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and the Egalitarian Solution**

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Bargaining theory over opportunity assignments
and the egalitarian solution^{*}

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Abstract

This paper discusses issues of axiomatic bargaining problems over opportunity assignments. The fair arbitrator uses the principle of “equal opportunity” for all players to make the recommendation on resource allocations. A framework in such a context is developed and the egalitarian solution to standard bargaining problems is reformulated and axiomatically characterized.

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1 Introduction

In standard axiomatic bargaining models originated from Nash (1950), a typical interpretation of the solution to bargaining problems is the recommendation made by a “*fair arbitrator*” such as the Judge in civil trials, or the function of the Dispute Settlement Body in the WTO mechanism, etc. In such models, this recommendation is based solely on players’ utilities. In many contexts, however, the “fair arbitrator” may have other principles in mind when making a recommendation.

For instance, consider the distribution issue of a father’s inheritance among his children. The father, as a “fair arbitrator,” may have the principle of “*equal opportunities*” for his children and would like to distribute his wealth among his children giving them equal opportunities to do well in their respective lives. Likewise, when educational resources are to be allocated among local public schools, the local government’s board of education, as the “fair arbitrator,” may propose an allocation that “equalizes” school children’s *opportunity sets* for future jobs, skills, college admissions, lives, etc. In both of the above examples, each recommendation of a resource allocation by the “fair arbitrator” effectively identifies a profile of “*opportunities*” or opportunity sets for the individuals involved. The crucial difference from standard axiomatic bargaining models in these examples is that the recommendation made by the arbitrator is not based on utilities of the individuals involved, but on opportunity sets that the recommended resource allocation may give rise to the involved individuals.

This departure from considerations of utilities of individuals to concerns of opportunity sets of individuals is well in line with the recent literature on opportunities and equality of opportunities. One branch of the literature is in political philosophy such as Sen (1980, 1985), Arneson (1989), and Cohen (1993), while the other is in economics, see, for example, Sen (2002), Pattanaik and Xu (1990), Kranich (1996), and Herrero (1997). In the latter branch of the literature, each individual is characterized by his opportunity sets, from which his well-being or welfare is evaluated.

An opportunity set of an individual is interpreted as a set of feasible options or alternatives available to the individual for living. Depending on the context, those alternatives can be commodity bundles, or bundles of characteristics *à la* Lancaster and Gorman, or bundles of functionings *à la* Sen (1980, 1985), and Nussbaum (1988, 1993, 2000). A resource allocation in an economy then identifies a collection of opportunity sets, one for each individ-

ual in the economy. Note that, for a given resource allocation, opportunity sets of individuals are necessarily interdependent. Note also that different resource allocations can give rise to various collections of opportunity sets for the individuals in the economy.

The question we address is, among various collections of opportunity sets for the individuals involved, how should the “fair arbitrator” make the recommendation on a resource allocation that yields a profile of opportunity sets for individuals in the economy, which is deemed as “fair”? For this purpose, we extend standard bargaining models to the setting in which each individual is endowed with his opportunity sets, which are generated by his consumption bundles given his individual characteristics, and, in which the fair arbitrator makes recommendations based on profiles of opportunity sets for the individuals in the economy.¹ We present two related formulations of extended bargaining models. In the first place, we formulate axioms in terms of profiles of opportunity sets. This formulation corresponds to standard bargaining models. The advantage of this formulation is to have a general and abstract framework to discuss bargaining problems in our setting. Since an important component of our primitive information about individuals is their opportunity sets, this formulation appeals directly to our intuition regarding this important component. To have a better understanding of the underlying allocations proposed by a solution to our extended bargaining models and with the above general formulation in hand, we next formulate our axioms in economic environments directly. For both formulations, we introduce the egalitarian solution for extended bargaining models and study it axiomatically.

The remainder of the paper is organized as follows. Section 2 introduces our economic environments and our problem. Section 3 defines and axiomatically characterizes the egalitarian solution in our context. Section 4 defines and axiomatically characterizes the egalitarian allocation rule in economic environments. We conclude the paper in Section 5 by briefly commenting on our approach and the results.

¹Gotoh and Yoshihara (2003) discuss allocation mechanisms which assign individuals capability sets through distributing outputs produced by them. Their approach is quite different from the approach based on bargaining that this paper addresses.

2 Economic environments and bargaining problems on opportunity assignments

2.1 Economic environments

There are (possibly) infinitely many types of goods (commodities). The universe of “potential goods” is denoted by Ξ , and the class of non-empty and finite subsets of Ξ is designated by \mathcal{M} , with generic elements, K, L, M, \dots . The cardinality of $M \in \mathcal{M}$ is denoted by $\#M = m$. For each $M \in \mathcal{M}$, let us denote a generic commodity bundle in \mathbb{R}_+^m by $x \in \mathbb{R}_+^m$.

The population in the economy is given by the set $N = \{1, \dots, n\}$, where $2 \leq n < +\infty$. Given a list of commodities $M \in \mathcal{M}$, every individual has a common consumption space \mathbb{R}_+^m . There are k *basic living conditions* in the economy, which are relevant for all individuals for the purpose of describing their objective well-beings attainable by means of their consumption vectors. These basic living conditions can be interpreted broadly. For example, they can be skills that individuals can develop through education, or they can be occupations which individuals can engage in after the graduation at school. Or they can be characteristics of commodities in the sense of Gorman (1980) and Lancaster (1966), or they can be various functionings according to Sen (1980, 1985) and Nussbaum (1988, 1993, 2000). For our formal analysis, we do not need to stick to a particular interpretation though a certain interpretation may be more appropriate than other interpretations for a given context.

Thus, an achievement of living condition f , where $f = 1, 2, \dots, k$, by individual i is denoted by $b_{if} \in \mathbb{R}_+$. Individual i 's achievement of basic living conditions is given by listing b_{if} : $\mathbf{b}_i = (b_{i1}, \dots, b_{ik}) \in \mathbb{R}_+^k$. Given $M \in \mathcal{M}$, each individual $i \in N$ can be characterized by his opportunity correspondence $c_i^m : \mathbb{R}_+^m \rightarrow \mathbb{R}_+^k$ which associates to every consumption vector $x_i \in \mathbb{R}_+^m$ a non-empty subset $c_i^m(x_i)$ of \mathbb{R}_+^k . The intended interpretation is that i is able to have access to each living-condition vector $\mathbf{b}_i \in c_i^m(x_i)$ by means of his consumption vector x_i . Each opportunity correspondence satisfies the following requirements:

- (a) For all $x_i, x'_i \in \mathbb{R}_+^m$ such that $x_i \leq x'_i$, $c_i^m(x_i) \subseteq c_i^m(x'_i)$ holds;²

²For all vectors $\mathbf{a} = (a_1, \dots, a_p)$ and $\mathbf{b} = (b_1, \dots, b_p) \in \mathbb{R}^p$, $\mathbf{a} \geq \mathbf{b}$ if and only if $a_i \geq b_i$ ($i = 1, \dots, p$); $\mathbf{a} > \mathbf{b}$ if and only if $\mathbf{a} \geq \mathbf{b}$ and $\mathbf{a} \neq \mathbf{b}$; $\mathbf{a} \gg \mathbf{b}$ if and only if $a_i > b_i$ ($i = 1, \dots, p$).

- (b) For some $x_i \in \mathbb{R}_+^m \setminus \{\mathbf{0}\}$, $c_i^m(x_i) \cap \mathbb{R}_+^k \neq \emptyset$ holds, and $c_i^m(\mathbf{0}) = \{\mathbf{0}\}$;
- (c) For all $x_i \in \mathbb{R}_+^m$, $c_i^m(x_i)$ is *compact* and *comprehensive* in \mathbb{R}_+^k ; and
- (d) c_i^m is *continuous* on \mathbb{R}_+^m with respect to the Hausdorff topology.

Let \mathfrak{C}^M be the set of all possible opportunity correspondences defined on \mathbb{R}_+^m , which satisfy the above (a), (b),(c) and (d). Given $M \in \mathcal{M}$, an *economy with \bar{x} endowments of M -goods* is described by a list $\mathbf{e} = (M, \mathbf{c}^m, \bar{x}) = (M, (c_i^m)_{i \in N}, \bar{x})$, where $M \in \mathcal{M}$, $\mathbf{c}^m \in \mathfrak{C}^{Mn}$, $\bar{x} \in \mathbb{R}_+^m$, and \mathfrak{C}^{Mn} stands for the n -fold Cartesian product of \mathfrak{C}^M . Let \mathcal{E}^M be the class of all such economies with \bar{x} endowments of M -goods. Let $\mathcal{E} \equiv \bigcup_{M \in \mathcal{M}} \mathcal{E}^M$. Given $\mathbf{e} = (M, \mathbf{c}^m, \bar{x}) \in \mathcal{E}^M$, a vector $\mathbf{x} = (x_i)_{i \in N} \in \mathbb{R}_+^{mn}$ is *feasible* for $\mathbf{e} \in \mathcal{E}^M$ if for all $i \in N$, $x_i \in \mathbb{R}_+^m$, and $\sum x_i \leq \bar{x}$. We denote by $A(\mathbf{e})$ the set of feasible allocations for $\mathbf{e} \in \mathcal{E}^M$. Let $A(\mathcal{E}) \equiv \bigcup_{\mathbf{e} \in \mathcal{E}} A(\mathbf{e})$.

