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"Estimating Noncooperative and Cooperative Models of Bargaining: An Empirical Comparison"

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Estimating Noncooperative and Cooperative Models of Bargaining: An Empirical Comparison

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Abstract

This paper examines the issue of model selection in studies of strategic situations. In particular, we compare estimation results from Adachi and Watanabe's (2008) noncooperative formulation of government formulation with those from two alternative cooperative formulations. Although the estimates of the ministerial ranking are similar, statistical testing suggests that Adachi and Watanabe's (2008) noncooperative formulation is best fitted to the observed data among the alternative models. This result implies that modeling the time structure in bargaining situations is crucially important at the risk of possibly misspecifying the details of the game.

Keywords: Model Selection; Bargaining; Government Formation; Structural Estimation.
JEL classification: C52; C71; C72: C78; H19.

1 Introduction

There have been two major game-theoretic approaches to modeling bargaining situations. As Osborne and Rubinstein (1994, pp.255-6, emphasis added) state, "a *coalitional* model is distinguished from a *noncooperative* model primarily by its focus on what groups of players can achieve rather than what individual players can do and by the fact that it does not consider the details of how groups of players function internally." Moreover, Osborne and Rubinstein (1994, p.256) emphasize that either of the two approaches should not be viewed as superior or more basic, and that "each of them reflects different kinds of strategic considerations and contributes to our understanding of strategic reasoning."

Although it seems that researchers must remain agnostic *a priori* about which approach is better, it is possible and interesting to *empirically* compare cooperative and noncooperative formuations. In the present paper, we study the issue of model

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seletion for bargaining games by using observed data from government formation. In particular, we compare estimation results from two alternative cooperative formulations with those of Adachi and Watanane (2008), who use a noncooperative bargaining model. Our primary focus is to obtain parameter estimates of relative ministerial weights in parliamentary democracies in Japan. This issue is related to an important question in political economics: *how do ministerial posts differ in their importance?* We argue that Adachi and Watanabe's (2008) bargaining formulation has a better fit than do cooperative formulations.

Among a number of solution concepts of cooperative games, the Shapley value gives us one specific set of payments for coalition members, which are deemed fair. In this study, we use the Shapley and Shubik (1954) solution concept, a modified version of the Shapley value, as well as a more familiar concept by Nash (1950). It is verified that the relative weight for the Prime Minister is estimated *lower* based on our cooperative bargaining models, although the estimates of the ministerial ranking are similar to Adachi and Watanabe's (2008) result. It is verified that Adachi and Watanabe's (2008) noncooperative model has the best fit to the observed data, although statistical testing does not reject either formulation.

Our result implies that modeling the time structure in bargaining situations would be crucially important at the risk of possibly misspecifying the details of the game. Simultaneuously, one must remember that this result holds in a specific situation with specific data. It would be natural that one expects that cooperative games give better results because they do not depend on the details of the timings and rules of government formation. In other situations with different data (such as household allocation and wage bargaining), the cooperative fomulation might perform better.

The rest of the paper is organized as follows. Section 2 explains our cooperative formulation of government formulation. We consider two solution concepts: the Nash solution and the Shapley-Shubik power index. Following econometric specification being presented in Section 3, we show empirical results in Section 4. We present likelihood ratio tests to compare our two formulations with Adachi and Watanabe's (2008) noncooperative formulation. In addition, we consider the modified Shapley-Shubik Index. Section 5 concludes the paper.

2 Cooperative Formulations of Government Formation

We model government formation as a bargaining game $\Gamma(\theta)$, where θ denotes a vector of model parameters. Throughout the paper, we consider a complete information environment. Thus, each element in θ is observable to all of the players in the game. Let $N = \{1, .., n\}$ be the set of political parties (players) that bargain over the surplus (normalized to 1) from government formation, and let $v = (v_1, ..., v_n)$ be the vector of players' payoffs ($\sum_{i=1}^{n} v_i \leq 1$). We describe below two alternative predictions of v (written as v^*) from cooperative formulations as well as from Adachi and Watanabe's (2008) noncooperative formulations.

