Chapter I

Equilibrium in a Model of Adverse Selection with Uncertain Lifetimes

1. Introduction

Sixteen years ago, Arrow (1969) provided a sketch of a model to explore the implications of uncertain lifetimes under adverse selection while indicating instances where a free market allocation need not be Pareto efficient. He wrote

> "Suppose, for example, there are two types of individuals A and B, with different life expectancies, but the insurance company has no way to distinguish the two; it cannot in fact identify the present state in all its relevant aspects. The optimal allocation of resource under uncertainty would require separate insurance policies for the two types, but these are clearly impossible. Suppose further that each individual knows which type he belongs to. The company might charge a rate based on the probability of death in the two types together, but the insurance buyers would respond differently; those in the type with more favorable experience, say A, will buy less insurance than those in type B, other things (income and risk aversion) being equal. The insurance company's experience would be less favorable than it intended, and it will have to raise its rates. An equilibrium rate would be reached which is, in general, between those corresponding to types A and B separately but closer to the latter. Such an insurance arrangement is, of course, not Pareto-efficient. It is not *a priori* obvious in general that this free market arrangement is superior to compulsory insurance even though latter is also not Pareto-efficient because it typically disregards individual differences in risk aversion."
> (pp. 54-55).

Our purpose here is to study more precisely the equilibrium concept Arrow alludes to. It turns out that not only what the insurance company knows about the risk characteristics of the individuals are important but the company's knowledge about every individual's total insurance contract purchase is also crucial. We shall also study the welfare enhancing role of the compulsory scheme that Arrow speculates about.

In recent years, increasing number of researchers have shown interest in models of uncertain lifetimes. Uncertain lifetimes lead to saving via annuities. Heterogeneity in terms of survival probabilities among annuitants with imperfect knowledge about the risk classes of the annuitants leads to imperfect markets for annuities. In this paper, we study the properties of an equilibrium where individuals have private information about their survival probabilities. Two principal findings are (1) There is an equilibrium with no intervention where the rate of return on annuities is lower than the economy wide actuarially fair rate; (2) For a class of economies, the government with a compulsory tax/transfer scheme but with no additional information will be able to improve upon the free market allocation. In addition, we also show that the government intervention has a negative effect on the equilibrium rate of return for private annuity contracts.

In the literature, markets with private information have been studied extensively. Depending on how an equilibrium is defined, different types of results have been obtained. For example, Rothschild and Stiglitz (1976) have shown that if the individuals are restricted to buy one annuity contract only, then there is no equilibrium where all individuals buy the same quantity (non-existence of pooling equilibrium). Purchasing of one contract only per individual requires monitoring of total amount of contracts purchased by all individuals alternatively it requires a full flow of information among all contract issuing firms. Jaynes (1978) has shown that firms have an incentive to conceal such information if they are maximizing profits. Therefore, we have used an equilibrium concept where the firms act very "passively." They set the "unit price" only (or equivalently, the rate of return per unit of contract purchased), and let the customers choose their optimal quantities. This concept of the equilibrium is implicit in Arrow (1969). It has also been used by Pauly (1974). More recently, Hellwig (1983), Pauly and Kunreuther (1985) and Abel (1985) have utilized this equilibrium concept to study the behavior of equilibria under moral hazard.

Under a set of conditions specified in section two, we show that an equilibrium exists. Then it is shown that the equilibrium rate of return for annuity contract will be lower than the economy-wide actuarially fair rate of return. This provides a general equilibrium model where the market for insurance contracts is "loaded" (in the sense that it cannot provide an economy wide rate of return to anyone).

In section three, we explore the implications of tax/transfer schemes for a subclass of models considered in section two. Specifically, we show that (a) a "small" balanced budget tax/transfer scheme reduces the equilibrium rate of return of private annuities; (b) by enforcing a compulsory tax/transfer scheme, the government can improve upon the private market equilibrium allocation without extra information.

2. Equilibria in a Model of Adverse Selection

We shall study a slight variant of Eckstein et. al. (1985) one good discrete time model. The specifications of the economy are given below.