For each individual $i \in N$, given $M \in \mathcal{M}$ and given i 's consumption vector x_i , $c_i^m(x_i)$ generates a opportunity set $C_i = c_i^m(x_i)$ for i . An opportunity assignment is a list of n opportunity sets one for each individual in the society. Given $\mathbf{e} = (M, \mathbf{c}^m, \bar{x}) \in \mathcal{E}$, the *set of possible opportunity assignments for $\mathbf{e} \in \mathcal{E}$* is:

$$\mathcal{C}(\mathbf{e}) \equiv \{\mathbf{C} = (C_i)_{i \in N} \subseteq \mathbb{R}_+^{kn} \mid \exists \mathbf{x} = (x_i)_{i \in N} \in A(\mathbf{e}) : C_i = c_i^m(x_i) (\forall i \in N)\}.$$

Note that for any $\mathbf{e} = (M, \mathbf{c}^m, \bar{x}) \in \mathcal{E}$, any $\mathbf{C} = (C_i)_{i \in N} \in \mathcal{C}(\mathbf{e})$, and any $i \in N$, the opportunity C_i is a compact, comprehensive set in \mathbb{R}_+^k containing the origin. For each $i \in N$ and each living condition $f = 1, \dots, k$, let $\max_f(C_i)$ be the maximum amount of living condition f by i that he can achieve under his opportunity set C_i ; that is, $\max_f(C_i) \equiv \max\{b_f \mid (b_1, \dots, b_f, \dots, b_k) \in C_i\}$. Let $\Sigma \equiv \{\mathcal{C} \mid \exists \mathbf{e} \in \mathcal{E} : \mathcal{C} = \mathcal{C}(\mathbf{e})\}$ be the class of all such possible sets of opportunity assignments. Note that each set \mathcal{C} in Σ is compact in terms of Hausdorff metric by the assumption (d) of the opportunity correspondence and the fact that $A(\mathbf{e})$ is compact for every $\mathbf{e} \in \mathcal{E}$. Also, for any $\mathcal{C} \in \Sigma$, if $\mathbf{C} = (C_i)_{i \in N} \in \mathcal{C}$, then for each $j \in N$, every living condition $f = 1, \dots, k$, and any $b_f \leq \max_f(C_j)$, there exists $\mathbf{C}' = (C'_j, \mathbf{C}_{-j}) \in \mathcal{C}$ such that $b_f = \max_f(C'_j)$ and $C'_j \subseteq C_j$ by the assumption of (a), (b), and (d) of opportunity correspondences.

2.2 Opportunity sets and their ranking

Let \mathcal{K} be the universal class of compact, comprehensive subsets in \mathbb{R}_+^k containing the origin. Thus, $C \in \mathcal{K}$ implies that for any $M \in \mathcal{M}$, there exists

$c^m \in \mathfrak{C}^M$ such that for some $x \in \mathbb{R}_+^m$, $c^m(x) = C$. Note that for each $\mathcal{C} \in \Sigma$ and every $i \in N$, there exists $C_i^* \in \mathcal{K}$ such that for every $\mathbf{C} \in \mathcal{C}$, $C_i^* \supseteq C_i$ holds, and $(C_i^*, \mathbf{C}_{-i}^0) \in \mathcal{C}$ with $C_j^0 \equiv \{\mathbf{0}\}$ for any $j \neq i$. This is followed from the requirement (a) of opportunity correspondences and the definition of Σ . Given $\mathcal{C} \in \Sigma$, let us denote such C_i^* by $m_i(\mathcal{C})$ for each $i \in N$.

How are various opportunity sets measured by individuals in the economy? We assume that there is an objective way of ranking various opportunity sets by individuals, where this objective measure of alternative opportunity sets is formalized as a binary relation $R \subseteq \mathcal{K} \times \mathcal{K}$. The relation R satisfies reflexivity: [for all $C \in \mathcal{K}$, $(C, C) \in R$], completeness: [for all $C, C' \in \mathcal{K}$, $(C, C') \in R$ or $(C', C) \in R$], and transitivity: [for all $C, C', C'' \in \mathcal{K}$, if $(C, C') \in R$ & $(C', C'') \in R$, then $(C, C'') \in R$]. Thus, R is an ordering over \mathcal{K} . Note P and I are respectively the asymmetric and symmetric parts of R .

For all $C, C' \in \mathcal{K}$, we write $C > C'$ if for all $\mathbf{b}' \in C'$, there exists $\mathbf{b} \in C$ such that $\mathbf{b} \gg \mathbf{b}'$. Note that, given the comprehensiveness of opportunity sets in \mathcal{K} , when $C > C'$, necessarily, we have C' as a proper subset of C .

In this paper, we assume that the ordering R on \mathcal{K} satisfies the following two properties:

Monotonicity: For all $C, C' \in \mathcal{K}$, if $C \supseteq C'$ then $(C, C') \in R$, and if $C > C'$, then $(C, C') \in P$.

Representability: There exists a real-valued, continuous function $G : \mathcal{K} \rightarrow \mathbb{R}_+$ such that for all $C, C' \in \mathcal{K}$,

$$G(C) \geq G(C') \Leftrightarrow (C, C') \in R.$$

It may be noted that, in our context, Monotonicity is a fairly non-controversial property and it essentially requires that a “bigger” opportunity set be ranked higher than a “smaller” opportunity set. Similar conditions have been used in the literature on ranking opportunity sets, see for example, Gaertner and Xu (2006), Pattanaik and Xu (2007), and Xu (2002, 2004). Representability requires the function G representing the ordering R to be continuous. See Pattanaik and Xu (2000), Xu (2004), and Savaglio and Vanucci (2006) for examples of such ordinal representations of a binary relation over opportunity sets.

2.3 Bargaining problems on opportunity assignments

The formal problem that we are interested in is the bargaining problem over opportunity assignments among individuals. Analogous to the standard bargaining model, we can interpret each $\mathcal{C} \in \Sigma$ as a bargaining problem, and a solution to the problem is to pick up a subset of opportunity assignments $\{\mathbf{C} = (C_i)_{i \in N}\}$ from \mathcal{C} . Then, a *bargaining solution* in this context is a correspondence F which associates to every $\mathcal{C} \in \Sigma$, a non-empty subset $F(\mathcal{C}) \subseteq \mathcal{C}$.

How is our model related to the motivation discussed in the Introduction? The following examples may help us in understanding our approach.

Example 1: Let k be the number of skills that an individual can develop through education, and let $x \in \mathbf{R}_+^m$ be an educational resource. Then, the k dimensions of the opportunity set $\mathbf{c}_i^m(x) \subseteq \mathbb{R}_+^k$ represent the types of skills, and each element $\mathbf{b}_i = (b_{if})_{f \in \{1, \dots, k\}} \in \mathbf{c}_i^m(x)$ implies that individual i can develop the level of each skill f up to b_{if} , whenever he is educated with the educational support x and some amount of his own effort. The difference of native talents among individuals is reflected in the difference of opportunity correspondences among them. In this setting, the bargaining problem would be to assign opportunities for future skills by allocating educational resources.

Example 2: The WTO consists of many member countries and one of its functions is to settle disputes among its member countries. Disputes between or among member countries are really about net trades of goods, services or capital. The Dispute Settlement Body of the WTO thus makes recommendations as how to structure net trades among the affected member countries.³ Each member country is concerned about, for example, the aggregate employment rate, the growth rates of several sectors like manufacturing, agriculture, and service, and the health condition of its population. These concerns correspond to our notion of achievements. Each member country's interests can be captured by the country's *opportunity sets* representing opportunities to achieve a degree of employment rate, to have reasonable growth rates for

³Quite often, disputes seemingly are about things like *access to member countries' markets and information, legal protection concerning trades from member countries, or pricing rules*. These are rules governing trade between and among nations and they have direct effect on net trade between member countries. As a consequence, we can interpret that disputes are really about net trade.

its concerned sectors, and to offer its population a good health. The bargaining problem can then be interpreted as follows. The Dispute Settlement Body in the WTO mechanism acts as the fair arbitrator and it recommends the settlements that affect net trade based on equal opportunities for the disputed member countries along the factors that we discussed above.

Example 3: Our last example concerns the allocation of the budget by a central government to its several local jurisdictions. In many cases, the allocation of this budget intends for different localities to have equal opportunities for growth and for access to clean water, for example. Growth and access to clean water are two of the many factors that different local jurisdictions are concerned about, and local governments are concerned about their *opportunities* along these factors. The bargaining problem in this example can thus be viewed as how the fair arbitrator, the central government, makes budgetary allocations on the basis of equal opportunities for different local jurisdictions along those factors such as growth and environmental quality of each region.

3 The egalitarian solution: a first characterization

Given a social evaluation of opportunity sets R satisfying Monotonicity and Representability and its representation G , the egalitarian solution we consider in the paper is defined as follows:

Egalitarian Solution: *A bargaining solution F^E is the egalitarian solution if, for every $\mathcal{C} \in \Sigma$, $\mathbf{C} \in F^E(\mathcal{C})$ implies that: (1) there is no other $\mathbf{C}' \in \mathcal{C}$ such that $(C'_i, C_i) \in P$ for all $i \in N$; and (2) $(C_i, C_j) \in I$ holds for any $i, j \in N$.*

3.1 Axioms on bargaining solutions

In this subsection, we shall present and discuss axioms on bargaining solutions over opportunity assignments. It may be remarked that most of the axioms introduced below are formulated in terms of opportunity assignments without explicitly referring to a given G function representing the ordering

R over opportunity sets. Such axioms are considerably weak and can appeal to our intuitions directly.

The first axiom is the corresponding weak efficiency axiom in standard bargaining models.

Weak Efficiency (WE): For each $\mathcal{C} \in \Sigma$ and each $\mathbf{C} = (C_i)_{i \in N} \in F(\mathcal{C})$, there is no $\mathbf{C}' = (C'_i)_{i \in N} \in \mathcal{C}$ such that for every $i \in N$, $C'_i > C_i$.

Therefore, the axiom (WE) requires that the solution should not select an opportunity assignment that is strictly dominated by another feasible opportunity assignment. It may be reminded that, when an opportunity assignment \mathbf{C}' strictly dominates an opportunity assignment \mathbf{C} , we have $[C'_i > C_i \text{ for every } i \in N]$, which requires that, for each $i \in N$, C'_i is obtained from C_i by expanding it “outwardly”; as a consequence, necessarily, each C_i is a proper subset of C'_i .

To introduce our next axiom, we first define the notion of an identical opportunity assignment and then some related concepts. Let $\mathcal{C} \in \Sigma$. We say that $\mathcal{C} \in \Sigma$ is *symmetric* if for every permutation $\pi : N \rightarrow N$, and for every $\mathbf{C} = (C_i)_{i \in N} \in \mathcal{C}$, $\pi(\mathbf{C}) \equiv (C_{\pi(i)})_{i \in N} \in \mathcal{C}$ holds. If $\mathbf{C}^* = (C_i^*)_{i \in N} \in \mathcal{K}^n$ is such that $C_i^* = C_j^*$ for any $i, j \in N$, then \mathbf{C}^* is said to be an *identical opportunity assignment*.