2.1 The Nash Solution

The Nash solution $v = (v_1, ..., v_n)$ is the solution that maximizes the product of the difference in each player's payoff when the negotiation is agreed on and when it breaks down. More formally, it is obtained by solving

$$\max_{v} \prod_{i=1}^{n} (v_i - c_i)^{p_i}, \tag{1}$$

where v_i is player i's payoff when the negotiation is agreed on, and c_i is that when the negotiation breaks down, where $v_i > c_i$ for any $i = 1, ..., n$. Player i's bargaining power is captured by $p_i > 0$ because the Nash solution concept is axiomatically constructed, and thus is free of negotiation procedure.[1]

Proposition 1 *The Nash solution is characterized by*

$$\frac{v_1 - c_1}{p_1} = \cdots = \frac{v_n - c_n}{p_n}.$$

Proof. See Appendix A1. ■

An important issue here is how to set $c = (c_1, ..., c_n)$. When a symmetric two-person Nash solution is analyzed, the maxmin values or the Nash equilibrium is customarily set as a breakdown point. However, such good ways do not exist to model the breakdown situation in the analysis of asymmetric n-person Nash solution. In our study, we assume that the breakdown point is where each party obtains payoff zero, because, for example, the party breaks down. Thus, $c = (0, ..., 0)$.

We further assume that player i's bargaining power is given by

$$p_i = \frac{w_i \exp(\alpha w_i)}{\sum_{l=1}^{n} w_l \exp(\alpha w_l)},$$

where w_i captures the "relative dominance" of player i, and $\alpha \geq 0$ captures the scale effect (if $\alpha > 0$, bargaining powers of players with (relatively) larger w_i are more than proportional to w_i). This assumption is based on Gamson (1961), which is also used by Adachi and Watanabe (2008) (see subsection 2.3 below). In estimation, party i's proportion of seats in the parliament at the time of government formation is used for w_i as data. By inserting $c_i = 0$ and p_i into the solution in Proposition 1, we obtain player i's payoff in the Nash solution as

$$v_i^* = v_i^{NS}(w; \alpha) \equiv \frac{w_i \exp(\alpha w_i)}{\sum_{l=1}^{n} w_l \exp(\alpha w_l)},$$

where $w = (w_1, ..., w_n)$, for each $i = 1, 2, ..., n$. Notice that the sum of payoffs is 1 ($\sum_{i=1}^{n} v_i^* = 1$) due to the normalization.

[1] The research question of what kind of negotiation process yields the Nash solution has been extensively studied in the research program "Nash Program." Although Rubinstein (1982) proposes such a process in two-person bargaining games, it remains unclear what kind of negotiation process yields the Nash solution in a general n-person bargaining games. See Okada (2010) for a noncooperative foundation for the Nash solution and Okada (2007) for its application.

2.2 The Shapley-Shubik Power Index

We call a set $S \subseteq N$ that is formed for a joint action a *coalition*. We define coalition S's payoff from their joint action by $v(S)$. The function $v(\cdot)$ is called a *characteristic function*. A game expressed by the set of players, N, and the characteristic function v is called a characteristic function form game, (N, v).

A characteristic function form game, (N, v), where the characteristic function of any coalition S takes value 0 or 1 is called a *voting game*. Coalition S is called a *winning coalition* if the alternative that all players in coalition S vote for is passed. The collection of all such S's is denoted by W. If the alternative voted by a coalition is not passed, the coalition is called a *losing coalition* (the collection is denoted by L). These relationships are succinctly summarized as

$$v(S) = \begin{cases} 1 \text{ if } S \subseteq W \\ 0 \text{ otherwise.} \end{cases}$$