The population: At date t, $t \geq 1$, the population consists of (young) members of generation t. Generation t is partitioned into two distinct groups H (high survival type) and L (low survival type) who appear in relative sizes of α and $1-\alpha$ respectively. Members of generation t live for, at most, two periods, the first of which (date t) they survive with certainty. Death can occur at the beginning of the second period (date t+1) with probability $1-p_i$, $0 < p_i < 1$, $i = H, L$. This is the only source of uncertainty in the model. We assume that $p_H > p_L$. With a continuum of agents of each type, there is no aggregate uncertainty in the model.

Preference/Endowment: Each young person of generation t and of type i maximizes the following state dependent von Neumann-Morgenstern utility function

$$p_i u_1(A) + (1-p_i) u_2(B) \tag{2.1}$$

where A(B) = the vector of all relevant variables associated with two (one) period of life, i.e., the variables that the individual cares about when she lives for two (one) period(s). With the assumption of no bequest motive, $A = (c^i_t, c^i_{t+1})$ and $B = (c^i_t, 0)$, where

$c^i_t(c^i_{t+1})$ is the consumption at date $t(t+1)$. For convenience, we shall simplify the utility function as follows:

$$u_1(c^i_t,\ c^i_{t+1}) = u(c^i_t) + v(c^i_{t+1}) \qquad (2.2)$$

and

$$u_2(c^i_t,\ 0) = u(c^i_t) \qquad (2.3)$$

Inserting (2.2) and (2.3) in (2.1), we get the following simplified utility function which the individual is assumed to maximize

$$u(c^i_t) + p_i\ v(c^i_{t+1}) \qquad (2.4)$$

Note that in this form, the utility function remains state dependent as u need not be the same function as v. We shall make the usual assumptions on u and v, namely, u', $v' > 0$; $v'(x) \to 0$ as $x \to \infty$ and $u'(x) \to \infty$ as $x \to 0$, $v'(x) \to \infty$ as $x \to 0$. Each old person of type i maximizes c^i_{t-1}. Each young member is endowed with w units of good t at birth which is storable: if $x \geq 0$ units are stored at t, the result is xR units at t+1 where $R > 0$.

Information: There are two informational assumptions in our model. One relates what the insurance companies know about the survival probabilities of their customers. The second postulates what each firm knows about the <u>total</u> annuity contract purchases of its customers.

(1) Each agent of generation t perceives correctly the probability of her survival but the annuity-supplying firms cannot distinguish between the types of individuals.

(2) Each annuity-supplying firm knows the amount of annuity contracts purchased by a given individual <u>from that firm</u> but not the <u>total</u> amount purchased <u>from other firms</u>.

These two assumptions together imply that: (a) the firms charge a uniform price for every unit of contract purchased by all individuals; (b) the firms cannot impose a quantity restriction on the <u>total</u> contracts purchased by any given individual. For a given member of generation t, one unit of t good brings R_{at} units of t+1 good from the annuity supplying firm, if she survives. Thus, the above assumptions on information imply that firms compete only in terms of contract "price" R_{at}.

We can now write the budget constraints of the individuals of each type

$$c^i_t \leq w - a^i_t \tag{2.5}$$

$$c^i_{t+1} \leq a^i_t R_{at} \tag{2.6}$$

for $i = H, L$.

We will consider only a two period economy, and therefore drop the subscript t from R_{at} and write only R_a. Let the maximized (2.4) subject to (2.5) and (2.6) yield demand functions $D(R_a, p_i)$, i=H, L. The profit function of the (representative) firm is given by (if we assume uniform distribution of customers among firms)

$$\pi(R_a) = \alpha D(R_a, p_H)(R - p_H \cdot R_a) + (1-\alpha) D(R_a, p_L)(R - p_L \cdot R_a). \tag{2.7}$$

Now we are ready to define the equilibrium concept which we use in this paper.

Definition: An Arrow subsidizing equilibrium1 is characterized by the rate of return R^*_a such that the consumer demand functions are generated by maximizing (2.4) subject to (2.5) and (2.6); with

(i) $\pi(R^*_a) \geq 0$; and

(ii) there is no $R'_a > R^*_a$ such that $\pi(R'_a) \geq 0$.

