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GROUP COMPOSITION, COLLECTIVE CONSUMPTION, AND COLLABORATIVE PRODUCTION

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GROUP COMPOSITION, COLLECTIVE CONSUMPTION, AND COLLABORATIVE PRODUCTION:

Martin C. McGuire*

I

Problem To Be Addressed

An enduring question in the analysis of groups is what determines their composition in terms of their individual constituents. In a universe of diverse people should homogeneous groups coalesce around like individuals, or heterogeneous groups of diverse units form? Two salient treatments of this problem are due to Tiebout (1956)-Buchanan (1965) and to Berglas (1976). The first argue that scale economies in local public good (LPG) consumption should lead to homogeneous groups provided individual income is unrelated to the group, club, or jurisdiction of residence. The second argues that precisely when the place of work and of LPG consumption coincide, mixed groups should coalesce, and conjectures that these jurisdictions should be uniformly heterogeneous across an entire population.

This paper builds a concise analysis of the group composition problem including the conditions under which Tiebout/Buchanan configurations dominate Berglas and vice versa, and conditions under which Berglas' conjecture of uniform heterogeneity applies. Applications of this theory include nation and alliance formation, region and local government configuration and, in fact any group organization or stability problem where the membership produce and consume in the same jurisdiction. The crucial tension used to explain group composition is a conflict between the disadvantage dissimilar people find from cooperating in collective good consumption versus the advantage they find from cooperating in production.

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Assumptions

To reduce the analysis to bare essentials we assume a population of two types--type 1 and 2. Individuals of each type are idential but different from the other type. The two differ both in tastes for collective goods and productive abilities in private good supply. Individual private good factor productivities are synergistic, represented by a linear homogeneous production function

$$X = F(L_1, L_2) \ : \ \partial F/\partial L_i = F_i \tag{1}$$

Each individual i=1,2 has one unit of L_i, and a utility function

$$U_i[\overbrace{(I_i - C_i)}^{Y_i}, G] \tag{2}$$

L_i = number of i-types

I_i = i's gross income

G = LPG consumption in the group

X = Total private good production

C_i = i's cost share for the provision of G

Y_i = i's private good consumption after payment of C_i

To exploit their complementarity in production, 1 and 2 must "live together" in the same jurisdiction, and compromise their differences as to LPG consumption. Scale economies in LPG production are also ruled out to yield a cost function for G, with per person cost per unit of LPG equal to one.

$$C_1L_1 + C_2L_2 = C = G(L_1 + L_2) \ : \ [C/((L_1 + L_2).G)] = 1 \tag{3}$$

Efficiency of Equal Taxation

Efficient and equilibrium LPG supply ordinarily depends on how costs are shared among a group's members. But when population mix is unconstrained, and the composition of a group is to be determined simultaneously with cost shares, efficiency requires the costs be shared equally (assuming all individuals of a type enjoy identical utility). Unequal costs effectively redistribute welfare

through income transfer but transfers are dominated by variation in group composition. This crucial effect allows us to finesse complexities of alternative tax sharing rules and to build a decisive analysis of the optimal group based on equal taxes. To see this consider a social welfare function incorporating the requirement that all 1's (all 2's) be treated equally.

$$\text{Max } \Sigma\lambda_i U_i[I_i - C_i), G] \tag{4}$$

Eq. (4) is to be maximized subject to eq. (3) and a requirement that pre-tax private income exhaust private production in each group.[1]

$$\Sigma I_i L_i = F \tag{5}$$

Necessary conditions for a maximum include

$$F_i - I_i + C_i - G = 0; \quad i = 1,2 \tag{6}$$

and

$$\Sigma L_i MRS_i = \Sigma L_i \tag{7}$$

Eq. (7) is the $\Sigma MRS = MC$ condition; eq. (6) entails private income equal to marginal product only if costs are equally shared. Thus, if each pays $C_i = G$ for his share of the LPG costs, income transfers are ruled out. Equivalently, if $I_i \neq F_i$, the excess or deficit must be offset exactly by differential tax shares. Fig. 1 shows the factor price frontier $F_1 = \phi(F_2)$. For CRS production ϕ is unique with slope equal to the associated ratio of factor consumers $(-1/\dot{\phi} = \rho = L_1/L_2)$ where $\dot{\phi}$ indicates $d\phi/dF_2$. For any given ratio, income redistribution possibilities are shown by the tangent line π.

1. The Lagrangian is

$$\lambda_1 U_1[(I_1 - C_1), G] + \lambda_2 U_2[(I_2 - C_2), G] + \theta_1[I_1 L_1 + I_2 L_2 - F(L_1 L_2)]$$
$$+ \theta_2[C_1 L_1 + C_2 L_2 - G(L_1 + L_2)]$$

to be maximized over $L_1, L_2, C_1, C_2, I_1, I_2, G$ where λ_i is the social welfare weight accorded to type i.

(At ρ^* for example the entire product if shared equally by L_1^*, gives each L_1 an income of I_{1*}^{max}). Evidently, ϕ dominates all distribution possibilities like π; that is group composition dominates income transfer for welfare redistribution.

This conclusion is not altered by the introduction of public goods--income redistribution remains inferior to group composition as an instrument of welfare [illegible]ge (always assuming equality among factor/consumers of the same type). Fig. [illegible] shows private good consumption opportunities with constant unit LPG costs and i=o...k...n units of G supplied to and paid for equally by all. Shifting ϕ from ϕ_o (no public good) to ϕ_k (G=k and C=k deducted from F_1 and F_2) to ϕ_n (with G=n and C=n deducted from everyone's earnings) shows a map of post-tax private consumption sets for various amounts of the LPG. Each ϕ is an equidistant shift from its neighbors along a 45° line. As ϕ_o dominates every one of its tangent lines so that income redistribution is inferior when no LPG is supplied, similarily each ϕ_k (k=1,2...n) dominates all its income redistribution possibilities.

The construction also shows distribution possibilities when the composition of a group is predetermined. Moving along any ϕ curve in a southeast direction entails lower ratios of L_1/L_2. Suppose we freeze group composition at a particular value $\rho^* = L_1^*/L_2^*$ on ϕ_o, and corresponding points on ϕ_1, ϕ_k ... ϕ_n. Then the map of private income distributions is given by the family of tangent lines π_k^*, k=0...n for each amount of G. In effect, freezing group compos[illegible]on at a given value imposes a new constraint which limits outcomes [illegible]econd best.

Special [illegible]:One Social Welfare Weight Zero

Imagine only one consumer's utility is positively valued in the SWF of eq. (4) and the other's counts as zero. Then the second (suppose it is 2) has value only as enhancing the utility of the first (1). From eq. ([illegible]) however,

society still must provide the LPG to all. Now 2's entire income should be used to pay for his share of LPG costs; eq. (6) changes to

$$F_2 - G = 0 \tag{6'}$$

meaning that all 2's productivity is spent on the LPG. Since only 1's count in the SWF, the Samuelson condition changes to

$$L_1 MRS_1 = \Sigma L_i \tag{7'}$$

In effect this special case maximizes the utility of type 1 only (written as $U_1[(I_1-C_1),G]$ since equal cost sharing entails $C_1=G$). Writing 1's resource constraint as

$$I_1-C_1 = (F(L_1,L_2)-G\cdot L_2)/L_1 - G \tag{4'}$$

shows L_2 as strictly instrumental to U_1; substituting eq. (6') yields

$$Y_1 = I_1-C_1 = F_1(\rho)-F_2(\rho);\ G = F_2(\rho) \tag{4''}$$

as the resource constraint for type 1 written in parametric form. Tangency of this constraint with 1's indifference map again yields (7').