The Shapley-Shubik power index is the application by Shapley and Shubik (1954) of the Shapley value (Shapley (1953)) to the voting game.[2] Let S' be a losing coalition. After player (voter) i is added, the coalition S' becomes $S' \cup \{i\}$.[3] If the coalition $S' \cup \{i\}$ is a winning coalition, then player i is the one who changes the losing coalition to the winning coalition. Such a player i is called a *pivotal voter*. The number of the permutation $N = \{1, 2, ..., n\}$ is $n!$. The expectation of player i being pivotal if each permutation is assumed to occur with the same probability is called the *Shapley-Shubik index*. It is given by

$$v_i^* = v_i^{SS}(w) \equiv \frac{1}{n!} \sum_{\substack{S \in W \\ S \setminus \{i\} \in L}} (s-1)! \times (n-s)!,$$

where $s = |S|$ and $n = |N|$. In practice, it is computationally burdensome to calculate the Shapley-Shubik power index. We use Tomoki Matsui's website[4] that displays the work of Matsui and Matsui (1998). We assume that the Lower House majority is attained by members of the Liberal Democratic Party (LDP).[5] In Subsection 4.5, we consider the case of the majority within the Lower House as a robustness check.

The Shapley-Shubik power index is frequently interpreted as the influence a voter exercises in an election. In our studies, however, this index should be interpreted as the Shapley value with the characteristic function taking the value either zero or one. The Shapley value is an ex-ante evaluation of how much payoff a player gains in each game. Similarly, the index is an ex-ante evaluation of how much each player gains in each voting game. Essentially, each party ex-ante predicts that it will receive the payoff that corresponds to the Shapley-Shubik index from a voting game (e.g., a presidential election in the LDP).

[2] See Hu (2006) for an extension of the Shapley-Shubik power index.

[3] Note that a voter here is a party. Considering the reality, it would be more natural that a member of parliament, not a party, has a vote. We assume a hypothetical situation where each party as a whole decides on its vote, binding its members' decisions.

[4] The page's URL is: http://hpcgi2.nifty.com/TOMOMI/index-e.cgi (retrieved: December 2011).

[5] Because the LDP attained a majority in the Lower House during the period of this study, this assumption is natural. See Appendix A of Adachi and Watanabe (2008) for details.

2.3 Adachi and Watanabe's (2008) Noncooperative Formulation

In contrast to the present study, Adachi and Watanabe (2008) propose a non-cooperative bargaining game of government formulation a là Baron and Ferejohn (1989).[6] First, player i is (randomly or nonrandomly) selected as a proposer. Player i, then, proposes a ministerial allocation and a monetary transfer to all other players. Each non-proposer independently agrees or disagrees with the proposal. If all non-proposers unanimously agree with it, then the bargaining game ends. However, if at least one non-proposer disagrees, then the bargaining moves on to the next stage, where a new proposer is *randomly* selected. The game continues in the same manner until the agreement is made. Adachi and Watanabe (2008) assume round-by-round time discounting, and the time discount factor is denoted by $\delta \in [0, 1)$. The recognition probability of player j that is selected as a proposer is specified by

$$\frac{w_j \exp(\alpha w_j)}{\sum_{l=1}^{n} w_l \exp(\alpha w_l)}.$$

Then, as a direct application of Eraslan's (2002) result, proposer i's equilibrium payoff is *unique* and it is given by

$$v_i^* = v_i^{AWp}(w; \alpha, \delta) \equiv 1 - \sum_{j \neq i} \delta \frac{w_j \exp(\alpha w_j)}{\sum_{l=1}^{n} w_l \exp(\alpha w_l)},$$

while non-proposer j's equilibrium payoff is also unique and it is given by

$$v_j^* = v_j^{AWn}(w; \alpha, \delta) \equiv \delta \frac{w_j \exp(\alpha w_j)}{\sum_{l=1}^{n} w_l \exp(\alpha w_l)}.$$