The characterization of an equilibrium by specifying the rate of return alone can be justified in two ways: (1) government regulations could force the firms not to discriminate among risk classes; (2) a more subtle reason would be to identify the equilibrium as an outcome of a non-cooperative game among the insurance firms (non-cooperation of a firm in terms of revelation of information about the quantity of insurance purchased by an individual to other firms). Jaynes (1978) has shown that some firms would not have an incentive to share this information with other firms.

From the definition of π, it is easy to see that if the demand for annuity is positive for both types of individuals, then for all R_a lying between R/p_H and R/p_L, the first (second) term on the right hand side of (2.7) is positive (negative). Therefore, it is not difficult to see that an Arrow subsidizing equilibrium lies in the interval $(R/p_H, R/p_L)$.

Proposition 1: If the demand for annuity is positive for all individuals, then there exists an R^*_a in $(R/p_H, R/p_L)$ such that $\pi(R^*_a) = 0$ and $\pi(R_a) < 0$ for all $R_a > R^*_a$.

Proof: Given $D(R_a, p_i) > 0$, $i=H,L,2$ it follows that for every R_a in $(R/p_H, R/p_L)$, $R - R_a p_H < 0$ and $R - R_a p_L > 0$. Note also that given the assumptions on the utility function, D is continuous in R_a. Therefore, π is a continuous function in R_a. Clearly, $\pi(R/p_H) > 0$ and $\pi(R/p_L) < 0$. By the intermediate value theorem, there is at least one R_a in $(R/p_H, R/p_L)$ such that $\pi(R_a) = 0$. Let

$$R^*_a = \max \{R_a \in (R/p_H, R/p_L): \pi(R_a) = 0\}.$$

It is easy to see that such an R^*_a satisfies the hypothesis of the proposition. Q.E.D.

The result in the above proposition is hardly surprising. The following theorem shows that we can say more about the nature of R^*_a, the equilibrium rate of return.

Theorem 1: There exists at least one equilibrium rate of return in the (open) interval $(R/p_H, R/p)$, where, $p_0 = \alpha p_H + (1-\alpha)p_L$.

This theorem rigorously shows what Arrow (1969) notes in his remark, "an equilibrium rate will be reached which is, in general, between those corresponding to types A and B [L and H in our model] separately but closer to the latter." (p. 55) In what sense is the equilibrium rate of return "closer to the latter"? This is spelled out in the sequel.

Specifically, p_0 is the "average" survival probability of the whole population. We shall show that the equilibrium rate of return $R^*_a < R/p_0$. In this sense of lower than average rate of return, is the equilibrium "closer to the latter" [type H]. The intuition behind this result is quite straightforward: Type H will demand a larger quantity of annuity contracts than type L; thus, the insurance companies will not be able pay a rate of return based on p_0 without taking into account the difference in demand of the two types.

Before we prove this result explicitly, we first prove a number of simple results. First one shows that higher survival probability results in higher demand for annuity contracts.

<u>**Lemma 1**</u>: $D(R_a, p_H) > D(R_a, p_L)$, where these demand functions are generated from maximization of (2.4) subject to (2.5) and (2.6).

<u>**Proof**</u>: Suppose not. i.e., let $a_H \leq a_L$. Then, $w-a_H \geq w-a_L$; so, by

$u'' < 0$, we get:

$$u'(w-a^H) \le u'(w-a^L) \qquad (2.9)$$

and clearly by $v'' < 0$, $v'(a^H \cdot R_a) \ge v'(a^L \cdot R_a)$. Therefore, by the fact $p_H > p_L$, we have

$$p_H \cdot R_a \cdot v'(a^H \cdot R_a) > p_L \cdot R_a \cdot v'(a^L \cdot R_a) \qquad (2.10)$$

But we know

$$u'(w-a^H) = p_H \; R_a \; v'(a^H \cdot R_a) \qquad (2.11)$$

and

$$u'(w-a^L) = p_L \; R_a \; v'(a^L \cdot R_a) \qquad (2.12)$$

Substracting (2.11) from (2.12), we get

$$u'(w-a^H) - u'(w-a^L) = p_H R_a v'(a^H R_a) - p_L R_a v'(a^L R_a) \qquad (2.13)$$

But, by (2.9), LHS of (2.13) is non-positive and by (2.10), RHS of (2.13) is positive. A contradiction! Therefore, $a^H > a^L$. Q.E.D.

