened (or the unscreened) may well depend on the number of individuals screened and labeled. This is a kind of pecuniary externality, but these pecuniary externalities--in the kind of environment with which we are concerned here--may lead to non-optimal resource allocations. (See Greenwald-Stiglitz (1982).)

4. Information and Accreditation

In our earlier discussion we distinguished between two kinds of information: information of the individual about his own abilities, and information of the employer concerning the individual's abilities. The individual may believe he knows his own ability (and he may well know it), but statements by the individual concerning his own ability will not be believed.[1] This problem of making credible statements concerning abilities we refer to as the problem of "creditation," and is the one with which Spence (1974) and Stiglitz (1975) have been concerned. Here, we are concerned with the incentive for an individual who is uninformed about his own abilities to obtain information about those abilities.

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1. Thus, not all true statements convey information; they must be known to be true.

Although for analytic purposes, we separate the two kinds
of information, in practice, we may not be able to distinguish
them; processes which provide the individuals with information
may make some of that information public, i.e., affect others'
beliefs concerning his ability. This, as we shall comment at
the end, will have an important effect on his demand for infor-
mation. Still, there is a sense in which the individual who is
being screened and the screener always acquire different informa-
tion. The individual being screened knows how difficult it was
for him to pass the given exam; he knows whether he guessed the
answer, whether he was lucky in the set of questions asked, etc.;
the examiner knows only the individual's performance.

But for now, we assume that the processes of obtaining in-
formation and those of making it available to others can be
separated. We wish to know whether individuals purchase too
much or too little private information about themselves.

If everyone is obtaining information about himself, those
who find out that they are more able will then make that infor-
mation public (be accredited, provided costs of accreditation
are not too large). Thus, if all individuals are initially un-
informed, and then purchase information, any individual who does
not purchase information and accreditation will be treated as
if he were of lower ability. In the absence of information,
attempting to become accredited as one of the more able is a
risky investment. If one is one of the more able, the invest-
ment pays off; if one is not, one makes a loss. Thus, the return

from purchasing information about one's ability is that, if one discovers one is unable, one will not make the investment in being accredited. Moreover, if it turns out one is among the more able it converts the risky investment of accreditation into a safe investment. Thus, whenever there is a screening equilibrium with uninformed individuals (as described in the previous section), there is likely to be a demand for information about abilities; but there are circumstances in which the only equilibrium when it is not possible to acquire pre-screening is a non-screening equilibrium; with the possibility of acquiring information, there exists an information equilibrium entailing information acquisition and full screening. Thus the likelihood of Pareto inefficient equilibrium (from an ex ante utility point of view) is increased by the possibility of acquiring information about one's abilities. Information lowers net national output and expected utility.

Not only may there be an incorrect expenditure on accreditation, there may also be an incorrect (in this case excessive) expenditure on information acquisition concerning abilities. Although in our particular example there is always an excessive expenditure on information acquisition, in other examples there may be a deficient expenditure as well.

These results may be seen formally using our general screening model. The only modification to our earlier analysis of Section 2 is that those who obtain information but discover that they are unable, pay out an amount i , while those who obtain

information and discover that they are able pay out an amount

i + c . Thus, if we let

> w(s) = wage of those without credentials when a
> fraction s of the population obtains s
> credential

and

> w_1 = wage of those who are certified to be
> more able,

equilibrium is described by

$$s = 0 \quad \text{if} \quad u(w(0)) \geq \lambda u(w_1-c-i) + (1-\lambda)\ u(w(0)-i)$$

$$s = 1 \quad \text{if} \quad u(w(1)) \leq \lambda u(w_1-c-i) + (1-\lambda)\ u(w(1)-i)$$

$$0 < s < 1 \quad \text{if} \quad u(w(s)) = \lambda u(w_1-c-i) + (1-\lambda)\ u(w(s)-i)$$

where, as before, we assume that the uninformed individual as-
sumes that there is a probability λ of his being more able
within the population.

. Consider the pure hierarchical model introduced earlier
with risk neutral individuals. It is clear that Pareto optimality
requires that there be no screening and no information acquisition;
each individual's wage should then simply be $w(0) = \overline{A}$. However,
if c and i are sufficiently small, this will never be an
equilibrium. For there to be a no-screening equilibrium requires

Expected gain from screening = $\lambda(A_1-\overline{A}) < i + \lambda c$ Cost of obtain-
ing information
and becoming
screened.