3 Econometric Specification

Now, we decompose player i's payoff (unobservable to researchers), v_i^*, into the part related to an observable (to researchers) part and an unobservable part. Basically, the difference between the payoff evaluation and the payoff that each party gains from allocation of ministerial weights is treated as the residual term. We thus employ the following specification:

$$v_i^* = x_i' \beta + \epsilon_i$$

where $x_i = [x_{i1}, ..., x_{ik}]'$ denotes player i's ministerial allocation, $\beta = [\beta_1, \ldots, \beta_k]'$ is the vector of *ministerial weights*, and ϵ_i is the monetary transfer (possibly negative) that player i obtains. Naturally, x_{ij} is a dummy variable that takes 1 (if player i obtains the post of minister j) or 0 (otherwise). We normalize the ministerial weights by assuming that $\sum_{j=1}^{k} \beta_j = 1$ and $0 \leq \beta_j \leq 1$. We further assume that the vector of monetary transfers satisfies $\sum_{i=1}^{n} \epsilon_i = 0$, signifying that the budget must balance among the players. From these assumptions, we have $\sum_{i=1}^{n} v_i = 1$. A natural imposition on player i's payoff is that it must be nonnegative: $v_i \geq 0$. Thus, $-1 \leq \varepsilon_i \leq 1$ for any player i.

[6] See, e.g., Okada (2011) for a recent extension of Baron and Ferejohn's (1989) model. Ray (2007) is an excellent survey of the noncooperative theory for coalition formation.

3.1 Data

The data set used for this study is the same as in Adachi and Watanabe (2008) with the following two additions: (1) numbers of diet members in each faction (player) for each government formation and (2) majority quotas at the time of each government formation. These two pieces of information are used for estimation of the Shapley-Shubik formulation. It is fairly natural to assume that a player in the game during this period was from each faction in the LDP.[7] The sample covers the ministerial allocation in the period from 1958 to 1993, when the LDP maintained a majority in the House of Representatives.

3.2 Maximum Likelihood Estimation

We assume that ε_i is (indipendently and identically) distributed according to the beta distribution of the first kind with a mean of zero. With the beta distribution, one can set the upper and lower bounds for the random variable, in contrast to the normal distribution that allows infinite values. Remember that the primitive and the normalization impose these restrictions on the range of ε_i. According to McDonald (1984, p.648 (2) or p.662 (A7)), its density function is given by

$$f(\epsilon_{i,t}|b,p,q) = \frac{\epsilon_{i,t}^{p-1}(1-(\epsilon_{i,t}/b))^{q-1}}{b^p B(p,q)} \quad \text{for } 0 \leq \epsilon_{i,t} \leq b$$

and zero otherwise, where $B(p,q)$ is the beta function:

$$B(p,q) = \int_0^1 u^{p-1}\,(1-u)^{q-1}\,du.$$

We assume $p = q \equiv \sigma$ because we have no reason to believe that the distribution is skewed in either way (here, $p = q$ implies symmetry of the density). Now we have

$$f(\epsilon_{i,t}|b,\sigma) = \frac{\epsilon_{i,t}^{\sigma-1}(b-\epsilon_{i,t})^{\sigma-1}}{b^{2\sigma-1}Beta(\sigma,\sigma)} \quad \text{for } 0 \leq \epsilon_{i,t} \leq b$$

and zero otherwise.[8] Note that we need to modify the above densify because the support is $[-1,1]$ in our case. To do so, we first set $b = 2$, and replace ϵ_i by $\epsilon_i + 1$ (with abuse of notation) that yields

$$f(\epsilon_{i,t}|\sigma) = \frac{(1+\epsilon_{i,t})^{\sigma-1}(1-\epsilon_{i,t})^{\sigma-1}}{2^{2\sigma-1}Beta(\sigma,\sigma)} \quad \text{for } -1 \leq \epsilon_{i,t} \leq 1$$

[7] See Adachi and Watanabe (2008) for a discussion of this assumption. Leiserson (1968) analyzes coalition formation during the early period of the LDP using cooperative game theory.