Lemma 1 is a variant of Wilson's (1977) Lemma 4 (pp. 176-7). We have a strict inequality as opposed to his weaker inequality (our assumption of strict monotonic utility function is stronger than his). Our utility function is different from his in two respects: (1) he considers only state independent utility function (in our notation, which means $u \equiv v$); (2) his utility function is instantaneous atemporal (ours is temporal).

Lemma 2: If $k_H > k_L \ge 0$, then $\alpha k_H A + (1-\alpha) k_L B < 0$, where $A = R - p_H \cdot R/p_0$ and $B = R - p_L \cdot R/p_0$.

Proof: First note that $\alpha A + (1-\alpha)B = 0$. Therefore $\alpha k_L A + (1-\alpha) k_L B = 0$. But $A < 0$. Thus, $\alpha k_H A + (1-\alpha) k_L B < 0$. Q.E.D.

Proof of theorem 1: We can write $R - R_a p$

$= p(R/p_0 - R_a) + (R - pR/p_0)$.

Therefore, we can write (2.7) as follows

$$\pi(R_a) = C + (R/p_0 - R_a)E \quad \text{where,}$$

$C = \alpha(R - p_H R/p_0)D(R/p_0, p_H)$

$+ (1 - \alpha)(R - p_L R/p_0)D(R/p_0, p_L)$

and $E = \alpha p_H D(R_a, p_H) + (1 - \alpha)p_L D(R_a, p_L)$.

Let $D(R/p_0, p_H) = k_H$ and $D(R/p_0, p_L) = k_L$.

Then $k_H > k_L \geq 0$ by Lemma 1. Applying lemma 2, $C < 0$.

Clearly, $E > 0$. Therefore, $\pi(R_a) < 0$ for $R_a \geq R/p_0$.

Q.E.D.

3. The Effects of Tax/Transfer in an Arrow Subsidizing Equilibrium

Any tax/transfer scheme will alter the endowment pattern between periods for an individual. Therefore, such a scheme will change the demand for annuities as well. Consequently, the equilibrium rate of return and the welfare of the individuals will change too. Arrow (1969) notes the potential for government intervention via a compulsory tax/transfer scheme: "It is not *a priori* obvious in general that this free market arrangement [in our model what we call an Arrow subsidizing equilibrium] is superior to compulsory insurance...." (p. 55).

In order to study the problem at hand in isolation, we shall assume the following about government intervention: (a) The aggregate tax/transfer schemes are balanced budget in nature (i.e., total taxes collected equal total benefits paid); (b) The government cannot distinguish between the risk types; (c) The government tax/transfer scheme is "small" (so that *some* individuals still have positive demand for private annuity contracts); (d) Government transfèrs are individual specific and nontradeable, i.e., individuals in their first periods of life cannot trade government papers which promise some second period consumption; (e) Government tax/transfer schemes are announced for every young individual *before* they make their choice of annuity contracts;3 (f) The tax/transfer scheme under consideration is unlike pay-as-you-go social security. The government collects tax from the young and stores it for them and promises to pay if an individual survives through period two; (g) The tax/transfer scheme is nondiscriminatory in the sense that all young (old) individuals of both types are treated alike.

3.1 The Effect of Tax/Transfer on the Equilibrium Rate of Return of Annuity Contracts[4]

Reconsider equation (2.7) with a government tax/transfer. Clearly, government tax/transfer affects the initial allocation of the individuals. Thus, the demand functions of both types of individuals will change by a tax/transfer scheme. Therefore, the equilibrium rate of return will be affected. We rewrite the equation (2.7) as follows:

$$\pi(R_a, t) = \alpha D_H(R_a, t)(R - R_a p_H) - (1 - \alpha) D_L(R_a, t)(R - R_a p_L) \qquad (3.1)$$