II

THE CONSUMPTION SET AND SOCIAL WELFARE OPTIMUM

The Opportunity Set

Fig. 3 will be used to give a graphic solution to the maximization of eq. (4). It extends Fig. 2 adding the two consumer indifference maps between private and LPG consumption. After tax consumption of each type depends on the location on the factor price frontier ϕ (ie on group composition L_1/L_2), and on how much G is produced/consumed. Fig. 3 constructs an LPG vs private consumption opportunity set for 1 given a fixed utility level for 2 (curve U_2^o). Combinations (a-b-c) and intermediate points all consistent with U_2^o form the locus S_1^o representing 1's consumption opportunities. For example, consider

point c on U_2^o. To pay for the associated G_c at a price of \$1 per unit, 2 must earn F_2^c. Tracing across to ϕ shows that 1 will earn F_1^c. If 1 then pays \$1 per unit of G_c his earnings are reduced along the 45° dashed line moving to c on S_1^o. Other combinations a and b are similarily constructed. Since 1 and 2 both pay the same \$1 per unit of G, the budget lines in the 2nd and 4th quadrants are parallel with slope 45°. With U_2 constrained to a lower level a larger opportunity set could be constructed (not shown) with a shape similar to S.

Properties of the Opportunity Set

To use this construct certain of its properties are pertinent. First, each point on S corresponds to a specific L_1/L_2 group composition; clockwise - downward movements along S imply lower L_1/L_2 ratios, with 1's having more 2's cooperating in private production up to (L_1/L_2)min at ρ^c (and at this point $G_c = G[(L_1/L_2)\text{min}]$). This limiting ratio of L_1/L_2 shows the mininum L_2- productivity consistent with U_2^o, where $\dot{U}_2^o = -1$ and 2's are supplied precisely the LPG they desire at a price of unity. For values of G on S(G) greater than $G_c = G[(L_1/L_2)\text{min}]$, the ratio L_1/L_2 reverses direction, retracing its path and increasing in value for further downward movements along S. If the constraining value of U_2 is lowered, the limiting ratio L_1/L_2 also declines.

Second, (See Fig. 4), if community compositions were frozen at a particular value of L_1/L_2, then a construction similar to Fig. 3 would generate a different U_2- constrained consumption opportunity set, say D, for each value of ρ. The set D (incorporating income transfers as the only redistribution mechanism available when group composition is frozen) is inferior to the corresponding S curve except where the income transfer option is not exercised. Thus S may be regarded as an envelope of such D curves, one for each L_1/L_2 combination.

Third, the equation of $I=S(G)$ can be obtained from

$$I_1 = F_1 - C(G); \quad F_1=\phi(F_2); \quad F_2=I_2+C(G); \quad I_2=V_2^o(G) \tag{8}$$

where V_2^o is the utility constraint for 2, $U_2=U_2[V_2^o(G),G]$, $C(G)$ is per person cost of G, and F_i and I_i are as defined already. Substituting successively

$$I=\phi[V_2^o(G) +C(G)] - C(G) = S(G) \tag{9}$$

The shape of the S-curve will prove critical to understanding when an optimal configuration of groups requires uniform heterogeneity -- and when non-uniform. In particular, it is important to know whether S is convex--which requires knowledge of first and second derivatives.

(Using a dot to indicate derivatives)

$$\frac{dI_1}{dG} = (\dot{V}_2^o + \dot{C})\,\dot{\phi} - \dot{C} = \dot{S} \tag{10}$$

with $\dot{\phi}<0$ being the slope of the factor price frontier (again $\dot{\phi}^{-1}=-L_1/L_2$), $\dot{C}$ marginal per person cost of G, and $\dot{V}$ the slope of 2's indifference curve.

Assuming $\dot{C}=C/G=1$, (10) simplifies to:

$$dI_1/dG = (\dot{V}_2^o + 1)\dot{\phi} -1; \quad \dot{V}_2^o<0, \quad \dot{\phi}<0 \tag{10'}$$

Differentiating (10) and substituting ($\dot{C}=1$; $\ddot{C}=0$) confirms that S is concave from below in the region of $\dot{S}=-1$ and may have two or more points of inflection ($\ddot{S}>0$ downward along the G-axis in the fourth quadrant). To see this work through the components of $\dot{S}=\dot{\phi}(\dot{V}_2^o+1)-1$ as G increases; if $\ddot{V}$ and $\ddot{\phi}$ were constant there would be just two inflection points.

$$\frac{d^2I_1}{dG^2} = \underset{(+)}{\ddot{\phi}}\,(\underset{(+)}{\dot{V}_2^o + 1})^2 + \underset{(-)}{\dot{\phi}}\,\underset{(+)}{\ddot{V}_2^o} = \ddot{S} \tag{11}$$

The precise locations of the implied non convex regions of S will depend on the rates of change in $\ddot{\phi}$ and $\ddot{V}$ (with non-constant average LPG costs $\ddot{C} \neq 0$ there might be many inflection points). It will become apparent that these non-convexities are pointedly relevant to Berglas' conjecture as to the optimality of uniform jurisdiction structures.

Properties of Consumption Opportunity Maps

Essential to the construction of a Consumption Opportunity Curve for one consumer is the specification of a constraining indifference curve for the other. For each admissible U_2 in the second quadrant, another S_1 curve can be constructed in the fourth. Higher admissible utility for 2 entails a lesser curve for 1. Similarily, opportunity sets for 2 may be constructed in the second quadrant, with each S_2 curve derived from a specified admissible indifference curve for 1, and higher levels of U_1 generating lesser S_2. Fig. 5 shows a map of such consumption opportunity curves for consumer factor 1.

When $\dot{S}_1 = -1$, consumer 2 just demands the indicated provision of G at a price of unity, receives in private earnings the minimum consistent with the indicated utility, and therefore is in the greatest majority (least minority or lowest value of (L_1/L_2) consistent with that utility. These points of $\dot{S}_1 = -1$ generate locus R_2, in 1's consumption quadrant showing amounts of LPG ideally desired by 2. In contrast, the LPG ideally desired by 1 is simply the income expansion path P_1. If the LPG is non-inferior, R will have negative slope as shown; while if the LPG is inferior R will have a positive slope. Where R and P curves intersect (α), 1's and 2's just agree on the supply of LPG. For other Pareto efficient assignments, gainers relative to α receive less than their desired LPG supply and losers more than their ideal. This follows from non-inferiority of the LPG; high private income is offset by inability to consume as much LPG as desired.