[8] See also McDonald (1984, p.653 (14)). We believe that there is a typo in equation (14); $p+q$ in the denominator should be $p+q-1$.

and zero otherwise. From the independence assumption, the log likelihood function for $\epsilon = (\epsilon_{i,t})$ is given by

$$
\begin{aligned}
L(\theta) &= \log \prod_{t=1}^{T} \prod_{i=1}^{n(t)-1} f(\epsilon_{i,t};\theta) \\
&= \sum_{t=1}^{T} \sum_{i=1}^{n(t)-1} \log \frac{(1+\epsilon_{i,t})^{\sigma-1}(1-\epsilon_{i,t})^{\sigma-1}}{2^{2\sigma-1} Beta(\sigma,\sigma)} \\
&= \sum_{t=1}^{T} \sum_{i=1}^{n(t)-1} \{(\sigma-1)\left[\log(1+\epsilon_{i,t}) + \log(1-\epsilon_{i,t})\right] \\
&\qquad\qquad - (2\sigma-1)\log 2 - \log Beta(\sigma,\sigma)\},
\end{aligned}
$$

where θ is the parameter vector, and $\epsilon_{i,t} = v^*_{i,t}(w; parameter) - x'_{i,t}\beta$ is plugged.[9,10]

3.3 Relationship of the Three Models

Notice that v^* under the Nash solution is a special case of Adachi and Watanane's (2008) formulation with $\delta = 1$. That is, the Nash formulation is *nested* in Adachi and Watanabe's (2008) model. The difference between the Shapley-Shubik formulation and the other two models is that the data generating processes for v^* are (nonparametrically) different. That is, the Shapley-Shubik model and the Adachi and Watanabe's (2008) model are *nonnested*.[11]

4 Empirical Results

4.1 Parameter Estimates

The estimation results are presented in Table 1[12], and Figure 1 is a graphical summary of estimiated ministerial ranking in the three formulations. The estimates in col-

[9] Remember that in the SS formulation $v^*_i(w; parameter)$ is not parameterized.

[10] In the actual estimation of the noncooperative game, we use

$$f(\epsilon'_{i,t};\sigma) = \frac{(1/\delta + \epsilon'_{i,t})^{\sigma-1}(1/\delta - \epsilon'_{i,t})^{\sigma-1}}{(2/\delta)^{2\sigma-1} Beta(\sigma,\sigma)} \quad \text{for } -1/\delta \le \epsilon'_{i,t} \le 1/\delta$$

and zero otherwise, where

$$\epsilon'_{i,t} = \frac{v^*_i(w) - x'_{i,t}\beta}{\delta},$$

to avoid the result with $\widehat{\delta} = 0$.

[11] Hart and Mas-Colell (1996); Laruelle and Valenciano (2008); Miyakawa (2008), Britz, Herings, and Predtetchinski (2010); and Predtetchinski (2011), among others, study the asymptotic coincidence of a noncorporative equilibrium to a cooperative solution. In particular, stationary subgame perfect equilibria in a n-player game where a proposer drops from the game with a small probability if the agreement is not reached converge to asymmetric Nash solution with each player's recognition probability being his or her power index.

[12] As in Adachi and Watanabe (2008), the standard errors are calculated using the bootstrap method.

umn "AW (2008)" are the same as those reported in Adachi and Watanabe (2008).[13] Remember that the two cooperative formulations do not take into account the time discount factor (δ). As we discuss below, the estimates of the ministerial ranking are similar in the three models. In particular, the Nash formulation has an indetical ranking as that of Adachi and Watanabe (2008). However, the estimate of the relative weight of the Prime Minister (25.2%) is double those in the cooperative models (10.5% in both formulations). This difference arises presumably because while Adachi and Watanabe (2008) use the *ex-post* information after government formation, namely, the proposer (i.e., the Prime Minister's faction) to estimate the relative ministerial weights, both of our cooperative bargaining models do not use that information. Thus, Adachi and Watanabe's (2008) non-cooperative bargaining model captures "formateur advantage."