We know that $\pi(R_a, t) = 0$ gives $R_a = R_a(t)$

Thus, we have

$$(\partial \pi / \partial R_a)(dR_a/dt) + (\partial \pi / \partial t) = 0. \qquad (3.2)$$

We use (3.2) in (3.1) and get the following expression for dR_a/dt:

$$dR_a/dt|_{t=0} = - A/B \qquad (3.3)$$

where, $A = \alpha[(R-p_H R_a)\, \partial D_H/\partial t] + (1 - \alpha)\, [(R - p_L R_a)\, \partial D_L/\partial t]$

and

$$B = \alpha[(R-p_H R_a)\, \partial D_H/\partial R_a - D_H p_H] + (1 - \alpha)[(R-p_L R_a)\, \partial D_L/\partial R_a - D_L p_L]$$

where A and B are evaluated at $t = 0$.

In general the signs of A and B are ambiguous since they contain both positive and negative terms. However, for specific utility functions, it is possible to determine the signs of A and B. For $u(x) = v(x) = \ln x$, we have calculated dR_a/dt. In this special case

$$dR_a/dt|_{t=o} = - A/B$$

where, $B = - \alpha D_H p_H - (1 - \alpha) D_L p_L < 0$,

$$A = - \alpha f_H g(p_H) - (1 - \alpha) f_L g(p_L)$$

where $D_i = w.p_i/(1+p_i)$ and $g(p_i) = (R + p_i R_a)/(1+p_i)$ for i = H, L.

The sign of $dR_a/dt < (>) 0$ if and only if $A > (<) 0$.

Now $\alpha(f_H + (1 - \alpha) f_L > 0$ can be easily verified and $f_H < 0 < f_L$. It can also readily be shown that $dg(p)/dp < 0$ by differentiation. Therefore, $0 < g(p_H) < g(p_L)$. Thus, $\alpha f_H g(p_H) + (1 - \alpha) f_L(p_L) > 0$. This proves that $A > 0$ which is in turn shows that in this case, $dR_a/dt<0$. We have thus proved the following:

<u>Proposition 2</u>: For loglinear utility funtions, a "small" tax/transfer scheme lowers the rate of return on annuities.

3.2 The Effet of Tax/Transfer on the Welfare of the Individuals

We have seen in the last subsection that for a class of utility funtions, an increase in tax/transfer "in the small" decreases the rate of return on annuity. In this subsection we ask whether such a reallocation of initial endowment by tax/transfer can make everyone of both types better off in all economies. Notice that such a question is not trivial because such a tax/transfer can lower the private annuity rate of return.

Before we attempt to answer this general question, it is instructive to examine an example.

Example: Let $u(c) = v(c) = \ln c$. Let $p_H = .9$; $p_L = .1$; $\alpha = .5$; $w = 1$ and $R = 1$. It is easy to verify that the equilibrium rate of return on annuity $R^*_a = 1.30$. The equilibrium allocations are

$$c^H = (.91, .12) \text{ and } c^L = (.53, .61).$$

The corresponding equilibrium utility levels are given by

$$u^H(R^*_a) = -.31 \text{ and } u_L(R^*_a) = -1.08.$$

[Insert figure 1]

In figure 1, AB represents the budget line for both types of individuals under the Arrow subsidizing equilibrium. In this example $R = 2$. Therefore, the line AD represents the "economy wide actuarially fair" budget line along which government can reallocate the initial endowment.

Given that the government can reallocate wealth along AD, we want to know whether the government can improve upon the allocation (cH, cL). Let C be the allocation which solves for

$$\ln c_1 + .9 \ln c_2 = uH(R^*a)$$

$$\ln c_1 + .1 \ln c_2 = uL(R^*a)$$

Then we can verify that

$$C = (.808, .381).$$

The equation of the line AD is given by $2c_1 + c_2 - 2 = 0$. It can easily be seen that C lies below the line AD. Thus, if the government reallocates in segment FG of AD, then both types will be better off.5 Notice that this welfare result holds as long as the Arrow subsidizing equilibrium allocation is such that the resulting c lies below the actuarially fair line AD.6

This example illustrates that there are some economies where some government intervention can improve upon free market allocation if there is adverse selection. However, a "large" government intervention need not produce a Pareto superior allocation. Consider a scheme of tax/transfer along AD which imposes a tax higher than tH. This will surely make type L worse off as any allocation inside the budget set defined by AD below G would. In this example any endowment tax of 20% or more will fail to produce an allocation which is Pareto superior to the allocation without government intervention because it will make type L worse off (even though the government scheme is economy wide actuarially fair).