And there will be a full screening equilibrium provided

$$\lambda(A_1 - A_2) \geq i + \lambda c$$

Thus, the results derived earlier (Stiglitz (1975)) on the inefficiency of market equilibrium do not depend on the assumption that individuals know their own ability. Indeed, if anything, there is now an even stronger presumption that the market is inefficient.

Job-Matching Screening

A similar analysis applies for those cases where there are real social returns to obtaining information. For simplicity, we again focus on the risk neutral case. Then a partial screening equilibrium entails

$$\lambda(w_1 - w(s) - c) = i$$

or

$$w(s) = w_1 - (\frac{i}{\lambda} + c) \quad .$$

Again, it is apparent that if $w'(s) > 0$, and if

$$w(0) < w_1 - (\frac{i}{\lambda} + c)$$

while

$$w(1) > w_1 - (\frac{i}{\lambda} + c)$$

there exists a partial screening equilibrium. By exactly the
same kind of analysis as used earlier, a subsidy on screening
costs or on information costs will result in a Pareto improvement.

5. Contrast Among Full Information, No Information, and
    Purchase Information Equilibria

What is nice about our model is that it allows us to see
how the nature of the equilibria depends on the informational
assumptions. In Figure 7 we show for the case when individuals
are fully informed concerning their abilities the different
patterns of equilibrium as a function of the two parameters c
and λ (the cost of accreditation and the proportion of the pop-
ulation which is able), given $A_1 - A_2$, the differences in
ability between the two groups and assuming risk neutrality. In
Figure 7, we see that there are three possible patterns; a full
screening equilibrium, a no-screening equilibrium, and, for values
of c in the shaded area, both no-screening, a partial screening,
and a full screening equilibrium. In contrast, when individuals
are completely uninformed concerning their abilities, and when
failures are not public, there are the same three patterns, ex-
cept the likelihood of full screening becomes much smaller, and
the likelihood of a no-screening equilibrium becomes greater (see
Figure 3). There still exists an intermediate range of values
for which there is both a no-screening and a full screening
equilibrium. Finally, in Figure 8 we see the case where the
individual can purchase information prior to making the decision
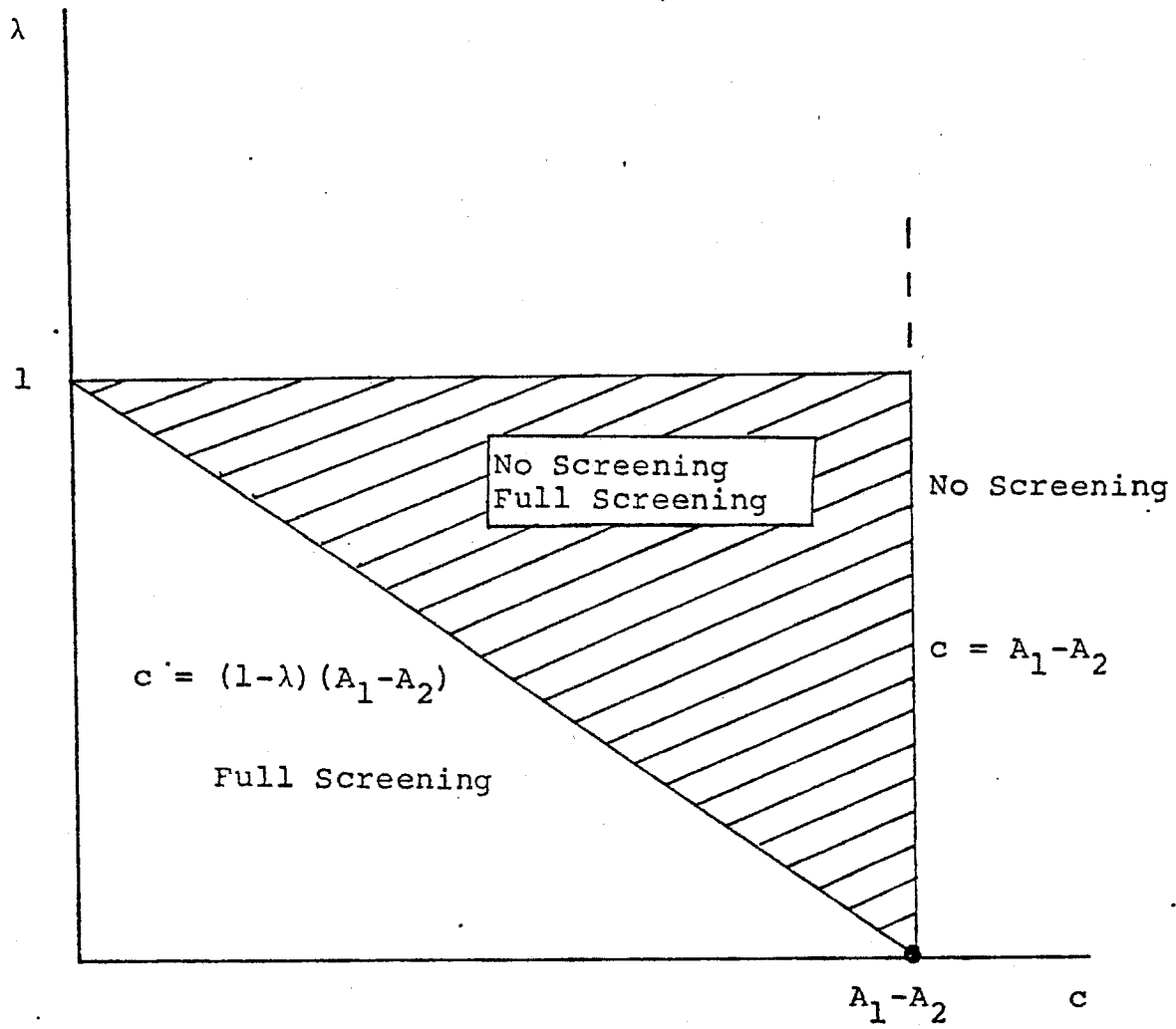to purchase accreditation. Again, the shape of the regions is