Table 2 ranks the ministers in highest to lowest order. Notice that the ranking of the four highest ministers (Prime Minister and Ministers of Transport, Construction, and Economic Planning) is common to all three models (Prime Minister, Transport, Construction, and Economic Planning). Thus, one of the main findings in Adachi and Watanabe (2008) that pork-related posts such as the Ministers of Construction and Transport had high values is relatively robust to the change in the formulation of bargaining. In addition, the estimated relative rankings of the Ministers of Foreign Affairs and Justice, which were considered as prestigious positions for senior politicians, are ranked low as in Adachi and Watanabe (2008).

[13] Notice that the values of log likelihood in Table 1 are positive. In Adachi and Watanabe (2008), it is incorrectly reported as the negative value. The reported estimates in Adachi and Watanabe (2008) are modified by Adachi and Watanabe (2010): the latter reestimated the model with the corrected data.

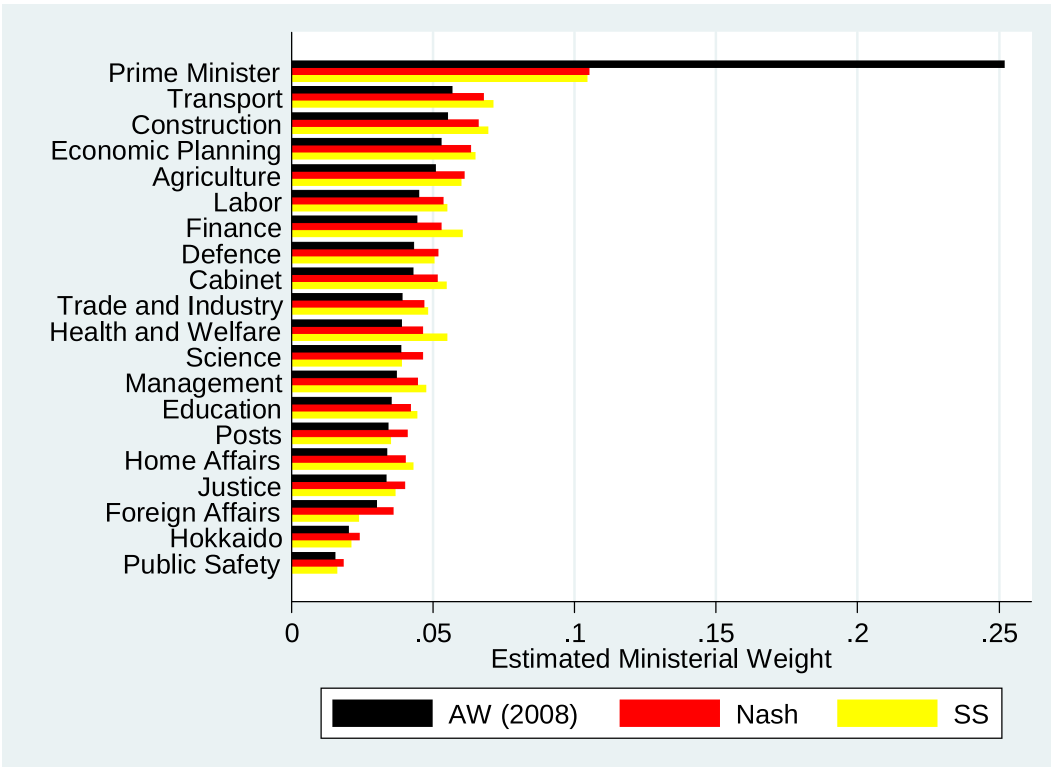

Figure 1: Estimated ministerial ranking.