Now we have completed all the preliminaries to ask a broader question: Is there any economy, such that there does not exist a tax/transfer scheme with balanced budget which can produce an allocation Pareto superior to the free market allocation? In other words does there always exist some government scheme of tax/transfer to improve upon the free market allocation for every economy?

Essentially, then, we are looking for a possible example of an economy where no tax/transfer can produce an allocation Pareto superior to the market allocation. We conducted a search with loglinear utility function with various specifications of p_H, p_L and α. First, in the light of the above example, we were able to eliminate a whole class of economies for which C lies below AD because for this class, we already know that such a search will be futile. However, there are economies for which lies above AD_2.

[Insert figure 2]

For example, if in the example discussed above we change α from .5 to .6 we shall get a situation where the actuarially fair line AD_2 lies below C. In such cases, it is not obvious that any tax/transfer scheme when supplemented by a private annuity market will be able to improve upon no-intervention allocation (as we have seen in 3.1 that a "small" tax/transfer scheme decreases private annuity rate of return for the class of loglinear utility functions). Our aim was to search for an economy such that for every tax/transfer scheme which results in endowment M on AD_2 such that the resulting "residual" market for the types ends up making at least one type worse off (one such possibility is depicted in figure 2 resulting in an allocation of c^H which is worse for type L than the allocation c_{HGM}) for every possible tax/transfer scheme.

Our search was limited to the economies with the following parametric specifications:

p_H, p_L = .1, .2,....., .9 with $p_H - p_L$ = .1, .2, ..., .8. and α = .1, ,2, ..., .9. For all of these specifications (where C lies above AD_2 as in figure 2), "small" tax/transfers of order t = .001, .002,..., .009 always resulted in higher welfare for each type of individual (although they resulted in lower equilibrium rate of return on annuity).[7] Thus, at least for loglinear utility functions, it seems that government intervention does indeed improve upon the allocation generated by the free market as Arrow (1969) conjectured.

4. Relationship with Literature

The work reported here is very closely related to two other papers:
Eckstein et. al. (1985) and Abel (1985). We discuss them in turn to indicate the similarities and dissimilarities.

Eckstein et. al. uses a model similar to ours to show that government intervention can be Pareto improving. However, the equilibrium concept they use is more strategic in nature. Specifically, they preclude the possibilities of one particular annuity contract offer subsidizing another. They use Wilson's (1977) notion of separating equilibrium and show that a compulsory scheme can improve matters. Thus, our work can be viewed as complementary to Eckstein et. al.'s paper.

Abel (1985) uses an equilibrium notion like ours. However, his paper's emphasis is somewhat different than ours. In his model, the individuals have a bequest motive and the class of utility function is resticted only to constant relative risk aversion type. He shows that economy wide actuarially fair social security raises the steady state level of average bequests and average consumption of the young. The steady state national capital stock rises or falls according to the strength of the bequest motive.

Footnotes

1. The reason why we call it a "subsidizing equilibrium" will be clear later as we show that the equilibrium rate of return R^*_a lies between R/p_H and R/p_L. As a result, in such an equilibrium, the low survival type ends up subsidizing the high survival type in the sense that type H (type L) gets a more (less) than actuarially fair rate of return. The annuity supplying firms do not break even on the contracts individually but they manage to break even "on the average."

2. The demand for annuities will be positive as long as $R_a > R$. If $R_a \leq R$, then the storage will generate at least as much second period consumption as the annuity contract. Therefore, no one may buy any annuity contracts.

3. Once the decisions about the annuity contacts are made, the individuals are identifiable by the total amounts of contracts by each individual chosen. However, if the individuals do not reveal the total annuity purchase to the government, they still will not be identifiable.