The Social Constraint on LPG

In addition to the constraint imposed by the other's indifference curve, each consumer is also limited by the necessity to provide equal LPG to all in the group. It follows that the absolute amount of LPG feasible is limited to what the less productive type could support with his entire earnings. For example, in Fig. 6 points G^* show the maximum LPG consistent with $(L_1/L_2)^*$; at that factor ratio, 1 could not obtain greater LPG unless 2 spent more than his total earnings on the public good. Moreover, the absolute maximum of LPG supply cannot exceed the max-min of marginal productivities (which occurs at a factor ratio where $F_1 = F_2 = G_{max}$). Connecting all maximum feasible LPG points identifies the social limit on LPG supply (M_1 or M_2 in the drawings). Equations of this outer frontier are

$$I_1 - C_1 = F_1(\rho) - F_2(\rho) \; ; \; G = F_2(\rho) \text{ for } M_1$$

and

$$I_2 - C_2 = F_2(\rho) - F_1(\rho) \; ; \; G = F_1(\rho) \text{ for } M_2 \tag{13}$$

two equations identical to eq. (4") derived for the case of zero welfare weight in the original SWF. Thus, for each point on locus M_1 or M_2 there is a corresponding point on the G-axis for 2 and 1 respectively, where all earnings are allocated to G. The absolute maximum utility for either consumer type occurs at the tangency between U_i and M_i.

Finally, note the connections between indifference curves in one quadrant and opportunity sets in the other. Intersections of U_i with M_i correspond to intersections of S_j with the G-axis. For example, in the fourth quadrant at points b and c, 1 enjoys U_1^o while 2's entire earnings are allocated to the LPG. The S_2^o consumption opportunity curve corresponding to U_1^o intersects 2's LPG axis at points also labeled c and b.

Pareto Efficient Allocations

When both welfare weights exceed zero, optimization requires tangency between U_i and S_i. At a tangency

$$MRS_i = dI_i/dG = (MRS_j + MC)(-L_j/L_i) - MC \quad \text{or} \quad (\text{with } i=1, j=2)$$

$$L_1 MRS_1 + L_2 MRS_2 = -(L_1 + L_2) \cdot MC \tag{14}$$

(Samuelson's condition again). The path of these tangencies (curves E_i in Fig. 7) gives Pareto efficient utility opportunities for 1 vs. 2.

III

GROUP EQUILIBRIA AND COMPOSITION

In many applications overall population composition is open to choice. Such would include interregional population and factor movements, and many problems of coalition formation and the core. More to our immediate purpose, however, our constructs apply to group configurations in a conventional economy with fixed endowments of each consumer type; specifically we can discern when Berglas' conjecture that jurisdictions should be uniformly heterogeneous applies, and we can isolate the conditions under which homogeneous Tiebout groups will dominate Berglas groups.

Equilibria

Each Pareto efficient utility combination (say a,b,c...as in Fig. 7) implies its own factor mix. And provided the opportunity curves are convex, the reverse is true also; each L_1/L_2 endowment then implies a zero transfer, equal cost equilibrium. This is the nominal Berglas case. The loci of such equilibria is shown in Fig. 7 as $E_i (i=1,2)$; the greater the equilibrium utility of a factor, the lesser must be its relative numbers, the greater its productivity, and the further its realized from its ideal LPG consumption -- a conclusion similar to analyses by Scotchmer (1987) in which the relative scarcity of different consumers determines group composition, and member

scarcity of different consumers determines group composition, and member utility.

Uniformity of Berglas Jurisdictions

Next we analyze whether it ever could be optimal to organize a given national L_1-L_2 endowment into dissimilar groups. If organization into non-uniform groups with different factor mixes were optimal, it could not be due to integer problems such as arise with Tiebout public goods and U-shaped average costs; for we have allowed no scale economies in public or private production. In this model the issue of uniform vs. non-uniform heterogeneity of Berglas groups depends entirely on the convexity of consumption opportunity sets. With S convex, diversity of groups is unambiguously inferior. In such case it is never optimal to form different groups and then equalize utilities within types by transfers. For instance, consider endowment ρ^o in Fig. 8. Rather than organize the entire population at that endowment ratio, groups of two compositions might be formed viz $\rho^1>\rho^o$ and $\rho^2<\rho^o$, each sized so as to just absorb the endowed L_1-L_2. Then to equalize utility among 1's and among 2's, transfers should have to be made along D^1 (π^1) and D^2 (π^2). The resulting outcome at d is Pareto inferior to ρ^o which gives the outcome at p; with S convex no combination of values for ρ^1 and ρ^2 can dominate ρ^o. However, if the sets S is not convex (as in Figure 9) then it could be superior to achieve the utility distribution U_1^*-U_2^o by organizing some groups with composition ρ^1 and others with composition ρ^2; these would dominate every uniform organization with proportions at ρ^o (for all $\rho^2<\rho^o<\rho^1$) and associated Pareto inferior welfare distribution U_1^o - U_2^o.

Where non-uniform groups dominate, income transfers still are no substitute for changes in group composition. But if the efficient utility distribution U_1^*-U_2^o is not socially optimal and redistributive transfers are therefore recommended, such transfers should have to be made across

jurisdictions as well as across consumer types within jurisdictions; because of different factor proportions in the two groups both kinds of transfer are necessary to equalize utilities of similar consumers.

Fig. 9 produces a special case to summarize and illustrate that over some range of endowment proportions uniform groups may be excluded as Pareto inferior to a mix of diverse groups. A more general case would be shown by a serpentine shaped S_1- curve tangent to one U_1- curve at two points. Thus, Berglas implicitely assumed S-convexity (in our terms) to derive uniform heterogeneity in the case he studied.

Tiebout vs Berglas

We also can compare Berglas groups with separate homogeneous Tiebout groups. Our diagrams supply a ready determination of which arrangement is superior. Fig. 10 shows a low (high) elasticity of substitution factor price frontier B_1 (B_2) and at point b the corresponding Berglas configuration of groups and utility distribution (assuming S convexity, uniform heterogeneity, and no income transfers). Here, endowed factor proportions are given as ρ^b the slope of B_1 or B_2 at b. Now consider a non-interactive technology (infinite elasticity of substitution between factors) as an alternative, where the productivity of factors L_1 and L_2 are MP_1^t and MP_2^t respectively, independent of any cooperation between them. The diagram shows that point t can make 1 and 2 just as well off in Tiebout clubs as they are at b in the identified Berglas clubs. The lower productivity of each at point t is just offset by the benefits of organizing for public good consumption in homogeneous groups. Moreover, any other non-cooperative production technology along line T (also with slope ρ^b is potentially equivalent to t since from any point on T, t can be reached via income transfer. It follows that every independent, non-cooperative technology above T will dominate point b.

Next, consider forming segregated Tiebout type clubs with the same B-technology. Could it ever be superior to form such separate clubs? Fig. 10 provides the answer. It depends on the shape of B. If the factor price frontier is tightly curved as B_2 -- indicating high elasticity of substitution-- then little is lost by forming Tiebout groups, and a combination such as b_2 is available which dominates t and therefore b. But if the elasticity of substitution is low as with B_1 then segregation implies productivities as at point b_1 which is inferior to t and therefore to b. In the diagram both 1 and 2 gain or lose in a switch from Tiebout to Berglas groups. However, if B_1 or B_2 were not symmetric about b, the change could on net harm one factor and aid the other; but in this case the question of potential Pareto superiority can be resolved by examination of the income transfer possibilities along a line with slope $-L_1/L_2$ through the point b_1 or b_2.

The diagram also indicates how preference maps of each consumer play a crucial role in comparison of Tiebout vs Berglas clubs. With greater differences in taste, and lower elasticity of substitution in consumption between public and private goods, the loss in productivity from organizing into Tiebout clubs can be greater before it becomes preferable to endure the loss from having to compromise wants for the LPG in heterogeneous Berglas clubs.

