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Alternative axiomatic characterizations of the Shapley and Banzhaf values

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Abstract

In a paper in 1975, Dubey characterized the Shapley-Shubik index axiomatically on the class of monotonic simple games. In 1979, Dubey and Shapley characterized the Banzhaf index in a similar way. This paper extends these characterizations to axiomatic characterizations of the Shapley and Banzhaf values on the class of control games, on the class of simple games and on the class of all transferable utility games. In particular, it is shown that the additivity axiom which is usually used to characterize these values on the class of all transferable utility games can be weakened without changing the result.

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1 Introduction

In a Transferable Utility (TU) game (N, v) as modeled by von Neumann and Morgenstern (1944), N is a finite set of players and the *characteristic* function v is a real valued function assigning to each subset S of N its worth, which is to be interpreted as the maximum gains the *coalition* S can guarantee by cooperating.

In politicology and sociology, TU-games have been used to study various kinds of voting situations. There, typically, the worths of the coalitions are restricted to $\{0, 1\}$. The interpretation is that the coalitions S with worth 1 can decide collectively on the issue under consideration without the help of players outside S. Therefore, these coalitions are called *winning*. TU-games of this kind are called *simple* games and were first considered in von Neumann and Morgenstern (1944). Further studies on simple games are e.g. Shapley-Shubik (1954), Shapley (1962), Banzhaf (1965), Shapley (1967), Dubey (1975), Dubey-Shapley (1979), Peleg (1981), Shapley(1981), Lehrer (1988) and Einy (1988).

In the literature, discussion of simple games is mostly concentrated on monotonic simple games, based on the voting interpretation. However, if the simple games model not only theoretical power but actual power, monotonicity may be lost. For example in parliament, a majoritarian coalition which is composed of people with opposing interests might theoretically form a government, but internal conflict will prevent all bills being passed. At the same time, excluding some members of this coalition might yield a coalition that succeeds in passing bills.

Because traditionally, simple games are used to model voting situations, a solution concept on the class of simple games is also called a power index : it measures the power of a voter. Shapley and Shubik (1954) introduced the Shapley-Shubik index, which is the Shapley value restricted to simple games. Dubey (1975) characterized this index axiomatically on the class of monotonic simple games. Another power index is the Banzhaf index, which was introduced by Banzhaf (1965) and which was characterized axiomatically by Dubey and Shapley (1979), again on the class of monotonic simple games. Einy (1988) extended these axiomatic characterizations to several classes of monotonic TU-games. The proofs of the characterizations on the class of monotonic simple games use *minimal* winning coalitions, i.e. winning coalitions such that every subcoalition is losing. While this concept is natural for monotonic simple games, it is not for nonmonotonic simple games.

In section 2, a different line of proof shows that with axioms similar to those of Dubey (1975), one can characterize the Shapley value on the class of control games, the class of all simple games, and also on the class of all TU-games. With a different efficiency axiom, we also extend the characterization of the Banzhaf value to these classes.

2 Axiomatic characterizations of the Shapley and Banzhaf values

A *simple* game (N, v) is a TU-game in which the range of the characteristic function v is $\{0, 1\}$. A simple game v is completely determined by the set

$$W(v) := \{S \subseteq N \mid v(S) = 1\}$$

of winning coalitions.

This definition of simple games coincides with the one given by Dubey (1975), while a number of authors, among them Von Neuman and Morgenstern (1944) and Shapley (1962) consider only *monotonic* simple games, i.e. simple games (N, v) such that $v(S) \leq v(T)$ for all $S \subseteq T \subseteq N$. Curiel, Derks, and Tijs (1989) used ***control*** games. These are simple games in which the grand coalition N is winning. Note that a non-zero monotonic simple game is a control game.

In the sequel, N will denote an arbitrary but fixed set of players and all games will have N as player set, unless specified otherwise. We often identify the game (N, v) with its characteristic function v. We denote the class of TU-games with player set N by G^N, the class of simple games with player set N by SG^N, the class of control games with player set N by CG^N and the class of monotonic simple games with player set N by MSG^N.