Let $\Lambda \subseteq \mathbb{R}_+$ be a set of index numbers with the minimal value $0 \in \Lambda$. Let $\{\mathbf{C}^s\}_{s \in \Lambda} \subseteq \mathcal{K}^n$ be a sequence of identical assignments such that (a) for any $s \in \Lambda$, $\mathbf{C}^s \in \mathcal{K}^n$ is an identical assignment; (b) for any $s, s' \in \Lambda$ with $s < s'$, $C^s \subseteq C^{s'}$; and (c) $\mathbf{C}^0 = \{\mathbf{0}\}$. We call such $\{\mathbf{C}^s\}_{s \in \Lambda}$ a *monotone path of identical assignments*. In general, Λ is not a closed set. If Λ is closed, then there exists the maximal identical assignment \mathbf{C}^{s^*} in $\{\mathbf{C}^s\}_{s \in \Lambda}$. In this case, $\{\mathbf{C}^s\}_{s \in \Lambda}$ is called a *closed monotone path of identical assignments*. $\mathcal{C} \in \Sigma$ is said to be *symmetric with a closed monotone path of identical assignments* $\{\mathbf{C}^s\}_{s \in \Lambda}$ if \mathcal{C} is symmetric, and $\{\mathbf{C}^s\}_{s \in \Lambda} \subseteq \mathcal{C}$ is such that the maximal identical assignment \mathbf{C}^{s^*} is a weakly efficient assignment in \mathcal{C} .

Symmetry (S): For each $\mathcal{C} \in \Sigma$, if \mathcal{C} is symmetric with a closed monotone path of identical assignments $\{\mathbf{C}^s\}_{s \in \Lambda}$, then $F(\mathcal{C}) \cap \{\mathbf{C}^s\}_{s \in \Lambda} \neq \emptyset$, and for no $\mathbf{C} \in F(\mathcal{C})$, $C_i > C_j$ for some $i, j \in N$.

The axiom (S) stipulates that, for each symmetric problem with a closed monotone path of identical assignments $\{\mathbf{C}^s\}_{s \in \Lambda}$, the solution selects at least

one identical opportunity assignment from $\{\mathbf{C}^s\}_{s \in \Lambda}$, and further, no opportunity assignment selected by the solution is such that one individual's opportunity set strictly dominates another individual's opportunity set.

The following axiom is analogous to the axiom of contraction independence in standard bargaining models:

Contraction Independence (CI): For each $\mathcal{C}, \mathcal{C}' \in \Sigma$ with $\mathcal{C} \supseteq \mathcal{C}'$, if $F(\mathcal{C}) \cap \mathcal{C}' \neq \emptyset$, then $F(\mathcal{C}') = F(\mathcal{C}) \cap \mathcal{C}'$.

The axiom (CI) corresponds to Nash's Independence of Irrelevant Alternatives in standard bargaining models. It requires that if an opportunity assignment is chosen from a "larger" problem and is still available when the larger problem shrinks to a smaller problem, then it should be chosen from the smaller problem as well.

Our final axiom is an informational requirement on a solution to a problem and is stated below:

Informational Invariance (II): For each $\mathcal{C} \in \Sigma$ and each $\mathbf{C} = (C_i)_{i \in N}$, $\mathbf{C}' = (C'_i)_{i \in N} \in \mathcal{C}$, if $\mathbf{C} \in F(\mathcal{C})$ and $(C'_i, C_i) \in I$ for all $i \in N$, then $\mathbf{C}' \in F(\mathcal{C})$.

According to the axiom (II), if two opportunity assignments are "equivalent" in the sense that the two opportunity sets for each and every individual specified by the corresponding opportunity assignments are ranked equally, then whenever one opportunity assignment is chosen by the solution, the other opportunity assignment should be chosen by the solution as well. The axiom (II) thus implies that the informational requirement in our context is contained exclusively in the social evaluation ordering R . A similar axiom, called *No Discrimination*, is discussed by Thomson (1983) in the context of fair allocation problems.

3.2 A characterization of the egalitarian solution

Before we present our characterization result, the following observations are useful throughout this subsection. Let G be the real-valued, ordinal representation of the social ordering R . For each bargaining problem $\mathcal{C} \in \Sigma$, we define

$$G(\mathcal{C}) \equiv \{G(\mathbf{C}) = (G(C_i))_{i \in N} \in \mathbb{R}_+^n \mid \mathbf{C} \in \mathcal{C}\}.$$

Let $\partial G(\mathcal{C})$ be the upper boundary of $G(\mathcal{C})$. Since \mathcal{C} is derived from an underlying economic environment $\mathbf{e} = (M, \mathbf{c}^m, \bar{x}) \in \mathcal{E}$, where \mathbf{c}^m is a profile

of opportunity correspondences satisfying the requirements (a), (b), (c), and (d), and G is continuous on \mathcal{K} , $\partial G(\mathcal{C})$ constitutes a connected set in \mathbb{R}_+^n . Moreover, since \mathcal{C} is *comprehensive*⁴ by the requirements (a), (b), and (d) of opportunity correspondences, $G(\mathcal{C})$ must be comprehensive. Finally, by choosing $G(\{\mathbf{0}\}) = 0$ for the zero vector $\mathbf{0} \in \mathbb{R}_+^k$, $G(\mathcal{C})$ has $\mathbf{0} \in \mathbb{R}_+^n$ as its element, since $\underbrace{(\{\mathbf{0}\}, \dots, \{\mathbf{0}\})}_{n\text{-times}} \in \mathcal{C}$.

Theorem 1: *The egalitarian solution F^E is the unique solution satisfying (WE), (S), (CI) and (II).*⁵

Proof. First, it may be checked that F^E satisfies the four axioms of the theorem.

Next, we show that if a solution F satisfies (WE), (S), (CI) and (II), then $F = F^E$. Let us choose any bargaining problem $\mathcal{C} \in \Sigma$, which is derived from an underlying economic environment $\mathbf{e} = (M, \mathbf{c}^m, \bar{x}) \in \mathcal{E}$. Suppose $F \neq F^E$. By (II), we can suppose that $G(F(\mathcal{C})) \neq G(F^E(\mathcal{C}))$ for this $\mathcal{C} \in \Sigma$. Then, there exists $\overline{\mathbf{G}}^* \in G(F(\mathcal{C})) \setminus G(F^E(\mathcal{C}))$. Given \mathcal{C} , we define $\mathcal{C}(i) \equiv \{C'_i \in \mathcal{K} \mid \exists \mathbf{C}_{-i} \in \mathcal{K}^{n-1} : (C'_i, \mathbf{C}_{-i}) \in \mathcal{C}\}$ for each $i \in N$. For each $i \in N$ and each $r \in \mathbb{R}_+$, define

$$\mathcal{C}(i; r) \equiv \{C'_i \in \mathcal{C}(i) \mid G(C'_i) = r\}.$$

Let $\mathbf{r}^* \equiv \overline{\mathbf{G}}^*$. Consider $\text{comp}\{\mathbf{r}^*\} \equiv \{\mathbf{r} \in \mathbb{R}_+^n : \mathbf{r} \leq \mathbf{r}^*\}$, and $\mathcal{C}^* \equiv G^{-1}(\text{comp}\{\mathbf{r}^*\})$.

Insert Figure 1 around here.

Since G is continuous, we can choose a continuous sequence $\mathcal{C}_s^* \subseteq \mathcal{C}^*$ in which (i) for each $\mathbf{r} \in \text{comp}\{\mathbf{r}^*\}$, there exists a unique $(C_i^{r_i})_{i \in N} \in \mathcal{C}_s^*$ such that $C_i^{r_i} \in \mathcal{C}(i; r_i)$ for each $i \in N$; (ii) for each $\mathbf{r}, \mathbf{r}' \in \text{comp}\{\mathbf{r}^*\}$, for each $i \in N$, $C_i^{r_i} = C_i^{r'_i}$ holds if $r_i = r'_i$ and $C_i^{r_i} > C_i^{r'_i}$ if $r_i > r'_i$; and (iii) for any $\mathbf{r}' \in \text{comp}\{\mathbf{r}^*\}$, $\lim_{\mathbf{r} \rightarrow \mathbf{r}'} (C_i^{r_i})_{i \in N} = (C_i^{r'_i})_{i \in N}$ holds. By definition, $G(\mathcal{C}_s^*) = \text{comp}\{\mathbf{r}^*\}$.

⁴ \mathcal{C} is comprehensive if, for each $\mathbf{C} \in \mathcal{C}$ and each $i \in N$ with $C_i \neq \{\mathbf{0}\}$, there exists $\mathbf{C}' \in \mathcal{C}$ such that $C'_i < C_i$ and $C'_j \subseteq C_j$ for all $j \in N \setminus \{i\}$.

⁵It may be noted that the result of Theorem 1 suggests the egalitarian solution to standard non-convex and comprehensive bargaining problems is characterized by the corresponding axioms of weak efficiency, symmetry and contraction independence. This indeed is the case, see Xu and Yoshihara (2006).

Now, by using the information of \mathcal{C}_s^* , we are ready to construct $\mathbf{e}^* = (M^*, \widehat{\mathbf{c}}^1, \bar{x}^*) \in \mathcal{E}$, in which $M^* \cap M = \emptyset$, $\#M^* = 1$, and $\bar{x}^* = 1$. Moreover, for each $i \in N$, the opportunity correspondence \widehat{c}_i^1 is defined as follows:

- (i) for all $x \in [0, \frac{1}{n}]$, $\widehat{c}_i^1(x) = C_i^{r'_i}$ with $r'_i = nx \cdot r_i^*$; and
- (ii) for all $x \in (\frac{1}{n}, 1]$, $\widehat{c}_i^1(x) = C_i^{r_i^*}$.

Then, consider $\mathcal{C}^{**} \equiv \mathcal{C}(\mathbf{e}^*) \in \Sigma$.

By (CI), $\mathbf{r}^* \in G(F(\mathcal{C}^{**}))$. Next, consider $\mathcal{C}^\Delta \equiv \cup_{\pi \in \Pi} \pi(\mathcal{C}^{**})$.

Insert Figure 2 around here.