III

CONCLUSIONS

This paper has examined the structure of club configurations when groups may serve as sites both for private good production and for local public good consumption. Special attention has been given to conditions under which heterogeneous production/consumption clubs will and should form and whether these clubs should be uniformly heterogeneous or not. A diagrammatic technique

has been introduced to resolve these questions with decisive results as follows:

(a) Changing the factor/consumer composition of a group is always a superior instrument of distribution which dominates lump sum income transfers.

(b) Usually for Berglas type production/consumption clubs to be efficient, a population should be organized into uniformly heterogeneous groups, but this is not necessary. For some taste and productivity configurations diverse mixes of heterogeneous clubs can be optimal.

(c) Comparisons of Tiebout and Berglas club configurations can be resolved by reference to differences in taste for public vs private goods among factor consumers, and differences in private factor productivities. Knowledge of elasticities of substitution in production and in consumption is also required to compare mixed interior and segregated corner solutions.

(d) None of these conclusions depends on economies of scale or integer problems of any sort whether in private or LPG production.

The applicability of these ideas would seem to be quite wide, extending to any situation in which there is tension due to differences in preference for collective goods combined with synergisms due to complementarities in production among the units which would make up a larger group.

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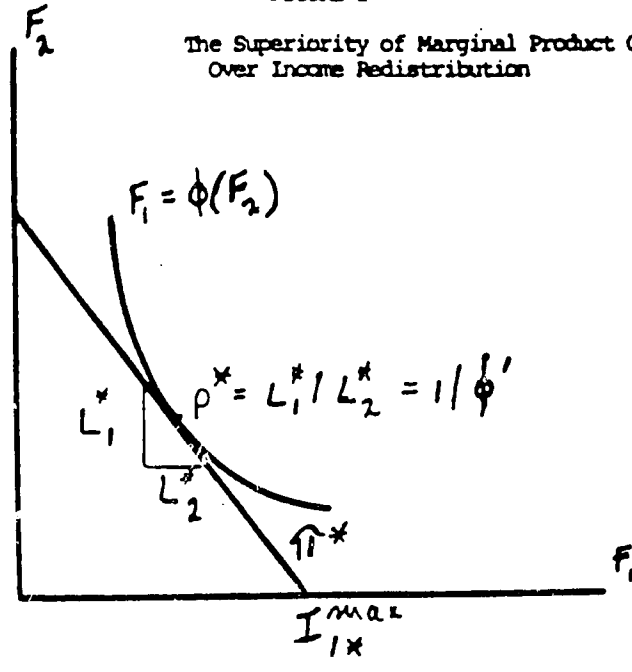
FIGURE 1

The Superiority of Marginal Product Change Over Income Redistribution



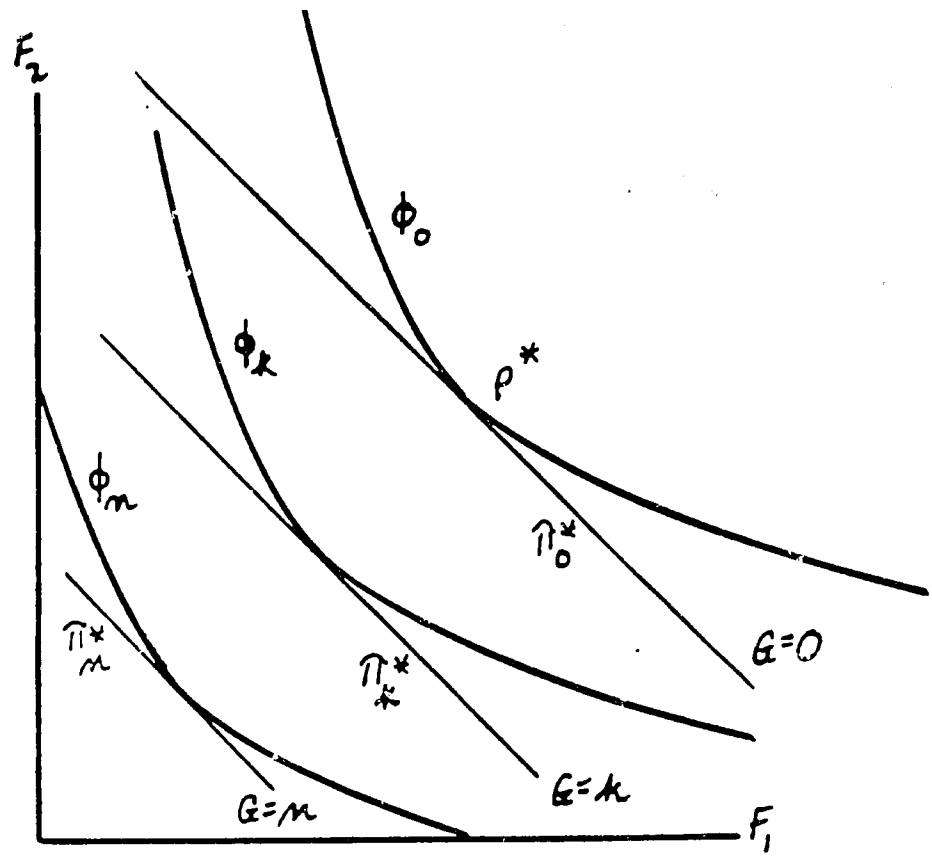


FIGURE 2

Under Equal Sharing of Costs, Income Transfers Along π Are Inferior to Factor Intensity Changes Along ϕ For All Factor Mixes and Supplies of the Public Good