For real numbers a and b, we denote $a \vee b := \max\{a, b\}$, and $a \wedge b := \min\{a, b\}$. For TU-games v, $w \in G^N$, $v \vee w$ and $v \wedge w$ denote the games defined by

$$(v \vee w)(S) := v(S) \vee w(S) \qquad \text{for all } S \subseteq N$$

$$(v \wedge w)(S) := v(S) \wedge w(S) \qquad \text{for all } S \subseteq N.$$

For each of the classes of simple games, control games and monotonic simple games it holds that if v and w are in the class, so are $v \vee w$ and $v \wedge w$.

A *solution concept* or *value* on a class $\mathcal{C}^N \subseteq G^N$ of TU-games is a vector valued function $\psi : \mathcal{C}^N \to \mathbf{R}^N$, assigning the real number $\psi_i(v)$ to each player i in the game $v \in \mathcal{C}^N$.

We proceed by providing some properties of a solution concept on a class $\mathcal{C}^N$.

- A solution ψ is *efficient* if $\sum_{i \in N} \psi_i(v) = v(N)$ for all games $v \in \mathcal{C}^N$.
- A solution ψ is *anonymous* if for all $v \in \mathcal{C}^N$ and for all permutations σ of N such that $\sigma v \in \mathcal{C}^N$,

  $$\psi_{\sigma(i)}(v) = \psi_i(\sigma v) \qquad \text{for all } i \in N,$$

  where the game σv is defined by

  $$\sigma v(S) = v(\sigma(S)) \qquad \text{for all } S \subseteq N.$$

- A *null player* in a game $v \in \mathcal{C}^N$ is a player $i \in N$ such that $v(S) = v(S \setminus \{i\})$ for all $S \subseteq N$ containing i.

  A solution ψ has the *null player property* if $\psi_i(v) = 0$ for all games $v \in \mathcal{C}^N$ with null player i.

- A *carrier* of a game $v \in \mathcal{C}^N$ is a coalition $T \subseteq N$ such that $v(S) = v(S \cap T)$ for all $S \subseteq N$.

  A solution ψ has the *carrier property* if $\sum_{i \in T} \psi_i(v) = v(T)$ for all games $v \in \mathcal{C}^N$ and each carrier T of v.

- A solution ψ has the *transfer* property if

$$\psi(v \vee w) + \psi(v \wedge w) = \psi(v) + \psi(w)$$

for all games $v, w \in \mathcal{C}^N$ such that $v \vee w,\ v \wedge w \in \mathcal{C}^N$.

- A solution is *additive* if

$$\psi(v + w) = \psi(v) + \psi(w)$$

for all games $v, w \in \mathcal{C}^N$ such that $v + w \in \mathcal{C}^N$.

The following should be noted : if $\mathcal{C}_1^N \subseteq \mathcal{C}_2^N$ and a solution ψ satisfies any of the properties named above on $\mathcal{C}_2^N$, it satisfies the property on the class $\mathcal{C}_1^N$ as well. On the class of control games, the additivity property is useless : all control games have a winning grand coalition, hence the sum of two control games is not a control game.

Furthermore, a value which is additive on G^N satisfies the transfer property on G^N and hence also on any subclass. To prove this, take $v, w \in G^N$. Then, using additivity,

$$\begin{aligned} \phi(v \vee w) + \phi(v \wedge w) &= \phi(v \vee w + v \wedge w) \\ &= \phi(v + w) \\ &= \phi(v) + \phi(w). \end{aligned}$$

Finally, we note that the carrier property is equivalent to the efficiency and null player properties together.

A widely studied solution concept is the *Shapley value* ϕ (cf. Shapley (1953)) of a game $v \in G^N$, defined by

$$\phi_i(v) = \sum_{S:i \in S} \frac{|N \setminus S|!\,|S \setminus \{i\}|!}{|N|!}(v(S) - v(S \setminus i))$$

for all $i \in N$. Here, $|S|$ denotes the cardinality of the set S.

It is well known that the Shapley value is efficient, anonymous, additive and satisfies the null player property on G^N and hence on any subclass of G^N. The remark above shows that it satisfies the transfer property on any class of TU-games.

The following theorem generalizes *Theorem II* in Dubey (1975).

Theorem 1 The unique value on the class of control games satisfying efficiency, anonymity, the null player property and the transfer property is the Shapley value.