We will construct a new economy $\mathbf{e}^\Delta = (M^\Delta, \mathbf{c}^{\Delta n}, \bar{x}^\Delta) \in \mathcal{E}$ such that $\mathcal{C}(\mathbf{e}^\Delta) \supseteq \mathcal{C}^\Delta$ and $G(\mathcal{C}(\mathbf{e}^\Delta)) = G(\mathcal{C}^\Delta)$. First, define an opportunity correspondence $c^n : [0, \bar{x}^*]^n \rightarrow \mathbb{R}_+^k$ by: for every $x = (x_i)_{i \in N} \in [0, \bar{x}^*]^n$, $c^n(x) \equiv \cup_{i \in N} \widehat{c}_i^1(x_i)$. Consider $\mathbf{e}^{(n)} = (M^{*(n)}, \mathbf{c}^n, (\bar{x}^*)^n) \in \mathcal{E}$, where $c_i^n = c^n$ for every $i \in N$, and $(\bar{x}^*)^n \equiv \underbrace{(\bar{x}^*, \dots, \bar{x}^*)}_{n\text{-times}}$. Then, $\mathcal{C}(\mathbf{e}^{(n)}) \supseteq \mathcal{C}^\Delta$, but

$$G(\mathcal{C}(\mathbf{e}^{(n)})) \not\supseteq G(\mathcal{C}^\Delta).$$

Insert Figure 3 around here.

Note that both $G(\mathcal{C}(\mathbf{e}^{(n)}))$ and $G(\mathcal{C}^\Delta)$ are symmetric, and $\partial G(\mathcal{C}(\mathbf{e}^{(n)}))$ is homeomorphic to $\partial G(\mathcal{C}^\Delta)$. Thus, we can take a continuous bijection $\boldsymbol{\lambda} : \partial G(\mathcal{C}(\mathbf{e}^{(n)})) \rightarrow \partial G(\mathcal{C}^\Delta)$ such that for any $\mathbf{r} \in \partial G(\mathcal{C}(\mathbf{e}^{(n)}))$, there exists a scalar $\lambda^{\mathbf{r}} > 0$ such that $\boldsymbol{\lambda}(\mathbf{r}) = (\lambda^{\mathbf{r}} \cdot r_i)_{i \in N} \in \partial G(\mathcal{C}^\Delta)$. Define an opportunity correspondence $c^{\Delta n}$ as follows: For any $(\lambda^{\mathbf{r}} \cdot r_i)_{i \in N} \in \partial G(\mathcal{C}^\Delta)$, any $i \in N$, any $r \in [0, \lambda^{\mathbf{r}} \cdot r_i]$, and any $x \in (c^n)^{-1} \circ G^{-1}(r)$, let $c^{\Delta n}(x) = c^n(x)$; and for any $\mathbf{r} \in \partial G(\mathcal{C}(\mathbf{e}^{(n)}))$, if $\lambda^{\mathbf{r}} \cdot r_i < r_i$, then for any $r \in (\lambda^{\mathbf{r}} \cdot r_i, r_i]$, and any $x \in (c^n)^{-1} \circ G^{-1}(r)$, let $c^{\Delta n}(x) \in G^{-1}(\lambda^{\mathbf{r}} \cdot r_i)$. Then, $\mathbf{e}^\Delta \equiv (M^{*(n)}, \mathbf{c}^{\Delta n}, (\bar{x}^*)^n) \in \mathcal{E}$, where $\mathbf{c}^{\Delta n} = \underbrace{(c^{\Delta n}, \dots, c^{\Delta n})}_{n\text{-times}}$. By defini-

tion, $\mathcal{C}(\mathbf{e}^\Delta) \supseteq \mathcal{C}^\Delta$, and $G(\mathcal{C}(\mathbf{e}^\Delta)) = G(\mathcal{C}^\Delta)$.

From the construction of $\mathcal{C}(\mathbf{e}^\Delta)$, by (WE), (S), and (II), we must have the following:

$$G(F(\mathcal{C}(\mathbf{e}^\Delta))) = \left\{ G\left(\mathbf{c}^{\Delta n} \left(\left(\frac{1^*}{n} \right)^n \right) \right) \right\},$$

$$\text{where } \mathbf{c}^{\Delta n} \left(\left(\frac{1^*}{n} \right)^n \right) = \underbrace{\left(c^{\Delta n} \left(\left(\frac{1^*}{n} \right)^n \right), \dots, c^{\Delta n} \left(\left(\frac{1^*}{n} \right)^n \right) \right)}_{n\text{-times}}$$

$$\text{and } \left(\frac{1^*}{n}\right)^n = \underbrace{\left(\frac{1^*}{n}, \dots, \frac{1^*}{n}\right)}_{n\text{-times}}.$$

Let $\mathbf{r}^{\Delta E} \equiv G(\mathbf{c}^{\Delta n}((\frac{1^*}{n})^n))$, which is the egalitarian outcome for the problem $\mathcal{C}(\mathbf{e}^\Delta)$.

Insert Figure 4 around here.

Since $\mathbf{r}^{\Delta E} \in \partial G(\mathcal{C}^{**})$, there exists $\mathbf{C}^{\mathbf{r}^{\Delta E}} \in \mathcal{C}^{**}$ such that $G(\mathbf{C}^{\mathbf{r}^{\Delta E}}) = \mathbf{r}^{\Delta E}$. Thus, by (CI), $\{\mathbf{r}^{\Delta E}\} = G(F(\mathcal{C}^{**}))$, which is a desired contradiction, since $\mathbf{r}^* \in G(F(\mathcal{C}^{**}))$.

Insert Figure 5 around here.

Thus, $G(F(\mathcal{C})) \setminus G(F^E(\mathcal{C})) = \emptyset$. By (II), clearly, $F = F^E$. ■

4 The egalitarian allocation rule in economic environments

In this section, we reformulate our bargaining problems directly in economic environments. For this purpose, we start by introducing some additional definitions.

An *allocation rule* is a correspondence φ which associates to every $\mathbf{e} \in \mathcal{E}$, a non-empty subset $\varphi(\mathbf{e}) \subseteq A(\mathbf{e})$. An allocation rule φ *attains* a bargaining solution F if and only if for every $\mathbf{e} \in \mathcal{E}$, $\mathbf{c}(\varphi(\mathbf{e})) = F(\mathcal{C}(\mathbf{e}))$, where $\mathbf{c}(\varphi(\mathbf{e})) \equiv \{\mathbf{C} = (C_i)_{i \in N} \in \mathcal{C}(\mathbf{e}) \mid \exists \mathbf{x} = (x_i)_{i \in N} \in \varphi(\mathbf{e}) : C_i = c_i^m(x_i) (\forall i \in N)\}$.

Egalitarian Allocation Rule: *An allocation rule φ^E is the egalitarian rule if it attains the egalitarian solution: for all $\mathbf{e} \in \mathcal{E}$, $\mathbf{c}(\varphi^E(\mathbf{e})) = F^E(\mathcal{C}(\mathbf{e}))$.*

We now present and discuss relevant axioms on allocation rules that attain bargaining solutions over opportunity assignments. We first introduce an axiom that is similar to weak efficiency in standard bargaining models. Its intuition is straightforward.

Weak Economic Efficiency (WEE): *For each $\mathbf{e} = (M, \mathbf{c}^m, \bar{x}) \in \mathcal{E}$ and each $\mathbf{x} \in \varphi(\mathbf{e})$, there is no $\mathbf{x}' \in A(\mathbf{e})$ such that for every $i \in N$, $c_i^m(x'_i) > c_i^m(x_i)$.*

We shall denote the set of weakly economic efficient allocations for \mathbf{e} by $WE(\mathbf{e})$.

The next two axioms correspond to the axioms of symmetry and contraction independence introduced in Section 3.

Economic Symmetry (ES): For each $\mathbf{e} = (M, \mathbf{c}^m, \bar{x}) \in \mathcal{E}$ with $c_i^m = c_j^m$ for all $i, j \in N$, if $\mathbf{x} \in \varphi(\mathbf{e})$, then for any $i, j \in N$, $c_i^m(x_i) = c_j^m(x_j)$.

Economic Contraction Independence (ECI): For each $\mathbf{e} = (M, \mathbf{c}^m, \bar{x}), \mathbf{e}' = (M, \mathbf{c}^m, \bar{x}') \in \mathcal{E}$ with $\bar{x} \geq \bar{x}'$, if $\mathbf{c}(\varphi(\mathbf{e})) \cap \mathcal{C}(\mathbf{e}') \neq \emptyset$, then $\mathbf{c}(\varphi(\mathbf{e}')) = \mathbf{c}(\varphi(\mathbf{e})) \cap \mathcal{C}(\mathbf{e}')$.

Informational requirements on allocation rules in the current setting are stated in the following axioms.

Strong Economic Informational Invariance (SEII) : For each $\mathbf{e} = (M, \mathbf{c}^m, \bar{x}), \mathbf{e}' = (L, \mathbf{c}^l, \bar{x}') \in \mathcal{E}$ with $\mathcal{C}(\mathbf{e}) = \mathcal{C}(\mathbf{e}')$, for any $\mathbf{x} \in \varphi(\mathbf{e})$ and any $\mathbf{x}' \in A(\mathbf{e}')$, if $(c_i^l(x'_i), c_i^m(x_i)) \in I$ holds for all $i \in N$, then $\mathbf{x}' \in \varphi(\mathbf{e}')$.

Economic Informational Invariance (EII) : For each $\mathbf{e} = (M, \mathbf{c}^m, \bar{x}) \in \mathcal{E}$, for any $\mathbf{x} \in \varphi(\mathbf{e})$ and any $\mathbf{x}' \in A(\mathbf{e})$, if $(c_i^m(x'_i), c_i^m(x_i)) \in I$ holds for all $i \in N$, then $\mathbf{x}' \in \varphi(\mathbf{e})$.

Full Correspondence (F) : For each $\mathbf{e} = (M, \mathbf{c}^m, \bar{x}) \in \mathcal{E}$, for any $\mathbf{x} \in \varphi(\mathbf{e})$ and any $\mathbf{x}' \in A(\mathbf{e})$, if $c_i^m(x'_i) = c_i^m(x_i)$ holds for all $i \in N$, then $\mathbf{x}' \in \varphi(\mathbf{e})$.