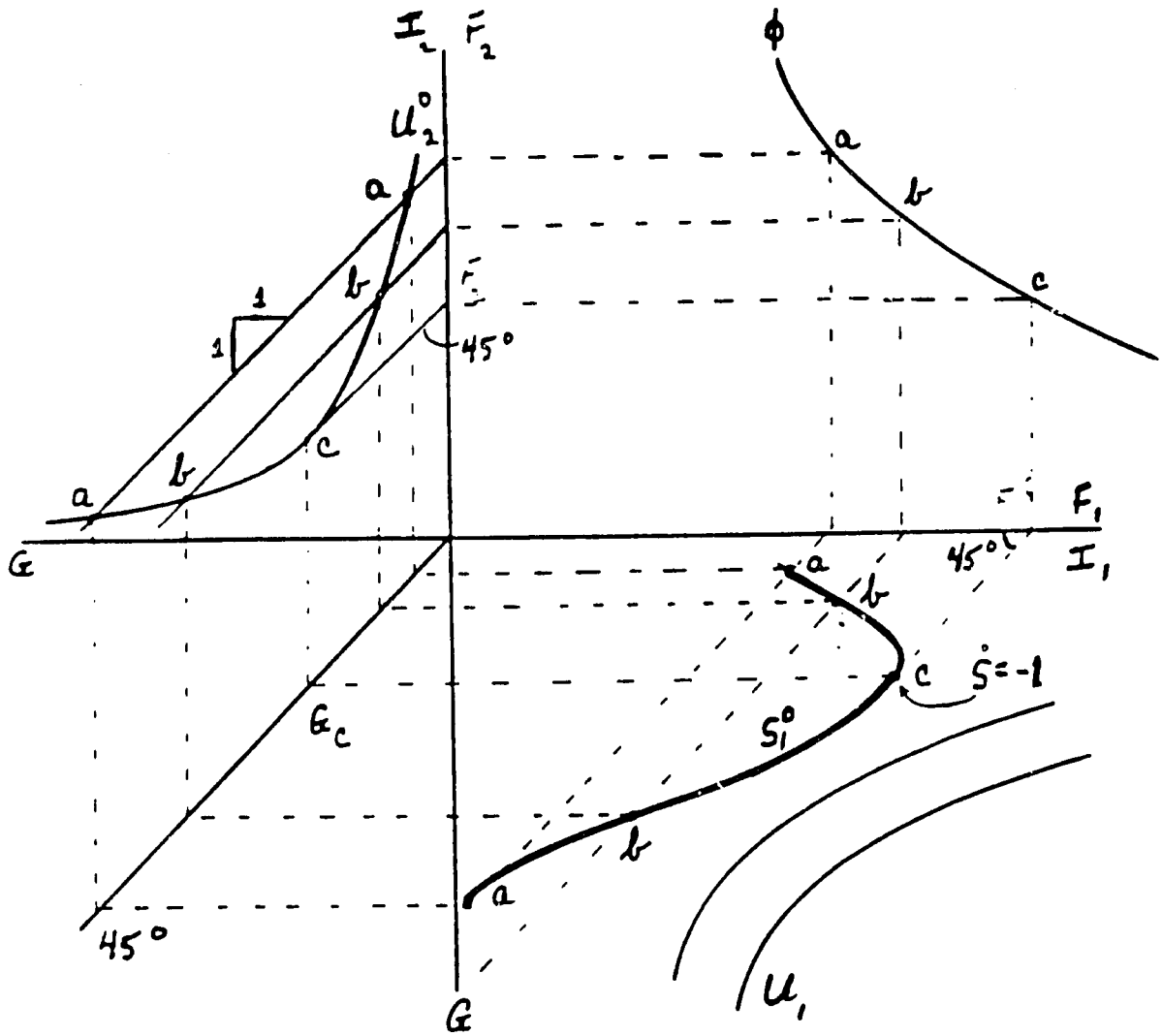


FIGURE 3

Derivation of the Consumption Opportunity Set, S, from the Utility Constraint U_2^0, and the Factor Productivity Frontier ϕ

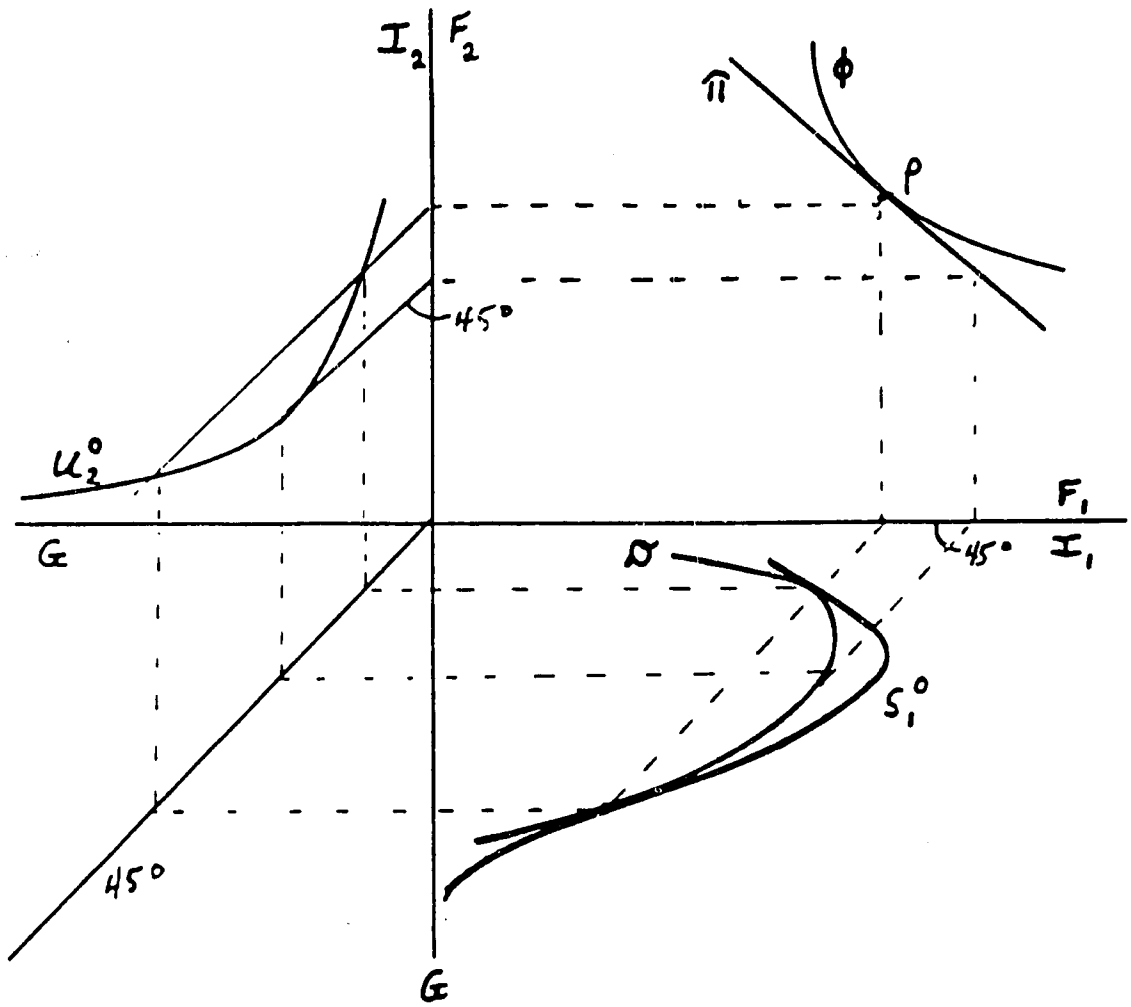


FIGURE 4

If Factor Endowments are Frozen at ρ, Consumption Opportunities Are Restricted to D, Compared to Opportunities Along S_1^0 When Group Composition is Allowed to Change Along ϕ.