Proof : It is clear that the Shapley value satisfies the four properties mentioned in the theorem. Suppose a solution concept ψ on satisfies these four properties as well. We prove ψ coincides with the Shapley value ϕ.

First, Dubey (1975) proved that the Shapley value is the unique value on the class of monotonic simple games satisfying anonymity and the carrier and transfer properties. The carrier property is equivalent to efficiency and the null player property combined, hence ψ coincides with the Shapley value on this class.

In order to extend this result to the class of all control games, we introduce the Dirac games δ_S defined by

$$\delta_S(T) = \begin{cases} 1 & \text{if } T = S, \\ 0 & \text{if } T \neq S. \end{cases}$$

Let the control games δ'_S be defined by $\delta'_S = \delta_S + \delta_N$. Note that $(u_S - \delta_S) \vee \delta'_S = u_S$ and $(u_S - \delta_S) \wedge \delta'_S = \delta_N = u_N$ for all $S \subset N$. Using the transfer property and the fact that $u_S - \delta_S$ is a control game we obtain

$$\psi(u_N) + \psi(u_S) = \psi(u_S - \delta_S) + \psi(\delta'_S).$$

$$\begin{aligned} \text{Hence}\quad \psi(\delta'_S) &= \psi(u_N) + \psi(u_S) - \psi(u_S - \delta_S) \\ &\overset{(1)}{=} \phi(u_N) + \phi(u_S) - \phi(u_S - \delta_S) \\ &\overset{(2)}{=} \phi(\delta'_S), \end{aligned}$$

where (1) follows from the monotonicity of u_N, u_S, $u_S - \delta_S$ and coincidence of ψ and ϕ on the class of monotonic simple games, and (2) because the Shapley value ϕ satisfies the transfer property.

Note that any arbitrary control game v can be written

$$v = \bigvee_{T \in W(v)} \delta'_T.$$

We prove $\psi(v) = \phi(v)$ for all $v \in CG^N$ by induction on $|W(v)|$:

- if $|W(v)| = 1$, then $v = u_N$ which is monotonic, hence $\psi(v) = \phi(v)$.
- if $|W(v)| = 2$, then $v = \delta'_T$ for some $T \subset N$, hence $\psi(v) = \phi(v)$.
- Choose $k \geq 2$ and suppose $\psi(v)$ coincides with $\phi(v)$ on all games $v \in CG^N$ with $|W(v)| \leq k$. Take a game v with $|W(v)| = k + 1$, and choose a $T \in W(v) \setminus \{N\}$. Then $v = (v - \delta_T) \vee \delta'_T$, $(v - \delta_T) \wedge \delta'_T = u_N$ and $W(v - \delta_T) = W(v) \setminus \{T\}$, so $|W(v - \delta_T)| = k$. Hence by the transfer axiom and the induction hypothesis

$$\begin{aligned} \psi(v) &= \psi(v - \delta_T) + \psi(\delta'_T) - \psi(u_N) \\ &= \phi(v - \delta_T) + \phi(\delta'_T) - \phi(u_N) \\ &= \phi(v). \end{aligned}$$

This proves the uniqueness of a solution satisfying the four properties on CG^N. □

Along the same lines one can prove

Theorem 2 The unique value on the class of simple games satisfying efficiency, anonymity, the null player property and the transfer property is the Shapley value.

In order to characterize the Shapley value on the class of all TU-games, we first need some lemmas. The zero game in G^N is denoted by $\underline{0}$.

Lemma 3 Let ψ be a solution on G^N satisfying the transfer property, with $\psi(\underline{0}) = 0$. Then for all games $v \in G^N$,

$$\psi(v) = \sum_{S \subseteq N} \psi(v(S)\delta_S). \tag{1}$$

Proof : We prove in three steps that equation (1) holds.

1. For the class of all non-negative games v the proof is by induction on

$$k(v) := |\{S \subseteq N \mid v(S) > 0\}|.$$

(A game v is non-negative if $v(S) \geq 0$ for all $S \subseteq N$.)