	AW (2008)	Nash	Shapley-Shubik
Prime Minister	0.2519	0.1052	0.1045
	(0.0524)	(0.0223)	(0.0255)
Foreign Affairs	0.0301	0.0360	0.0238
	(0.0069)	(0.0078)	(0.0077)
Home Affairs	0.0338	0.0404	0.0430
	(0.0116)	(0.0138)	(0.0131)
Finance	0.0443	0.0529	0.0604
	(0.0085)	(0.0091)	(0.0083)
Justice	0.0335	0.0400	0.0367
	(0.0060)	(0.0079)	(0.0073)
Education	0.0353	0.0422	0.0444
	(0.0074)	(0.0090)	(0.0081)
Health and Welfare	0.0389	0.0465	0.0549
	(0.0071)	(0.0079)	(0.0078)
Agriculture	0.0510	0.0610	0.0599
	(0.0057)	(0.0067)	(0.0055)
International Trade and Industry	0.0391	0.0468	0.0481
	(0.0077)	(0.0093)	(0.0096)
Transport	0.0567	0.0678	0.0712
	(0.0073)	(0.0076)	(0.0068)
Posts and Telecommunications	0.0343	0.0410	0.0351
	(0.0063)	(0.0076)	(0.0084)
Labor	0.0451	0.0540	0.0550
	(0.0062)	(0.0082)	(0.0066)
Construction	0.0552	0.0660	0.0694
	(0.0098)	(0.0111)	(0.0110)
Management and Coordination	0.0372	0.0445	0.0476
	(0.0073)	(0.0081)	(0.0088)
Economic Planning	0.0530	0.0634	0.0649
	(0.0087)	(0.0102)	(0.0091)
Hokkaido Development	0.0201	0.0240	0.0211
	(0.0073)	(0.0086)	(0.0091)
National Public Safety	0.0154	0.0184	0.0162
	(0.0116)	(0.0138)	(0.0131)
Defence	0.0433	0.0518	0.0504
	(0.0071)	(0.0083)	(0.0092)
Science and Technology	0.0388	0.0465	0.0390
	(0.0080)	(0.0092)	(0.0095)
Cabinet Secretary	0.0430	0.0516	0.0547
	(0.0212)	(0.0212)	(0.0247)
Disturbance (σ)	377.9132	264.0860	229.1852
	(26.7977)	(27.6005)	(23.2149)
Scale Effect (α)	0.0004	-0.0018	-
	(0.4862)	(0.5595)	
Time Discounting (δ)	0.8361	-	-
	(0.0491)		
Log Likelihood	636.9577	636.9105	610.6515

Table 1: Parameter estimates and standard errors (in parentheses).

Rank	AW (2008)	Nash	Shapley-Shubik
1	Prime Minister	Prime Minister	Prime Minister
2	Transport	Transport	Transport
3	Construction	Construction	Construction
4	Economic Planning	Economic Planning	Economic Planning
5	Agriculture	Agriculture	Finance
6	Labor	Labor	Agriculture
7	Finance	Finance	Labor
8	Defence	Defence	Health and Welfare
9	Cabinet Secretary	Cabinet Secretary	Cabinet Secretary
10	International Trade and Industry	International Trade and Industry	Defence
11	Health and Welfare	Health and Welfare	International Trade and Industry
12	Science and Technology	Science and Technology	Management and Coordination
13	Management and Coordination	Management and Coordination	Education
14	Education	Education	Home Affairs
15	Posts and Telecommunications	Posts and Telecommunications	Science and Technology
16	Home Affairs	Home Affairs	Justice
17	Justice	Justice	Posts and Telecommunications
18	Foreign Affairs	Foreign Affairs	Foreign Affairs
19	Hokkaido Development	Hokkaido Development	Hokkaido Development
20	National Public Safety	National Public Safety	National Public Safety

Table 2: Comparison of the ministerial ranking reported in Adachi and Watanabe (2008), and the Nash and the Shapley-Shubik.