It may be noted that (SEII) implies (EII) and (EII) implies (F). (SEII) requires that, for any two economies having the same set of opportunity assignments, if an allocation \mathbf{x} is chosen by the allocation rule for the first economy and if an allocation \mathbf{x}' is feasible in the second economy, then the allocation \mathbf{x}' should be chosen for the second economy as long as every individual views the opportunity set generated under \mathbf{x} being indifferent to the opportunity set generated under \mathbf{x}' . (EII) is weaker than (SEII) in that (EII) is confined to the same economy, and (F) is weaker than (EII) in that the allocation \mathbf{x}' should be chosen for the second economy as long as (i) \mathbf{x} is chosen for the first economy, (ii) \mathbf{x}' is feasible, and (iii) \mathbf{x}' generates the same opportunity set for every individual as \mathbf{x} .

(SEII) can be further decomposed. It turns out that (SEII) embodies an element relating to dimensional changes in endowments of commodities. To capture this idea formally, we introduce a definition first.

Letting $x \in \mathbb{R}_+^m$ and $c_i^m \in \mathfrak{C}^M$ and letting K be a proper subset of M , we say that *each good in K is useless for individual $i \in N$ at x* if, for all $x'_K \equiv (x'_f)_{f \in K} \in \mathbb{R}_+^k$, $c_i^m(x'_K, x_{M \setminus K}) = c_i^m(x_K, x_{M \setminus K})$, where $x_K \equiv (x_f)_{f \in K}$. Therefore, a commodity is useless for an individual at a commodity bundle x if it does not “contribute” anything to this individual’s opportunity set under x .

Independence of Useless New Commodities (INC): Let $\mathbf{e} = (M, \mathbf{c}^m, \bar{x}) \in \mathcal{E}^M$, and let $\hat{\mathbf{x}} = (\hat{x}_i)_{i \in N} \in \varphi(\mathbf{e})$ be weakly economic efficient. Let $\mathbf{e}' = (M \cup L, \mathbf{c}^{m+l}, (\bar{x}, \bar{y})) \in \mathcal{E}^{M \cup L}$, where $M \cap L = \emptyset$, be such that (1) for any $\mathbf{x} = (x_i)_{i \in N} \in WE(\mathbf{e})$, there exists $(y_i(\mathbf{x}))_{i \in N} \in \mathbb{R}_+^{nl}$ such that

$$c_i^{m+l}(x_i, y_i(\mathbf{x})) = c_i^m(x_i) \quad (\forall i \in N) \text{ and } (x_i, y_i(\mathbf{x}))_{i \in N} \in WE(\mathbf{e}'),$$

and (2) each good of L is useless for every agent $i \in N$ at $(\hat{x}_i, \mathbf{0}) \in \mathbb{R}_+^{m+l}$. Then, $(\hat{x}_i, \mathbf{0})_{i \in N} \in \varphi(\mathbf{e}')$.

(INC) essentially requires that, by adding useless new commodities to an economy, those allocations that “preserve” the original allocations chosen by an allocation rule for the original economy and use none of the useless new commodities should continue to be chosen from the “enlarged” economy by the allocation rule.

The characterization of the egalitarian allocation rule is summarized in the following theorem, Theorem 2.

Theorem 2: *The egalitarian allocation rule φ^E is the unique rule satisfying WEE, ES, ECI, EII, and INC.*

To prove Theorem 2, we first prove the following series of lemmas. The proof of Theorem 2 will then follow.

Lemma 1: *Let $\mathbf{e}_1, \mathbf{e}_2 \in \mathcal{E}$ be such that $\mathbf{e}_1 = (M, \mathbf{c}^m, \bar{x}) \in \mathcal{E}^M$, $\mathbf{e}_2 = (L, \mathbf{c}^l, \bar{y}) \in \mathcal{E}^L$, and $\mathcal{C}(\mathbf{e}_1) = \mathcal{C}(\mathbf{e}_2)$. Then, the allocation rule φ which satisfies WEE, F, and INC has the following property: $\mathbf{c}(\varphi(\mathbf{e}_1)) = \mathbf{c}(\varphi(\mathbf{e}_2))$.*

Proof. Let $\mathbf{e}_1, \mathbf{e}_2 \in \mathcal{E}$ be such that $\mathbf{e}_1 = (M, \mathbf{c}^m, \bar{x}) \in \mathcal{E}^M$, $\mathbf{e}_2 = (L, \mathbf{c}^l, \bar{y}) \in \mathcal{E}^L$, and $\mathcal{C}(\mathbf{e}_1) = \mathcal{C}(\mathbf{e}_2)$. In the following, we will construct another economy

$\mathbf{e}_3 = (S, \mathbf{c}^k, \bar{z}) \in \mathcal{E}^S$ such that $s = m + l$ and $\mathcal{C}(\mathbf{e}_3) = \mathcal{C}(\mathbf{e}_1) = \mathcal{C}(\mathbf{e}_2)$. Then, we will show that **WEE**, **F**, and **INC** imply $\mathbf{c}(\varphi(\mathbf{e}_1)) = \mathbf{c}(\varphi(\mathbf{e}_3))$. Once this claim holds, it can also be shown that **WEE**, **F**, and **INC** imply $\mathbf{c}(\varphi(\mathbf{e}_2)) = \mathbf{c}(\varphi(\mathbf{e}_3))$. Thus, $\mathbf{c}(\varphi(\mathbf{e}_1)) = \mathbf{c}(\varphi(\mathbf{e}_2))$.

Let S be a set of commodities such that $\#S = s \equiv m + l$. For each $\mathbf{C} \in \mathcal{C}$, there exist $\mathbf{x} \in A(\mathbf{e}_1)$ and $\mathbf{y} \in A(\mathbf{e}_2)$ such that $c_i^m(x_i) = C_i = c_i^l(y_i)$ for each $i \in N$. Then, for each $i \in N$, let

$$\begin{aligned} c_i^*(x_i, y) &= C_i \text{ for any } y \geq y_i; \text{ and} \\ c_i^*(x, y_i) &= C_i \text{ for any } x \geq x_i. \end{aligned}$$

Such a construction of c_i^* implies that $c_i^* \in \mathfrak{C}^S$ for each $i \in N$. Define $\mathbf{e}_3 = (S, \mathbf{c}^*, (\bar{x}, \bar{y}))$ with $\mathbf{c}^* = (c_i^*)_{i \in N}$. Then, $\mathcal{C}(\mathbf{e}_3) = \mathcal{C}$. Next, for each $i \in N$, let us define $\hat{c}_i : \mathbb{R}_+^s \rightarrow \mathbb{R}_+^k$ as: $\hat{c}_i(x_i, y) = c_i^m(x_i)$ for any $y \in \mathbb{R}_+^l$. Define $\hat{\mathbf{e}}_1 = (S, \hat{\mathbf{c}}, (\bar{x}, \bar{y}))$ with $\hat{\mathbf{c}} = (\hat{c}_i)_{i \in N}$. Then, $\mathcal{C}(\hat{\mathbf{e}}_1) = \mathcal{C}$.

Compare \mathbf{e}_3 and $\hat{\mathbf{e}}_1$. By construction, for any $(x, y) \in \mathbb{R}_+^s$, $\hat{c}_i(x, y) \geq c_i^*(x, y)$ holds for each $i \in N$, and given x , there exists $y_i(x)$ such that for any $y' \geq y_i(x)$, $\hat{c}_i(x, y') = c_i^*(x, y')$. Moreover, for any $(x, y) \in \mathbb{R}_+^s$, there exists $(\delta(x), \delta(y)) \in \mathbb{R}_+^s$ with $(\delta(x), \delta(y)) \geq (x, y)$ such that $\hat{c}_i(x, y) = c_i^*(\delta(x), \delta(y))$. Then, let us define a new commodity space $\mathbb{R}_+^s \times [0, \bar{w}^i]$ and a new correspondence $\hat{c}_i^* : \mathbb{R}_+^s \times [0, \bar{w}^i] \rightarrow \mathbb{R}_+^k$ as: for any $(x, y) \in \mathbb{R}_+^s$,

- (i) $\hat{c}_i^*(x, y, \bar{w}^i) = \hat{c}_i(x, y)$;
- (ii) $\hat{c}_i^*(x, y, 0) = c_i^*(x, y)$;
- (iii) for each $w \in (0, \bar{w}^i)$, there exists $(x', y') \in [(x, y), (\delta(x), \delta(y))]$ such that $\hat{c}_i^*(x, y, w) = c_i^*(x', y')$; and
- (iv) for any $w, w' \in (0, \bar{w}^i)$ with $w \geq w'$, $\hat{c}_i^*(x, y, w) \supseteq \hat{c}_i^*(x, y, w')$.

Let us denote the name of commodity in $[0, \bar{w}^i]$ by $T(i)$. Such \hat{c}_i^* can be constructed to meet $\hat{c}_i^* \in \mathfrak{C}^{S \cup T(i)}$.

Given $(\hat{c}_i^*)_{i \in N}$, let us define a new commodity space $\mathbb{R}_+^s \times (\prod_{i \in N} [0, \bar{w}^i])$ and a profile of new correspondences $(\hat{c}_i^{**})_{i \in N}$ as follows: for each $i \in N$, $\hat{c}_i^{**} : \mathbb{R}_+^s \times (\prod_{i \in N} [0, \bar{w}^i]) \rightarrow \mathbb{R}_+^k$ is given by: for each $(x, y, w_1, \dots, w_n) \in \mathbb{R}_+^s \times (\prod_{i \in N} [0, \bar{w}^i])$, $\hat{c}_i^{**}(x, y, w_1, \dots, w_n) = \hat{c}_i^*(x, y, w_i)$. Let us denote the set of commodities in $\prod_{i \in N} [0, \bar{w}^i]$ by T . Define a new economy $\hat{\mathbf{e}}^{**} \equiv (S \cup T, \hat{\mathbf{c}}^{**}, (\bar{x}, \bar{y}, (\bar{w}^i)_{i \in N})) \in \mathcal{E}$ with $\hat{\mathbf{c}}^{**} \equiv (\hat{c}_i^{**})_{i \in N}$. Then, $\mathcal{C}(\hat{\mathbf{e}}^{**}) = \mathcal{C}$ still holds, since $\mathcal{C}(\hat{\mathbf{e}}^{**}) = \mathcal{C}(\mathbf{e}_3) = \mathcal{C}(\hat{\mathbf{e}}_1)$.