Figure 7

Full Information

No Screening: $c > A_1 - \overline{A} = (1-\lambda)(A_1 - A_2)$

Full Screening: $c < A_1 - A_2$

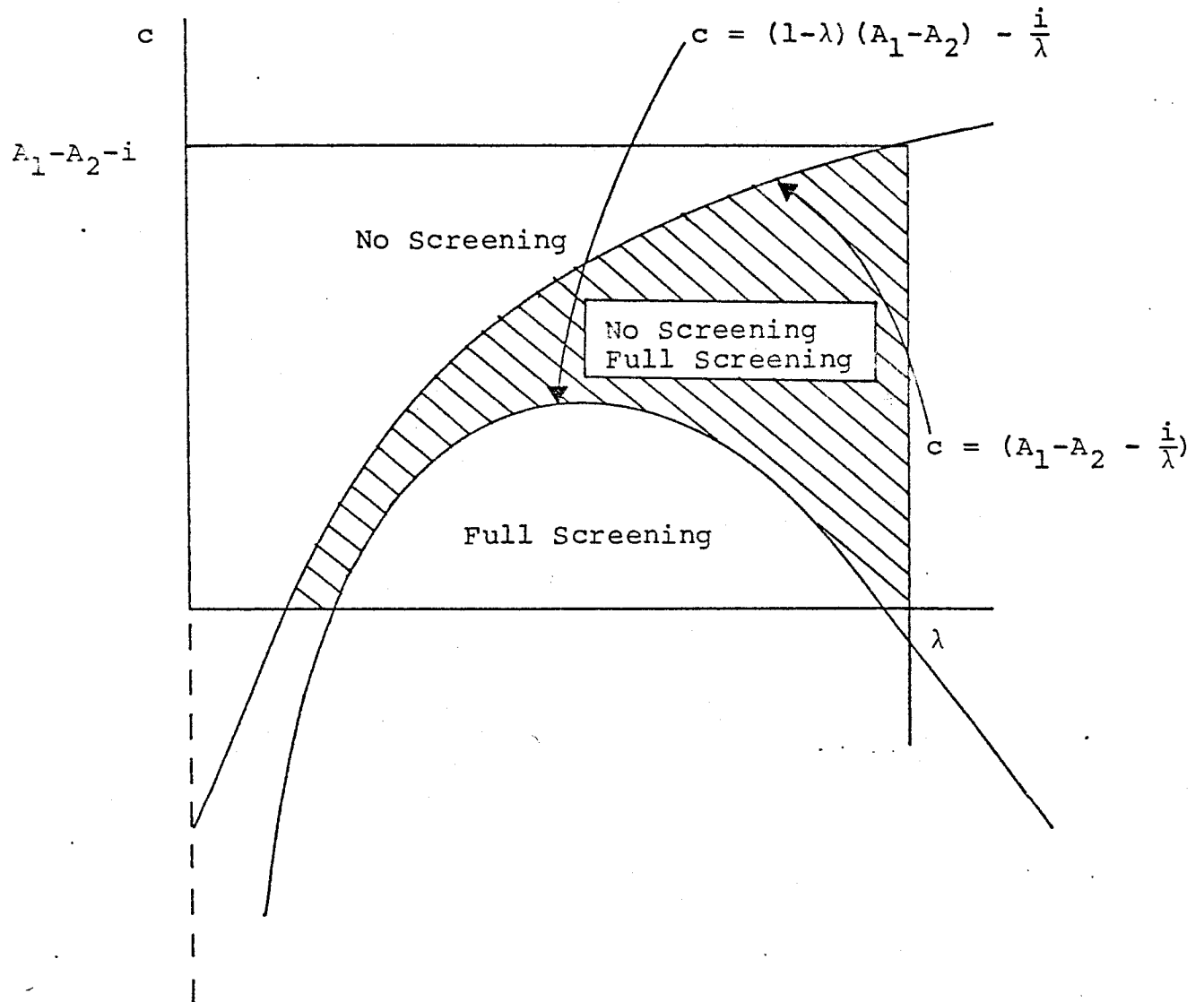Figure 8

changed markedly, and again there is a set of values of the parameters for which there exist both screening and no-screening equilibria.

6. Calculation of the Value of Information[1]

In each of the situations we have depicted, we can easily calculate the value of information. If s individuals have been screened, so that the wage of an unscreened individual is $w(s)$, then the value of information can be calculated in one of two ways:

(a) If in the absence of the information, the individual would have remained unscreened and so would have received a wage of $w(s)$, then information about an individual's ability allows him to decide to purchase the credential (at a cost c) <u>if</u> he is informed that he is one of the more able. This occurs with probability λ . Thus, information about one's ability has a value of

$$\lambda(w_1 - w(s) - c)$$

(b) If in the absence of the information, the individual would have become screened, then the information allows the individual to save on the screening cost a fraction $(1-\lambda)$ of the time. Thus, the value of the information is

$$(1-\lambda)c$$

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1. For a more extensive discussion of the value of information in screening models, the reader is referred to Radner and Stiglitz (forthcoming).

It should be clear from the above analysis that the value of
information depends critically on the general equilibrium of
the economy; in this case, on the number of other individuals
who have become screened.

7.   Policy Implications for Product Markets

We noted in the Introduction that the basic results of this