4. This subsection has benefited from a discussion with Ashok Chaudhury of the University of Minnesota.

5. Even though both types are better off along FG, there is still some scope for the private annuity market to

improve upon the allocation of type L. Type H, however, will drop out of the market completely after the reallocation.

6. We should also note that the Pareto improving role of the government has not been achieved by assuming that the government has more information. It arises out of the compulsory nature of the government scheme.

7. The program in BASIC, which was used to obtain this result is available from the author. Solving for equilibrium rate of return R^*_a and finding C involves finding roots of nonlinear equations approximately. The rest is routine algebra.

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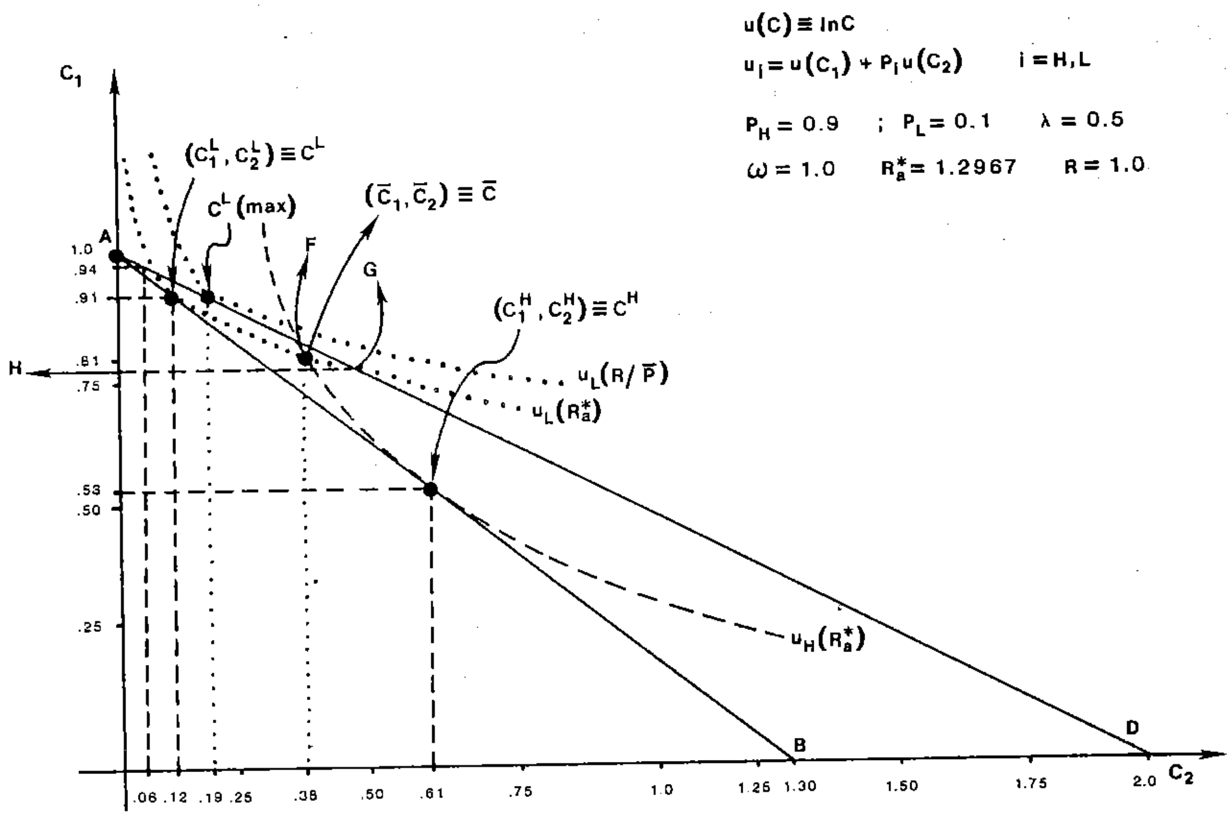
u(C) ≡ lnC
$u_i = u(C_1) + P_i u(C_2)$ i = H, L
$P_H = 0.9$; $P_L = 0.1$ λ = 0.5
ω = 1.0 $R_a^* = 1.2967$ R = 1.0
C_1
C_2
$(C_1^L, C_2^L) \equiv C^L$
$C^L(max)$
$(\bar{C}_1, \bar{C}_2) \equiv \bar{C}$
$(C_1^H, C_2^H) \equiv C^H$
$u_L(R/\bar{P})$
$u_L(R_a^*)$
$u_H(R_a^*)$
A
B
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Figure 1