Let $(\hat{\mathbf{x}}, \hat{\mathbf{y}}, \hat{\mathbf{w}}) \in \varphi(\hat{\mathbf{e}}^{**})$. By **WEE**, w. l. o. g., we can assume that each $i \in N$ receives $(\hat{x}_i, \hat{y}_i, (\bar{w}^i, \mathbf{0}_{-i}))$ in the allocation $(\hat{\mathbf{x}}, \hat{\mathbf{y}}, \hat{\mathbf{w}})$, since the commodity $T(i)$ is only useful for $i \in N$. Moreover, by **WEE** and **F**, w. l. o.

g., we can assume that $\widehat{c}_i^{**}(\widehat{x}_i, \widehat{y}_i, (\overline{w}^i, \mathbf{0}_{-i})) = \widehat{c}_i^{**}(\widehat{x}_i, \widehat{y}_i, \mathbf{0}) = c_i^*(\widehat{x}_i, \widehat{y}_i)$ for each $i \in N$. In fact, if $\widehat{c}_i^{**}(\widehat{x}_i, \widehat{y}_i, (\overline{w}^i, \mathbf{0}_{-i})) \not\supseteq \widehat{c}_i^{**}(\widehat{x}_i, \widehat{y}_i, \mathbf{0})$ for some $i \in N$, it implies that either $\sum_{i \in N} \widehat{y}_i < \overline{y}$ or $\widehat{c}_j^{**}(\widehat{x}_j, \widehat{y}_j, (\overline{w}^j, \mathbf{0}_{-j})) = \widehat{c}_j^{**}(\widehat{x}_j, \widehat{y}_j, \mathbf{0}) = c_j^*(\widehat{x}_j, y_j(\widehat{x}_j))$ with $\widehat{y}_j > y_j(\widehat{x}_j)$ holding for some other $j \in N$. Then, by reallocating \overline{y} from $(\widehat{y}_i)_{i \in N}$ to $(y_i(\widehat{x}_i))_{i \in N}$ with $\sum_{i \in N} y_i(\widehat{x}_i) = \overline{y}$, we can have $\widehat{c}_i^{**}(\widehat{x}_i, y_i(\widehat{x}_i), (\overline{w}^i, \mathbf{0}_{-i})) = \widehat{c}_i^{**}(\widehat{x}_i, \widehat{y}_i, (\overline{w}^i, \mathbf{0}_{-i})) = \widehat{c}_i^{**}(\widehat{x}_i, y_i(\widehat{x}_i), \mathbf{0})$ for each $i \in N$. Thus, $(\widehat{x}_i, \widehat{y}_i, (\overline{w}^i, \mathbf{0}_{-i}))_{i \in N} \in \varphi(\widehat{\mathbf{e}}^{**})$ implies $(\widehat{x}_i, \widehat{y}_i, \mathbf{0})_{i \in N} \in \varphi(\widehat{\mathbf{e}}^{**})$ by **WEE** and **F**, and each of the commodities T is useless for each $i \in N$ at $(\widehat{x}_i, \widehat{y}_i, \mathbf{0})$.

Compare $\widehat{\mathbf{e}}^{**}$ and $\widehat{\mathbf{e}}_1$. For any $(\mathbf{x}, \mathbf{y}) \in WE(\widehat{\mathbf{e}}_1)$, $(\mathbf{x}, \mathbf{y}, (\overline{w}^i, \mathbf{0}_{-i}))_{i \in N} \in WE(\widehat{\mathbf{e}}^{**})$ holds, and $\widehat{c}_i^{**}(x_i, y_i, (\overline{w}^i, \mathbf{0}_{-i})) = \widehat{c}_i(x_i, y_i)$ holds for every $i \in N$. Then, by **INC**, $(\widehat{\mathbf{x}}, \widehat{\mathbf{y}}) \in \varphi(\widehat{\mathbf{e}}_1)$. By **F**, $\mathcal{C}(\widehat{\mathbf{e}}^{**}) = \mathcal{C}(\widehat{\mathbf{e}}_1)$ implies $\mathbf{c}(\varphi(\widehat{\mathbf{e}}^{**})) = \mathbf{c}(\varphi(\widehat{\mathbf{e}}_1))$.

Compare $\widehat{\mathbf{e}}^{**}$ and \mathbf{e}_3 . For any $(\mathbf{x}, \mathbf{y}) \in WE(\mathbf{e}_3)$, $(\mathbf{x}, \mathbf{y}, \mathbf{0}) \in WE(\widehat{\mathbf{e}}^{**})$ holds, and $\widehat{c}_i^{**}(x_i, y_i, \mathbf{0}) = c_i^*(x_i, y_i)$ holds for every $i \in N$. Then, by **INC**, $(\widehat{\mathbf{x}}, \widehat{\mathbf{y}}) \in \varphi(\mathbf{e}_3)$. By **F**, $\mathcal{C}(\widehat{\mathbf{e}}^{**}) = \mathcal{C}(\mathbf{e}_3)$ implies $\mathbf{c}(\varphi(\widehat{\mathbf{e}}^{**})) = \mathbf{c}(\varphi(\mathbf{e}_3))$.

Compare $\widehat{\mathbf{e}}_1$ and \mathbf{e}_1 . For any $\mathbf{x} \in WE(\mathbf{e}_1)$, $(\mathbf{x}, \mathbf{y}) \in WE(\widehat{\mathbf{e}}_1)$ and $\widehat{c}_i(x_i, y_i) = c_i^m(x_i)$ hold for any $\mathbf{y} \in \mathbb{R}_+^{nl}$ and every $i \in N$. Moreover, any commodity in L is useless for each $i \in N$ at $(x_i, \mathbf{0})$ under $\widehat{\mathbf{e}}_1$. Thus, by **INC**, $\widehat{\mathbf{x}} \in \varphi(\mathbf{e}_1)$. By **F**, $\mathcal{C}(\widehat{\mathbf{e}}_1) = \mathcal{C}(\mathbf{e}_1)$ implies $\mathbf{c}(\varphi(\widehat{\mathbf{e}}_1)) = \mathbf{c}(\varphi(\mathbf{e}_1))$.

Note that $\mathbf{c}^m(\widehat{\mathbf{x}}) = \mathbf{c}^*(\widehat{\mathbf{x}}, \widehat{\mathbf{y}})$. By **F**, $\mathcal{C}(\mathbf{e}_3) = \mathcal{C}(\mathbf{e}_1)$ implies $\mathbf{c}(\varphi(\mathbf{e}_1)) = \mathbf{c}(\varphi(\mathbf{e}_3))$. ■

Lemma 2: **WEE**, **EII**, and **INC** imply **SEII**.

Proof. Let $\mathbf{e}_1, \mathbf{e}_2 \in \mathcal{E}$ be such that $\mathbf{e}_1 = (M, \mathbf{c}^m, \overline{x}) \in \mathcal{E}^M$, $\mathbf{e}_2 = (L, \mathbf{c}^l, \overline{y}) \in \mathcal{E}^L$, and $\mathcal{C}(\mathbf{e}_1) = \mathcal{C}(\mathbf{e}_2)$. Noting that **EII** implies **F**, by **Lemma 1**, $\mathbf{c}(\varphi(\mathbf{e}_1)) = \mathbf{c}(\varphi(\mathbf{e}_2))$. Then, **EII** implies **SEII** follows easily. ■

Lemma 3: **WEE**, **F**, **ES**, and **INC** imply **S**.

Proof. Let \mathcal{C} be a symmetric problem with a closed monotone path of identical assignments $\{\mathbf{C}^s\}_{s \in \Lambda}$. Then, there exists $\mathbf{e} = (M, \mathbf{c}^m, \overline{x}) \in \mathcal{E}^M$ such that $\mathcal{C}(\mathbf{e}) = \mathcal{C}$. We will construct a new economy $\mathbf{e}' = (L, \mathbf{c}^l, \overline{y}) \in \mathcal{E}^L$ such that $c_i^l = c_j^l$ for all $i, j \in N$ and $\mathcal{C}(\mathbf{e}') = \mathcal{C}$. Then, **WEE**, **F**, **ES**, and **INC** imply that $F(\mathcal{C})$ contains weakly efficient and identical assignments.

Given $\mathbf{e} = (M, \mathbf{c}^m, \overline{x}) \in \mathcal{E}$ with $\mathcal{C}(\mathbf{e}) = \mathcal{C}$, let us consider $\mathbf{e}_{\{1,2\}} = (M, (c_2^m, c_1^m, \mathbf{c}_{-\{1,2\}}^m), \overline{x}) \in \mathcal{E}$. Then, since $\mathcal{C}(\mathbf{e})$ is symmetric, $\mathcal{C}(\mathbf{e}_{\{1,2\}})$ is also

symmetric, and $\mathcal{C}(\mathbf{e}_{\{1,2\}}) = \mathcal{C}$. Then, define $\mathbf{e}^{1,2} = (M^{1,2}, (c_i^{2m})_{i \in N}, (\bar{x}, \bar{x}))$ with $\#M^{1,2} = 2m$ as follows: For each $\mathbf{C} \in \mathcal{C}$ and each $i \in \{1, 2\}$, if $c_1^m(x_1) = C_i = c_2^m(x_2)$, then

$$\begin{aligned} c_i^{2m}(x_1, x) &= C_i \text{ for any } x \geq x_2; \text{ and} \\ c_i^{2m}(x, x_2) &= C_i \text{ for any } x \geq x_1. \end{aligned}$$

In addition, for any other $i \in N \setminus \{1, 2\}$, if $c_i^m(x_i) = C_i$, then $c_i^{2m}(x_i, x) = c_i^m(x_i)$ for any $x \geq 0$. Then, $\mathcal{C}(\mathbf{e}^{1,2}) = \mathcal{C}$. If $N = \{1, 2\}$, then $\mathbf{e}^{1,2}$ is an economy with $c_i^{2m} = c_j^{2m}$ for all $i, j \in N$.