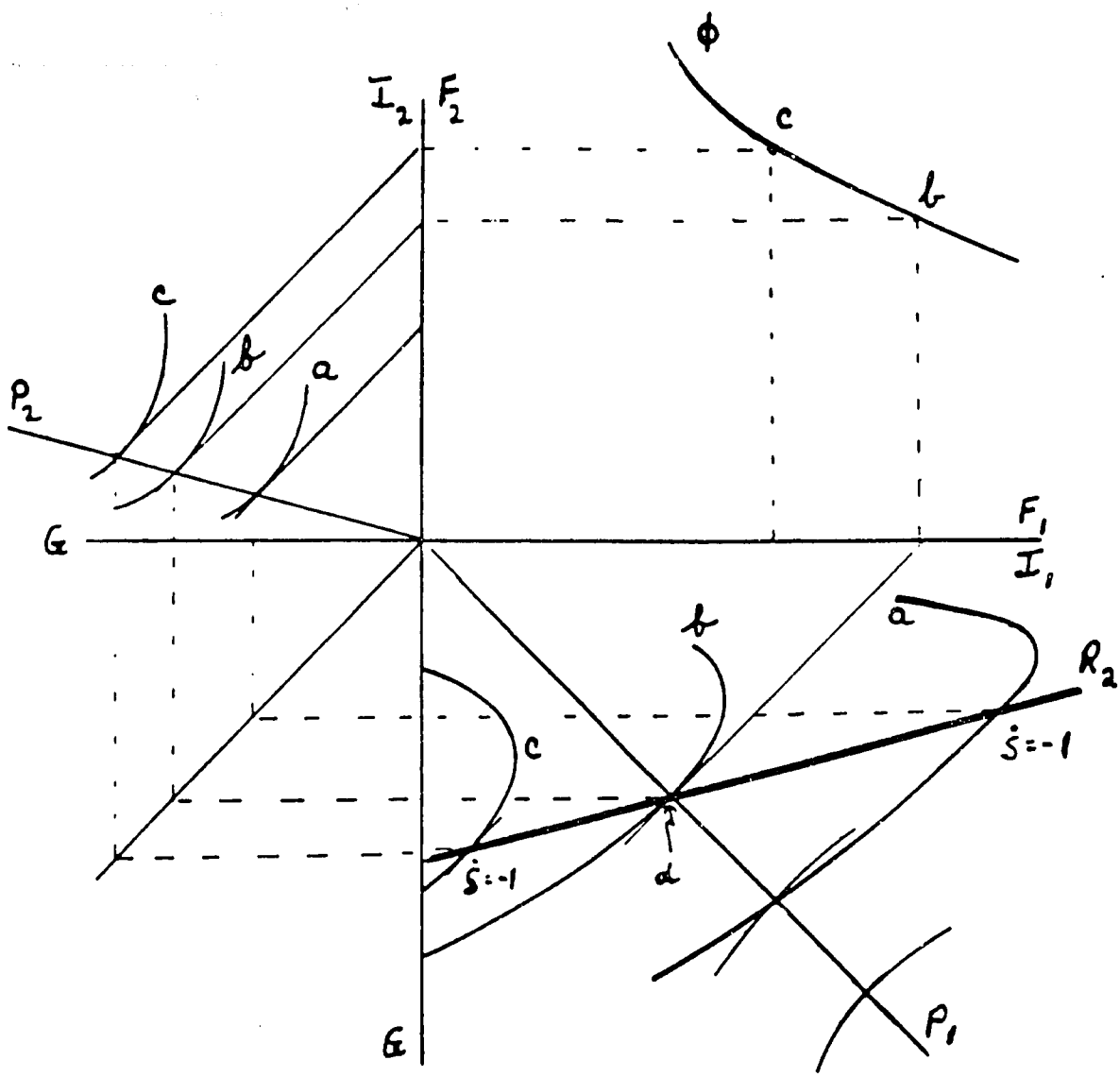


FIGURE 5

Consumption Opportunity Map

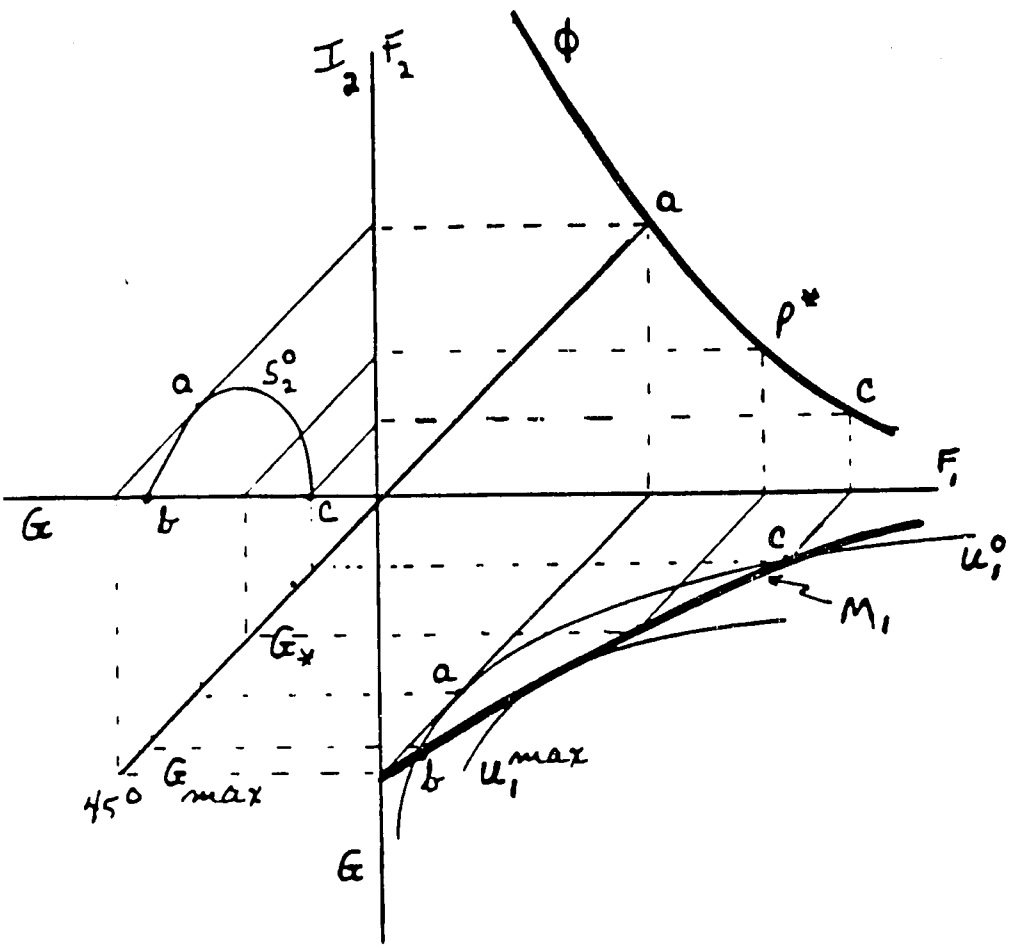


FIGURE 6

Derivation of the Maximum Feasible LPG Frontier M_1

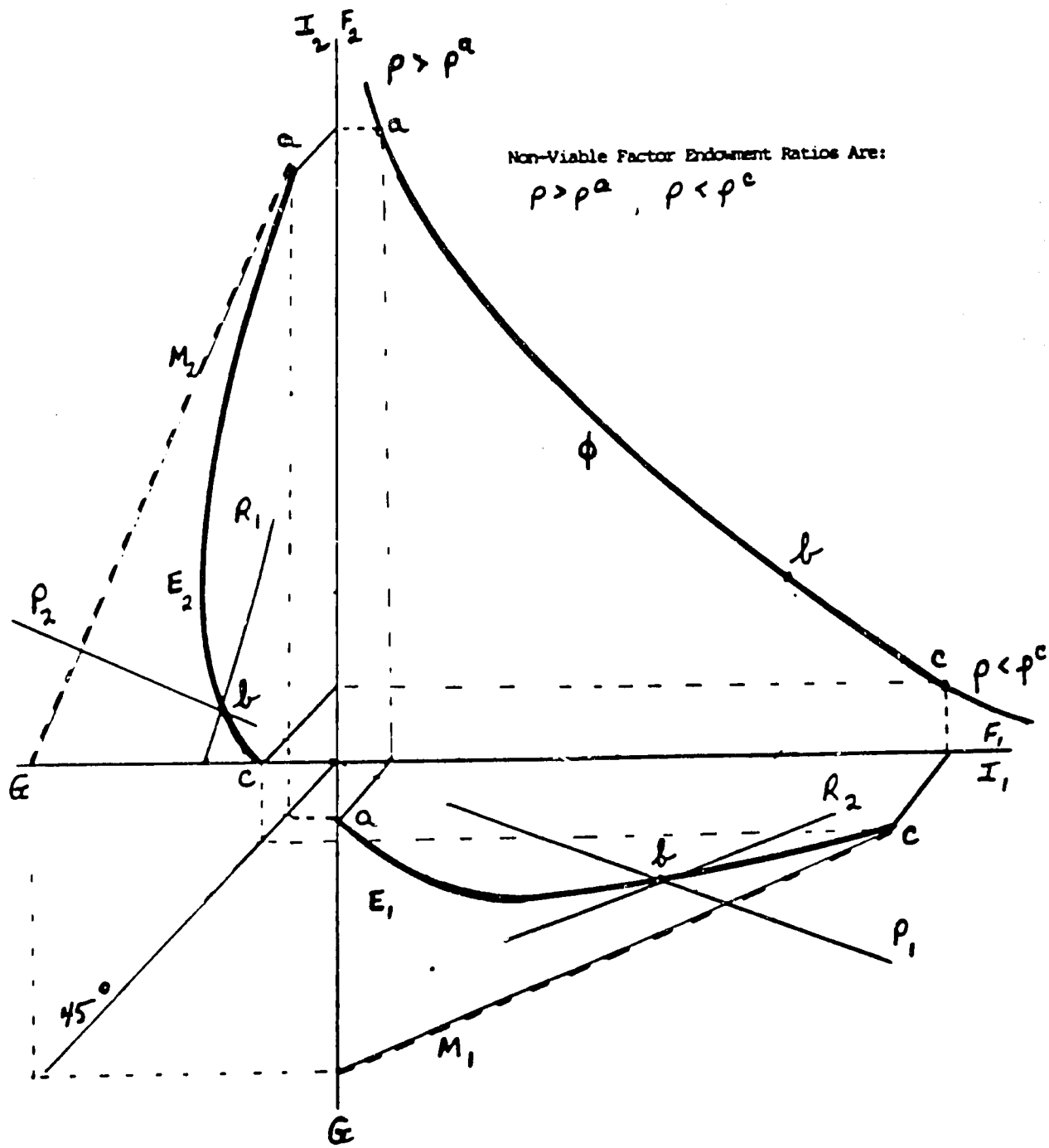