   - If $k(v) = 0$ then $v = \underline{0}$ and so $\psi(v) = 0 = \sum_{S \subseteq N} \psi(v(S)\delta_S)$.
   - Take $k > 0$ and suppose equation (1) holds for all non-negative games v with $k(v) < k$. For a non-negative game v with $k(v) = k$, choose a coalition $T \subseteq N$ such that $v(T) > 0$. Then $k(v - v(T)\delta_T) = k - 1$, hence using transfer and the induction hypothesis, we obtain

$$\begin{aligned}
\psi(v) &= \psi[v - v(T)\delta_T] + \psi[v(T)\delta_T] - \psi[(v - v(T)\delta_T) \wedge v(T)\delta_T] \\
&= \sum_{S \subseteq N} \psi[(v - v(T)\delta_T)(S)\,\delta_S] + \psi[v(T)\delta_T] - \psi(\underline{0}) \\
&= \sum_{S \in 2^N \setminus \{T\}} \psi(v(S)\delta_S) + \psi(v(T)\delta_T) \\
&= \sum_{S \subseteq N} \psi(v(S)\delta_S).
\end{aligned}$$

2. For non-positive games one proves analogously (interchanging maxima and minima) that equation (1) holds.

3. For an arbitrary game v, use the transfer property to write

$$\begin{aligned}
\psi(v) &= \psi(v) + \psi(\underline{0}) \\
&= \psi(v \vee \underline{0}) + \psi(v \wedge \underline{0}) \\
&= \sum_{S \subseteq N} [\psi((v \vee \underline{0})(S)\delta_S) + \psi((v \wedge \underline{0})(S)\delta_S)] \\
&= \sum_{S \subseteq N} \psi(v(S)\delta_S).
\end{aligned}$$

Hence equation (1) holds for all TU-games. □

Remark The converse is also true : If a solution concept ψ on G^N satisfies equation (1) for all games $v \in G^N$ then ψ satisfies the transfer property and $\psi(\underline{0}) = 0$.

While lemma 3 shows that a solution concept satisfying the transfer property is determined by its value on multiples of Dirac games, the next lemma shows it is also determined by its values on multiples of unanimity games.

Lemma 4 Let N be fixed. Suppose for each $S \in 2^N \setminus \{\emptyset\}$ and for each real number α, a vector $\psi_{\alpha,S} \in \mathbf{R}^N$ is given, satisfying $\psi_{0,S} = 0$ for all $S \in 2^N \setminus \{\emptyset\}$. Then there exists a unique solution concept on G^N satisfying the transfer property, such that

$$\psi(\alpha u_S) = \psi_{\alpha,S} \qquad \text{for all } \alpha \in \mathbf{R}, \text{ and all } S \in 2^N \setminus \{\emptyset\}. \tag{2}$$

Proof : First we prove unicity. Suppose there exists a solution ψ satisfying equation (2) and the transfer property. Then $\psi(\underline{0}) = \psi(0u_N) = \psi_{0,N} = 0$. Hence according to lemma 3, equation (1) holds, and applying it to the game αu_S, we obtain

$$\psi_{\alpha,S} = \psi(\alpha u_S) = \sum_{T:T\supseteq S} \psi(\alpha\delta_T) \qquad \text{for all } \alpha \in \mathbf{R}, \text{ for all } S \in 2^N \setminus \{\emptyset\}. \tag{3}$$

For each fixed α this finite system of linear equations (with variables $\psi_{\alpha,S}$ and $\psi(\alpha\delta_S)$, $S \in 2^N \setminus \{\emptyset\}$) is easily inversed, yielding

$$\psi(\alpha\delta_T) = \sum_{S:S\supseteq T} (-1)^{|S\setminus T|} \psi_{\alpha,S} \qquad \text{for all } \alpha \in \mathbf{R} \text{ and all } T \in 2^N \setminus \{\emptyset\}. \tag{4}$$

Hence by equation (1),

$$\psi(v) = \sum_{T\subseteq N} \sum_{S:S\supseteq T} (-1)^{|S\setminus T|} \psi_{v(T),S} \qquad \text{for all TU-games } v, \tag{5}$$

which implies ψ is unique.