Given, $\mathbf{e}^{1,2} \in \mathcal{E}$, consider $\mathbf{e}_{\{1,3\}}^{1,2} = (M^{1,2}, (c_3^{2m}, c_1^{2m}, c_1^{2m}, \mathbf{c}_{-\{1,2,3\}}^{2m}), (\bar{x}, \bar{x}))$ and $\mathbf{e}_{\{2,3\}}^{1,2} = (M^{1,2}, (c_1^{2m}, c_3^{2m}, c_1^{2m}, \mathbf{c}_{-\{1,2,3\}}^{2m}), (\bar{x}, \bar{x}))$. Then, $\mathcal{C}(\mathbf{e}_{\{1,3\}}^{1,2}) = \mathcal{C}(\mathbf{e}_{\{2,3\}}^{1,2}) = \mathcal{C}$. Then, define $\mathbf{e}^{1,2,3} = (M^{1,2,3}, (c_i^{4m})_{i \in N}, (\bar{x}, \bar{x}, \bar{x}, \bar{x}))$ with $\#M^{1,2,3} = 4m$ as follows: For each $\mathbf{C} \in \mathcal{C}$ and each $i \in \{1, 2, 3\}$, if $c_1^{4m}(x_1) = C_i = c_3^{4m}(x_3)$, then

$$\begin{aligned} c_i^{4m}(x_1, x) &= C_i \text{ for any } x \geq x_3; \text{ and} \\ c_i^{4m}(x, x_3) &= C_i \text{ for any } x \geq x_1. \end{aligned}$$

In addition, for any other $i \in N \setminus \{1, 2, 3\}$, if $c_i^{2m}(x_i) = C_i$, then $c_i^{4m}(x_i, x) = c_i^{2m}(x_i)$ for any $x \geq 0$. Then, $\mathcal{C}(\mathbf{e}^{1,2,3}) = \mathcal{C}$. If $N = \{1, 2, 3\}$, then $\mathbf{e}^{1,2,3}$ is an economy with $c_i^{4m} = c_j^{4m}$ for all $i, j \in N$.

By repeating such a procedure up to n , we obtain

$$\mathbf{e}^{(1,\dots,n)} = (M^{1,\dots,n}, (c_i^{2^{n-1}m})_{i \in N}, (\bar{x}, \dots, \bar{x}))$$

with $(\bar{x}, \dots, \bar{x}) \in \mathbb{R}_+^{2^{n-1}m}$ and $\mathcal{C}(\mathbf{e}^{(1,\dots,n)}) = \mathcal{C}$, such that $(c_i^{2^{n-1}m})_{i \in N}$ is an identical profile. ■

Lemma 4: WEE, F, ECI, and INC imply CI.

Proof. Let $\mathcal{C}, \mathcal{C}' \in \Sigma$ be such that $\mathcal{C} \supseteq \mathcal{C}'$ and $F(\mathcal{C}) \cap \mathcal{C}' \neq \emptyset$. Then, there exist $\mathbf{e}_1 = (M, \mathbf{c}^m, \bar{x})$, $\mathbf{e}_2 = (L, \mathbf{c}^l, \bar{y}) \in \mathcal{E}$ such that $\mathcal{C}(\mathbf{e}_1) = \mathcal{C}$ and $\mathcal{C}(\mathbf{e}_2) = \mathcal{C}'$. We will construct two new economies $\mathbf{e}_3 = (S, \mathbf{c}^k, \bar{z})$, $\mathbf{e}_4 = (S, \mathbf{c}^k, \bar{z}') \in \mathcal{E}$ such that $\bar{z} \geq \bar{z}'$, $\mathcal{C}(\mathbf{e}_3) = \mathcal{C}$, and $\mathcal{C}(\mathbf{e}_4) = \mathcal{C}'$. Then, **WEE, F, ECI, and INC** imply that $F(\mathcal{C}') = F(\mathcal{C}) \cap \mathcal{C}'$.

Let S be a set of commodities such that $\#S = s \equiv m + l$. Because $\mathcal{C}(\mathbf{e}_1) \supseteq \mathcal{C}(\mathbf{e}_2)$, for each $\mathbf{C} \in \mathcal{C}(\mathbf{e}_2)$, there exist $\mathbf{x} \in A(\mathbf{e}_1)$ and $\mathbf{y} \in A(\mathbf{e}_2)$ such that $c_i^m(x_i) = C_i = c_i^l(y_i)$ for each $i \in N$. Then, let us construct $\mathbf{c}^* = (c_i^*)_{i \in N}$ as in the proof of **Lemma 1**. Define $\mathbf{e}^* = (S, \mathbf{c}^*, (\bar{x}, \bar{y}))$ with $\mathbf{c}^* = (c_i^*)_{i \in N}$. Then, $\mathcal{C}(\mathbf{e}^*) = \mathcal{C}(\mathbf{e}_2)$ holds. Define also $\hat{\mathbf{e}}_1 = (S, \hat{\mathbf{c}}, (\bar{x}, \bar{y}))$ with $\hat{\mathbf{c}} = (\hat{c}_i)_{i \in N}$, as in the proof of **Lemma 1**. Then, $\mathcal{C}(\hat{\mathbf{e}}_1) = \mathcal{C}(\mathbf{e}_1)$.

Next, exactly as in the proof of **Lemma 1**, define $\hat{\mathbf{e}}^{**} \equiv (S \cup T, \hat{\mathbf{c}}^{**}, (\bar{x}, \bar{y}, (\bar{w}^i)_{i \in N})) \in \mathcal{E}$ with $\hat{\mathbf{c}}^{**} \equiv (\hat{c}_i^{**})_{i \in N}$. Then, $\mathcal{C}(\hat{\mathbf{e}}^{**}) = \mathcal{C}(\mathbf{e}_1)$ holds. Moreover, define another new economy $\mathbf{e}^{**} \equiv (S \cup N, \hat{\mathbf{c}}^{**}, (\bar{x}, \bar{y}, \mathbf{0})) \in \mathcal{E}$ with $\hat{\mathbf{c}}^{**} \equiv (\hat{c}_i^{**})_{i \in N}$. Then, $\mathcal{C}(\mathbf{e}^{**}) = \mathcal{C}(\mathbf{e}_2)$ holds. By **ECI**, we have $\mathbf{c}(\varphi(\mathbf{e}^{**})) = \mathbf{c}(\varphi(\hat{\mathbf{e}}^{**})) \cap \mathcal{C}(\mathbf{e}^{**})$. By **WEE**, **F**, **ECI**, and **INC**, we can apply **Lemma 1**, so that $\mathbf{c}(\varphi(\mathbf{e}^{**})) = \mathbf{c}(\varphi(\mathbf{e}_2))$ and $\mathbf{c}(\varphi(\hat{\mathbf{e}}^{**})) = \mathbf{c}(\varphi(\mathbf{e}_1))$. ■

Proof of Theorem 2. It is easy to check that φ^E satisfies **WEE**, **ES**, **ECI**, **EII**, and **INC**. Suppose that φ satisfies **WEE**, **ES**, **ECI**, **EII**, and **INC**. Then, by **Lemmas 2**, **3**, and **4**, φ attains a bargaining solution which satisfies **WE**, **S**, **CI**, and **II**. By **Theorem 1**, φ attains F^E . ■

5 Discussion and Conclusion

In this paper, we have extended the standard bargaining model to situations in which players are characterized by their opportunity sets rather than by their utilities and in which the fair arbitrator makes the recommendation with the guiding principle of equal opportunity for all players. In such a setting, we have formulated our problems in terms of bargaining problems among players on opportunity assignments, defined the egalitarian solution in our context and studied it axiomatically. Most of the axioms used in our axiomatic characterization of the proposed solutions correspond to their counterparts in standard bargaining models, but formulated either in terms of opportunity assignments or directly in economic environments. We have discussed and commented on the axioms that are unique in our context.

In what follows, we shall present a discussion of our egalitarian solution and make a connection between our egalitarian solution and the notion of equality of opportunity proposed by Roemer (1998).

Structurally, the egalitarian solution of bargaining over opportunity assignments and the standard egalitarian solution to the problems of utility allocations are similar. However, their conceptual implications are quite dif-

ferent.

First, our φ^E attempts to capture the idea of equality of opportunity, whereas the egalitarian solution for the standard bargaining problems is based on the idea of equality of outcome or equality of welfare. The egalitarian principle based on outcomes or welfares has been under critical scrutiny in recent years and rival theories of equality based on opportunities have been advocated by several people. For instance, Sen (1980) proposed equality of capabilities, which requires equalizing opportunities among individuals to realize their functionings, and contrasted and emphasized the difference between equality of outcome in any form and equality of capabilities in their respective performances. Our φ^E can be viewed as a mechanism to implement the idea of equality of capabilities.

Secondly, as we discussed earlier in the Introduction and in Section 2, there are situations in which bargaining problems are about opportunity assignments rather than final outcomes or payoffs of players. In such cases, one plausible guiding principle is “leveling players’ playing fields as much as possible” (Roemer (1998)). This guiding principle does not necessarily guarantee the equalization of players’ final outcomes, and our egalitarian solution is a way to ensure that players have the same playing field. The egalitarian solution to the problems of bargaining over opportunity assignments seems to fit those situations well.

Thirdly, our φ^E does not actually guarantee equal final outcomes for players. To see this, let us consider the situation discussed in **Example 1**. Given an allocation \mathbf{x} recommended by φ^E in an economy $\mathbf{e} = (M, \mathbf{c}^m, \bar{x})$, each individual $i \in N$ is guaranteed to acquire any level of skills within $c_i^m(x_i)$ by devoting his effort appropriately. However, the exact levels of skills he actually acquires depend on his effort level. Suppose that every individual has the common utility function $u(\mathbf{b}, e)$, which is a function of realized skill vector \mathbf{b} and the effort level e . Each individual i chooses his effort level e_i and \mathbf{b}_i in order to maximize $u(\mathbf{b}, e)$ subject to $\mathbf{b} \in c_i^m(x_i)$. Let $v(c_i^m(x_i)) \equiv \max_{\mathbf{b} \in c_i^m(x_i)} u(\mathbf{b}, e)$. The standard egalitarian solution recommends an allocation \mathbf{x}' in order to guarantee $v(c_i^m(x'_i)) = v(c_j^m(x'_j))$ for any $i, j \in N$. On the other hand, φ^E guarantees that, for a given ordering R over opportunity sets, $(c_i^m(x_i), c_j^m(x_j)) \in I$ for any $i, j \in N$, but $[v(c_i^m(x_i)) = v(c_j^m(x_j))]$ may not hold for some individuals $i, j \in N$. Therefore, the recommendation by φ^E is much different from the recommendation of the standard egalitarian solution. In the context of **Example 1**, we be-

lieve that φ^E is more plausible than the standard egalitarian solution. This is because the choices of e_i and \mathbf{b}_i are a matter of personal responsibility, and φ^E delegates this personal responsibility to individual players while the standard egalitarian solution does not.