FIGURE 7
Competitive Equilibria, E AS Dependent On Factor Endowments

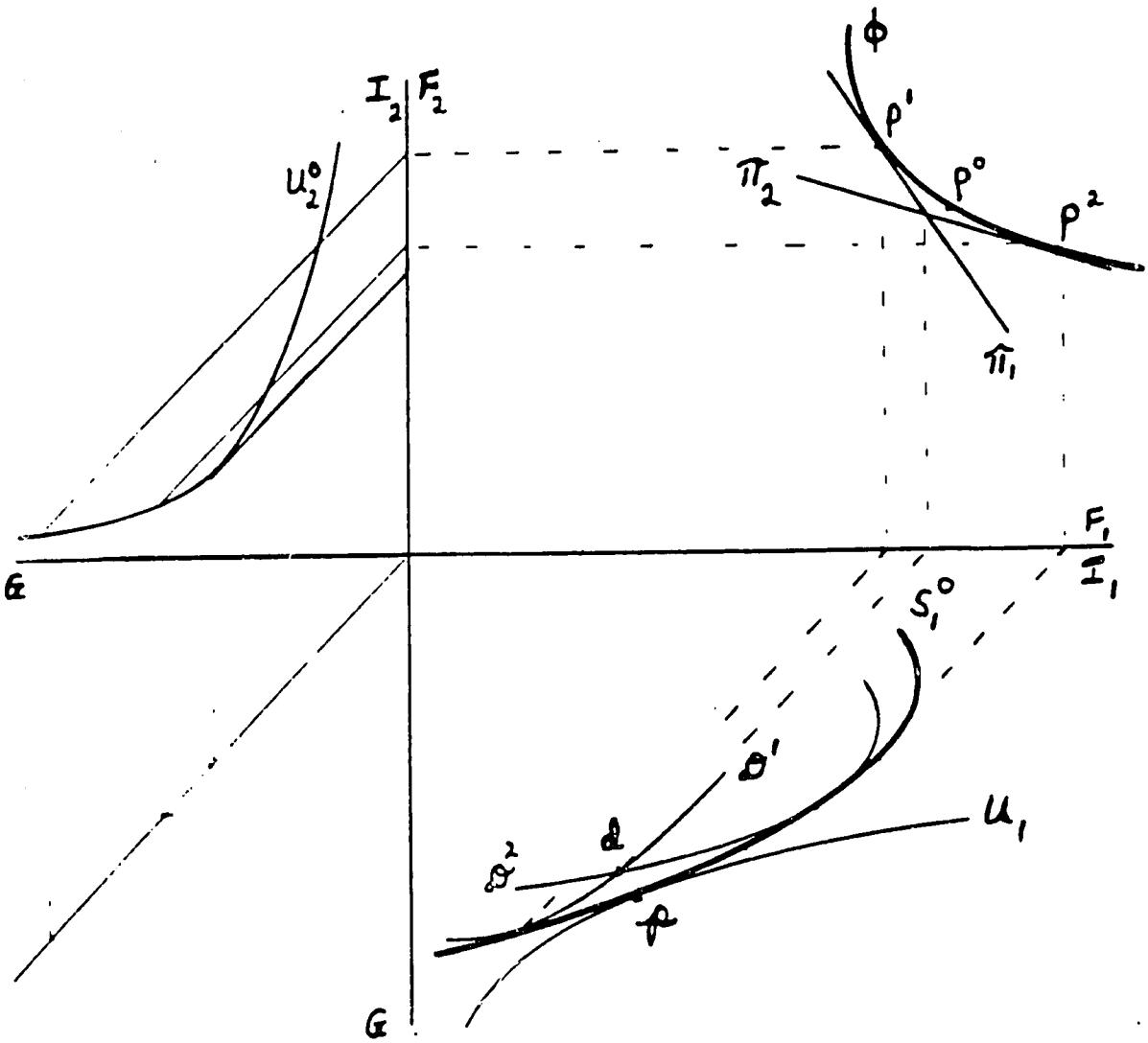


FIGURE 8

Superiority of Uniformly Mixed Groups When S is Convex

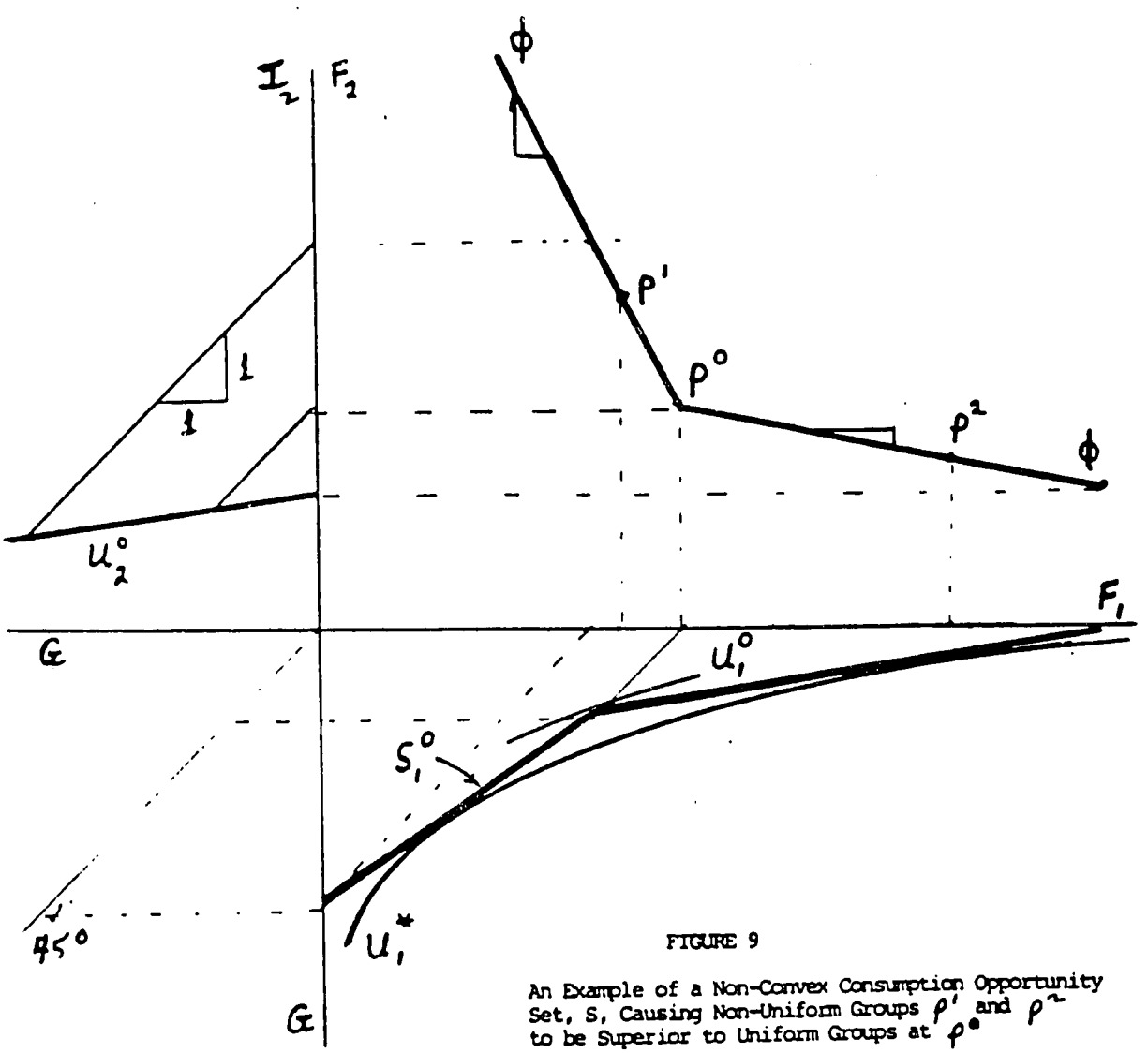


FIGURE 9