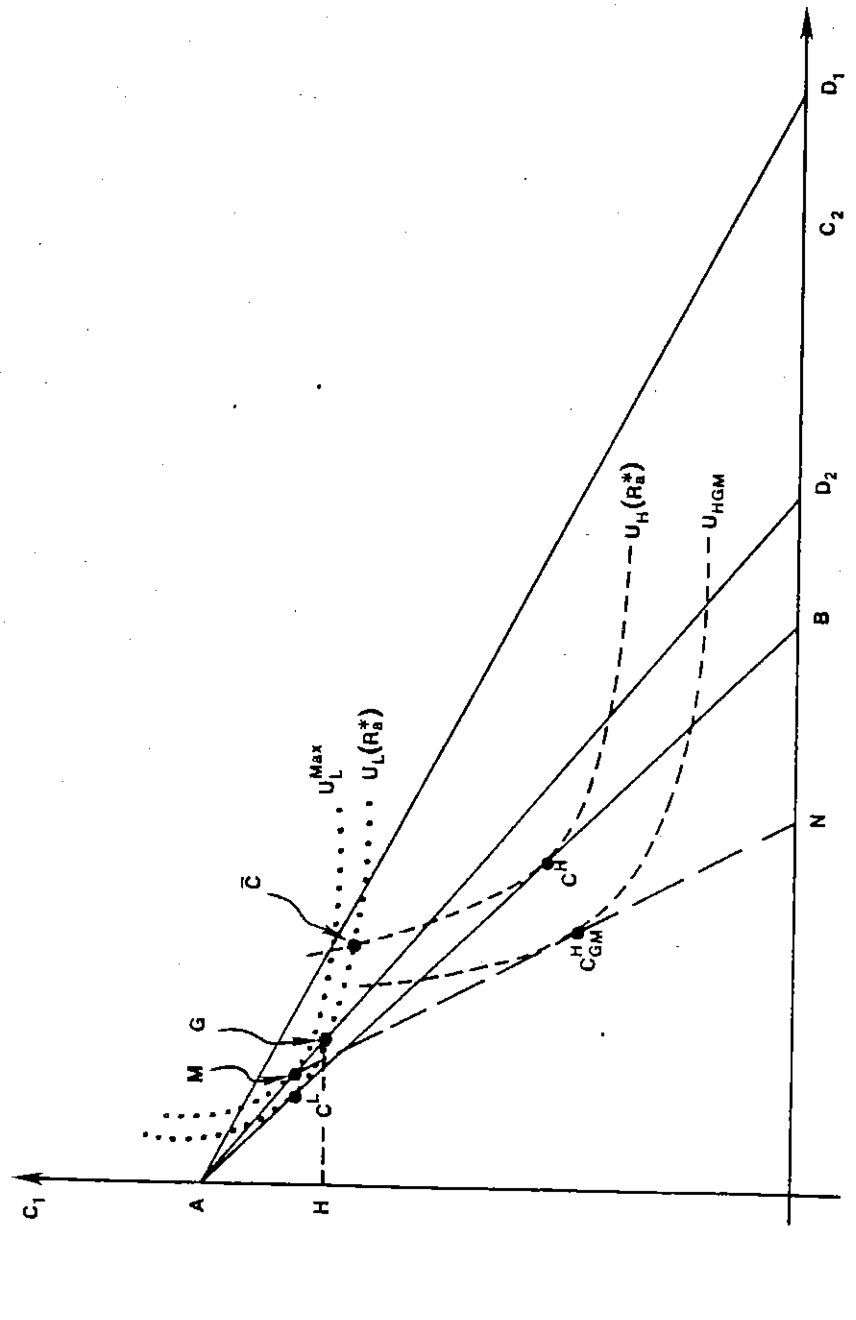

Figure 2