This construction of ψ proves existence as well : given the numbers $\psi_{\alpha,S}$ for all $\alpha \in \mathbf{R}$ and $S \in 2^N \setminus \{\emptyset\}$, construct a solution ψ first on Dirac games, using equation (4) and then on all TU-games using equation (1). This solution ψ will then satisfy equation (1), hence it satisfies the transfer axiom. It also satisfies equation (2), so it is the solution concept asked for. □

Using this lemma, we now prove

Theorem 5 The Shapley value is the unique value on G^N satisfying efficiency, anonymity, the null player property and the transfer property.

Proof : We already noted that the Shapley value satisfies the four properties. To prove uniqueness, let ψ be a value that satisfies the four properties mentioned. Consider a game of the form αu_S. By the null player property, $\psi_i(\alpha u_S) = 0$ if i is not a member of S, and by anonymity, all players in S obtain the same payoff. Hence,

$$\psi_i(\alpha u_S) = \begin{cases} 0 & \text{if } i \notin S \\ x & \text{if } i \in S \end{cases}$$

for some real number x. Efficiency then yields $|S|x = \alpha u_S(N) = \alpha$ and $x = \alpha/|S|$. Hence ψ is determined on multiples of unanimity games, $\psi(0u_S) = 0$ for all nonempty coalitions S, and lemma 4 implies uniqueness. □

Another solution concept is the *Banzhaf* value η (cf. Banzhaf (1965), Owen (1975)), defined on G^N by

$$\eta_i(v) = \sum_{S\ni i} [v(S) - v(S\setminus i)]$$

for all $i \in N$. It is easily seen that the Banzhaf value satisfies anonymity, additivity and the null player property. Being additive, it satisfies the transfer property as well. Note that it does not satisfy efficiency. Define $\bar{\eta}(v) := \sum_{i \in N} \eta_i(v)$. Now the characterization by Dubey and Shapley (1979) of the Banzhaf value on the class of monotonic simple games can be extended to characterizations on the class of all simple games and the class of all TU-games. Along similar lines as theorems 1, 2 and 5 one can show

Theorem 6

1. The Banzhaf value is the unique value ψ on CG^N satisfying anonymity, the null player property and the transfer property such that

$$\sum_{i \in N} \psi_i(v) = \bar{\eta}(v) \qquad \text{for all } v. \tag{6}$$

2. The Banzhaf value is the unique value ψ on SG^N satisfying anonymity, the null player property, the transfer property and (6).

3. The Banzhaf value is the unique value ψ on G^N satisfying anonymity, the null player property, the transfer property and (6).

References

Banzhaf JF III (1965) 'Weighted voting doesn't work : a mathematical analysis'. *Rutgers Law Review* 19, 317–343.

Curiel IJ, Derks J, and Tijs SH (1989) 'On balanced games and games with committee control'. *OR Spectrum* 11, 83–88.

Dubey P (1975) 'On the uniqueness of the Shapley value'. *Int. J. of Game Theory* 4, 131–139.

Dubey P, and Shapley LS (1979) 'Mathematical properties of the Banzhaf power index'. *Math. Oper. Res.* 4, 99–131.

Einy E (1988) 'The Shapley value on some lattices of monotonic games'. *Math. Social Sciences* 15, 1–10.

Lehrer E (1988) 'An axiomatization of the Banzhaf value'. *Int. J. of Game Theory* 17, 89–99.

Neumann J von, and Morgenstern O (1944) Theory of games and economic behavior. Princeton University Press, Princeton.

Owen G (1975) 'Multilinear extensions and the Banzhaf value'. *Naval Res. Logist. Quart.* 22, 741–750.

Peleg B (1981) 'Coalition formation in simple games with dominant players'. *Int. J. of Game Theory* 10, 11–33.

Shapley LS (1953) 'A value for n-person games'. *Annals of Mathematical Studies* 28, 307–317.

Shapley LS (1962) 'Simple games : an outline of the descriptive theory'. *Behavioral Science* 7, 59–66.

Shapley LS (1967) 'On committees'. In : New methods of thought and procedure. (Eds. Zwicky and Wilson) . Springer New York, 246–270.

Shapley LS (1981) 'Measurement of power in political systems'. *Proceedings of Symposia in Applied Mathematics* 24, 69–81.

Shapley LS, and Shubik M (1954) 'A method for evaluating the distribution of power in a committee system'. *American Political Science Review* 48, 787-792.

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