An Example of a Non-Convex Consumption Opportunity Set, S, Causing Non-Uniform Groups ρ' and ρ^2 to be Superior to Uniform Groups at ρ^0

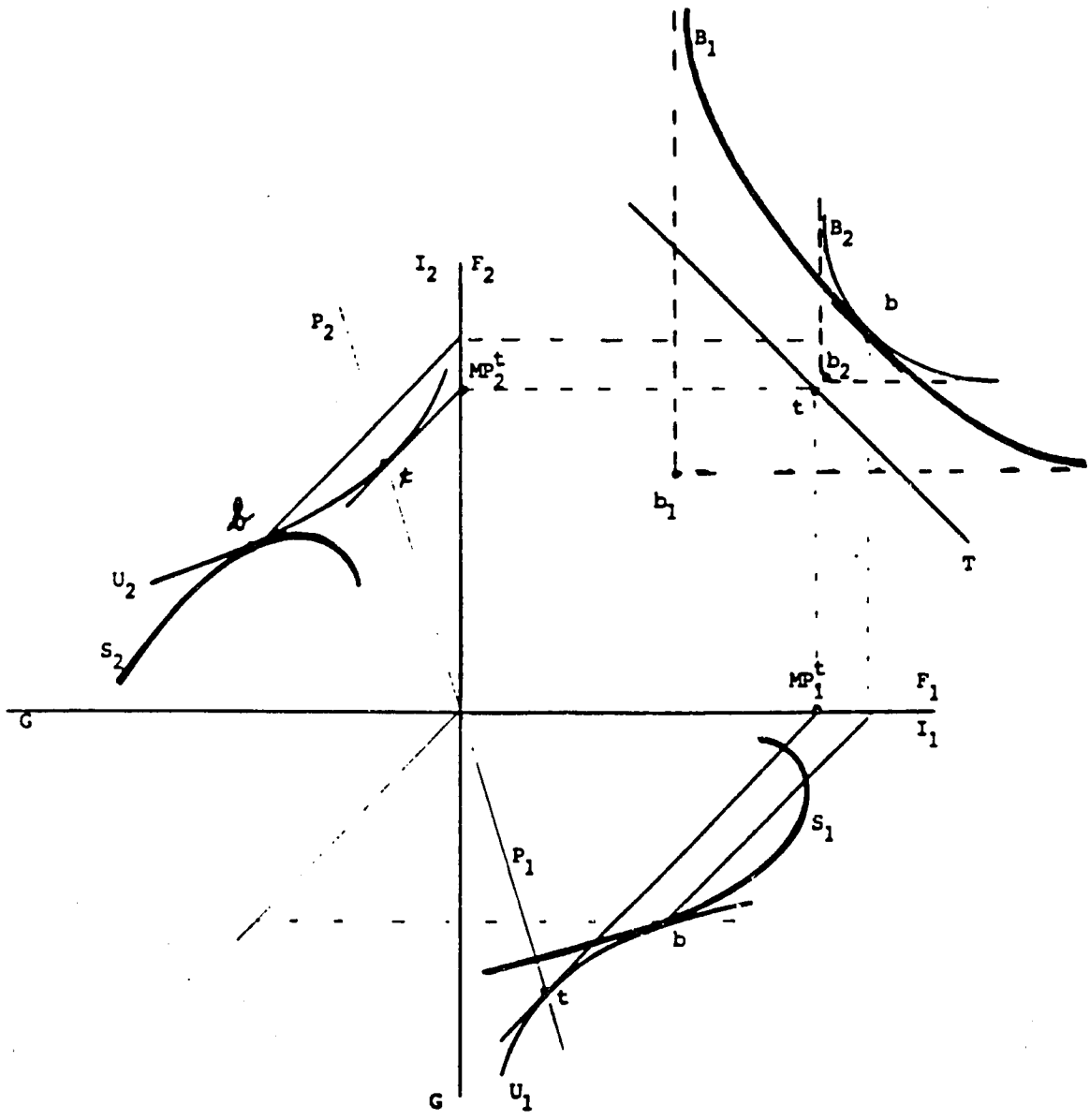


FIGURE 10

Comparisons Between Berglas and Tiebout Groups