paper apply to a wide variety of "screening" problems. One appli-
cation, which has been the center of some recent policy debates,
relates to product markets. Do market forces lead forms to re-
veal "enough" information concerning the characteristics of the
products they sell? Should there be disclosure laws, compelling
firms to disclose additional information (as the government does
in a variety of circumstances)? Should the government subsidize
the provision of additional information (as it has done, for
example, both in the insurance market and the automobile market)?

In an earlier study (Stiglitz (1975)) I showed that if in-
dividuals were perfectly informed about their abilities, and if
the costs of conveying that information were zero, then in market
equilibrium there would be full disclosure; in the absence of
information, all individuals would be grouped together, and thus
receive the mean marginal product of the entire population. It
would always be in the interests of the best individual to have
his ability revealed; but then, the remaining individuals are
all grouped together, and it pays the best individuals of this
"remnant" to have their ability revealed. By this process, it
is in the interest of all individuals except the worst to have

their ability revealed; but by what I referred to as the Walras' law of screening, if all but one of the groups in a population have their characteristics revealed, the last group itself is identified.

This argument may be immediately applied to product markets[1] as well: if all firms had perfect information concerning their products, and it were costless to reveal the information, then in the market equilibrium there would be full revelation. Disclosure laws at best would be redundant; at worst (if disclosure is costly), lead to an excessive expenditure on information.