How is our approach in the paper related to the *theory of equality of opportunity* discussed by Roemer (1998)? There are some differences between our approach in this paper and Roemer's model (1998). For example, for Roemer (1998), the task is to propose a social welfare function that determines the optimal equal opportunity policy, while in this paper, we define and characterize "fair" solutions for bargaining problems based on players' opportunity sets. There are also similarities between our model and Roemer's model. In Roemer (1998), the resource allocation determined by the optimal policy is to guarantee any two individuals the equal opportunity of access to the same level of "advantages" regardless of their "types", if their effort rankings within their own "types" are identical. In our model, an individual's type in the sense of Roemer is reflected in the individual's opportunity correspondence, and a bargaining solution such as F^E determines a resource allocation to guarantee an equitable assignment of opportunities among individuals, under which every individual may access to the same level of living-condition vectors.

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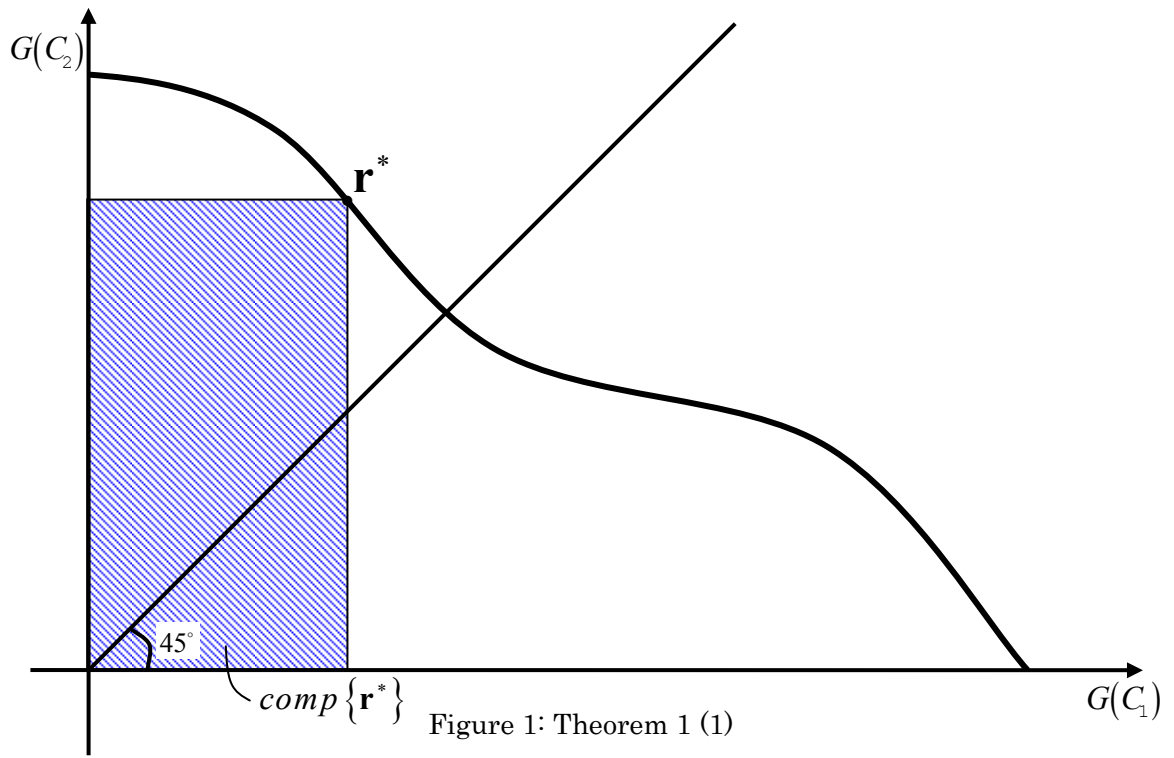
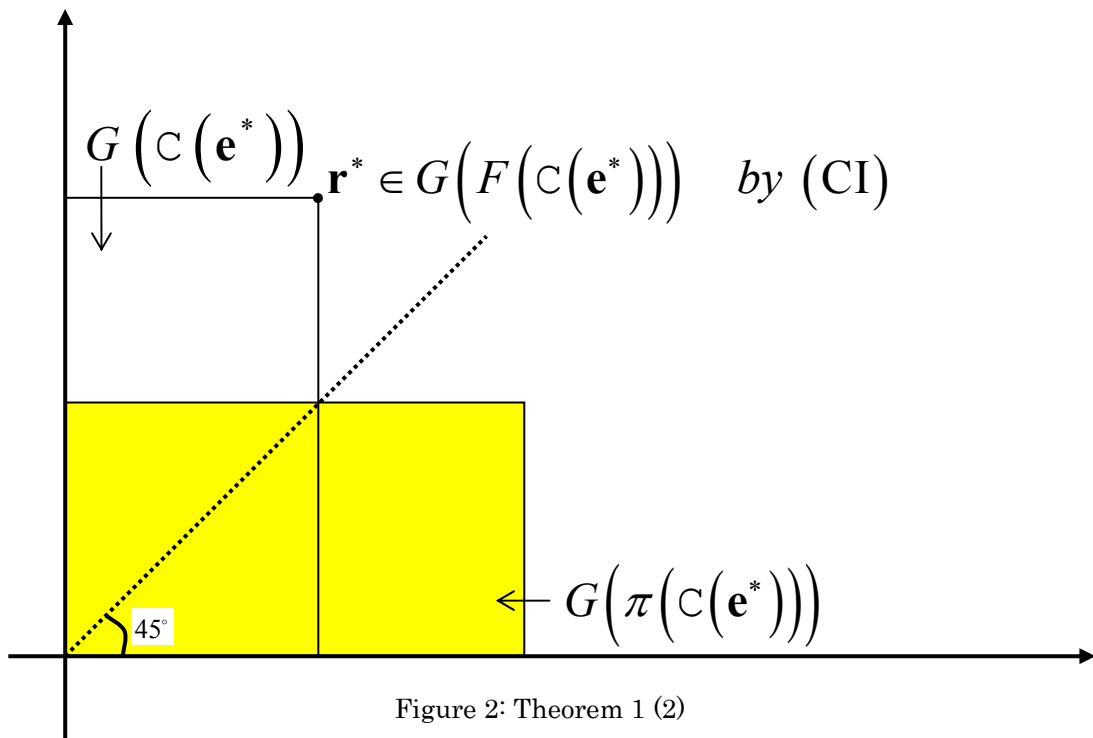


Figure 1: Theorem 1 (1)



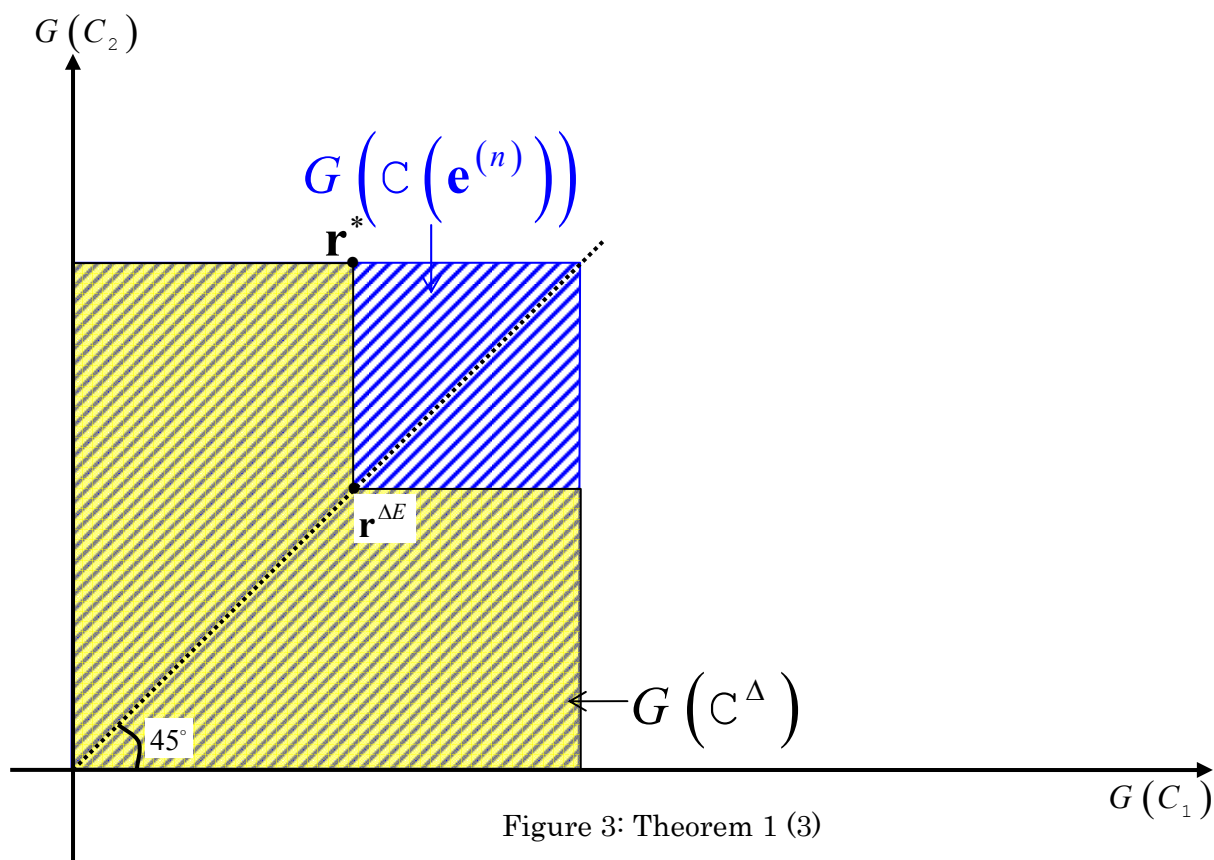


Figure 3: Theorem 1 (3)