The analysis of this paper shows, however, that there is in fact no presumption that the market allocation of resources on information--both on the acquisition of information by producers concerning their own products and on its dissemination to consumers--is optimal.[2] For instance, if the costs of "screening" for some firms are higher than others, so some firms do not screen; and if it is possible for firms who do test their products to dispense with their "failures" in such a way as not to disclose that they have in fact been tested; then it will not

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1. The application is direct for product markets in which the supply of goods is inelastic. In the case of elastically produced goods, the analysis needs to be slightly modified (Stiglitz (forthcoming)). The consequences of imperfect information may, in that context, be more severe, since the market will provide the wrong incentives for firms to supply commodities of different qualities.

2. This argument has been developed more extensively by Golding.

be in their interests to disclose this information, even if
from a social point of view such disclosure would be beneficial.
Laws compelling disclosure of all available information may
lead to the disclosure of this testing information; alternatively,
however, it may induce firms to acquire less information concern-
ing their products. And laws specifying what information firms
must acquire and disclose may well result in excessive expendi-
tures on information acquisition and dissemination. We should
emphasize, however, that the inefficiencies associated with the
failure to disclose information may be far more serious when
product quality is, itself, an endogenous variable. Though our
analysis has clearly established that there are in fact no grounds
for claiming that the market provides an efficient level of in-
formation, the problems of government intervention in this area
are formidable, and there is no presumption that the kinds of
interventions one is likely to obtain will, on the whole, be
welfare improving.

8. Conclusions

This paper has produced a number of striking results. Al-
though it is widely believed that more information (or cheaper
information) is a good thing, and improves welfare, we have
shown that it may result in making everyone worse off. Although
we have focused our discussion on the labor market, the principle
underlying this result is quite general: information results in
our distinguishing states (individuals) which, in the absence of
the information we would not distinguish. In Stiglitz (1975) it
was noted that the absence of information acted like an _ability_

tax (we called it the "ignorance tax") because individuals with a low ability received more than their marginal product. But the absence of information also acts like an insurance policy if, in the ex ante situation, we do not know whether we are "more able" or "less able." We receive the same wage regardless of what our ability turns out to be. When there is not a complete set of insurance markets, this "insurance" function of ignorance can be quite important. (That there are not insurance markets for many of the kinds of uncertainties with which we are concerned here is no accident: these are matters which we shall take up elsewhere.)

Let us consider a few other examples where improved information lowers welfare. Consider a farmer growing a crop in which there is considerable price fluctuation. If the elasticity of demand is very low, the variability in his income will be much greater than the variability in his crop size. Thus, if he could be guaranteed a price (on at least a part of his crop) his risk would be reduced. If speculators had no information about the crop size next period, they would be willing, at the beginning of the period, to guarantee his price; but if information about the crop size became available before the farmer had sold his crop forward, but after his crop was planted, then he could not obtain insurance and his welfare would be reduced.[1]

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1. The example is admittedly somewhat artificial; in this particular case, if information became available prior to planting, it would obviously be of considerable value.

Similarly, in the stock market, an increase in information may increase the variability of stock market prices, and thus possibly lower welfare. (See Grossman and Stiglitz (1980).) Again, the reason is that individuals cannot obtain perfect insurance on the value of the stock next period.

These are, of course, not the only reasons that improved information may lower welfare. There are at least two quite different kinds of arguments for why improved information may lower welfare: the set of contracts which can be chosen in equilibrium is affected by what information the two sides to the contract have available before they undertake an action. Improving the information available to one side of the contract opens up the possibility that that individual can take advantage of the other individual in a way in which he could not with less perfect information; knowing this, the equilibrium contract must be altered, and as a result, both parties to the contract may be worse off.

In Salop and Stiglitz, we show an improvement in information may alter the degree of competitiveness in an economy with product heterogeneity; the result again may be a lowering of welfare.

The second important contribution of this paper is a strengthening of earlier results concerning screening equilibria. The results on non-optimality of market equilibria do not depend on asymmetric information. Under quite general conditions all individuals, not only the more able, are, in an ex ante expected utility sense, worse off as a result of lowering the cost of

information, in environments in which there is hierarchical screening. With job-matching screening, all individuals may be made better off as a result of a screening subsidy.

Finally, we should note that there are strong incentives within the economy for producing asymmetric information. In the analysis of Section 3, all individuals initially were completely uninformed. But not only is it easier for the individual to obtain information about his own ability than it is for others to obtain the same information, there is a strong incentive for the individual to obtain the information in such a way that others do not, at the same time, obtain the information.

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