4.2 Statistical Comparison

Remember that the Nash model is nested in the sense that it corresponds to the case of $\delta = 1$ in the noncooperative model of Adachi and Watanabe (2008). We thus apply the likelihood ratio test to compare Adachi and Watanabe with Nash. The likelihood ratio statistic $LR = 2[L(\widehat{\theta}^{AW}) - L(\widehat{\theta}^{NS})]$ is, under the hypothesis that $\delta = 1$ is a correctly specified restriction, asymptotically distributed according to the chi-square distribution with the degree of freedom being one (the number of parametric constraints).[14] Because the value for LR is $2 \times (636.9577 - 636.9105) = 0.0944$,[15] the restriction "$\delta = 1$" on Adachi and Watanabe's (2008) model is not rejected.

Next, we compare Adachi and Watanabe with Shapley and Shubik. We apply Vuong's (1989) test[16] because the two models are nonnested. Let observation t's contribution to the log likelihood function under Adachi and Watanabe be defined by $L_{t,AW}(\widehat{\theta}^{AW})$, and that under Shapley and Shubik by $L_{t,SS}(\widehat{\theta}^{SS})$. Then, Vuong's (1989) static,

$$V = \frac{\sqrt{T}\left(\frac{1}{T}\sum_{t=1}^{T}(L_{t,SS}(\widehat{\theta}^{SS}) - L_{t,AW}(\widehat{\theta}^{AW}))\right)}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(\{L_{t,SS}(\widehat{\theta}^{SS}) - L_{t,AW}(\widehat{\theta}^{AW})\} - M)^2}}$$

is asymptotically distributed according to $N(0,1)$, where

$$M = \frac{1}{T}\sum_{t=1}^{T}\left(L_{t,SS}(\widehat{\theta}^{SS}) - L_{t,AW}(\widehat{\theta}^{AW})\right).$$

Because the value for V is calculated as -0.3490, the two models are "equivalent" in the sense that neither model is rejected.

4.3 The Shapley-Shubik Index in Case of the Lower House Majority

In this subsection, we make a modification to the Shapley-Shubik concept. The formulation we have employed till now assumes that the consensus over government formation is made (i.e., the value of the characteristic function becomes 1) if the majority is attained *within* the LDP members. Instead, we assume below that the consensus is made if the majority is attained within all *parliamentary* members. Table 3 shows the results.

[14] See, e.g., Wooldridge (2010, p.481).

[15] The chi square values at different significance levels are given by:

Significance Level	10%	5%	1%
Chi Square	2.7055	3.8415	6.6349

[16] See, e.g., Greene (2008, pp.140-142) and Wooldridge (2010, pp.505-509).

To compare the modified Shapley-Shubik formulation with the original Shapley-Shubik formulation, we can calculate Vuong's (1989) statistic. Because the (absolute) value of Vuong's (1989) statistic is 0.3408, neither model is rejected.

	SS (Party)	SS (Parliament)
Prime Minister	0.1045 (0.0255)	0.1259 (0.0404)
Foreign Affairs	0.0238 (0.0077)	0.0584 (0.0103)
Home Affairs	0.043 (0.0131)	0.0482 (0.0159)
Finance	0.0604 (0.0083)	0.0581 (0.0115)
Justice	0.0367 (0.0073)	0.0292 (0.0083)
Education	0.0444 (0.0081)	0.0412 (0.0091)
Health and Welfare	0.0549 (0.0078)	0.0395 (0.0103)
Agriculture	0.0599 (0.0055)	0.0598 (0.0089)
International Trade and Industry	0.0481 (0.0096)	0.0503 (0.0104)
Transport	0.0712 (0.0068)	0.0679 (0.0098)
Posts and Telecommunications	0.0351 (0.0084)	0.0344 (0.0098)
Labor	0.055 (0.0066)	0.0537 (0.0094)
Construction	0.0694 (0.0110)	0.0732 (0.0123)
Management and Coordination	0.0476 (0.0088)	0.0368 (0.0106)
Economic Planning	0.0649 (0.0091)	0.0681 (0.0129)
Hokkaido Development	0.0211 (0.0091)	0.0188 (0.0115)
National Public Safety	0.0162 (0.0131)	0.0052 (0.0138)
Defence	0.0504 (0.0092)	0.0519 (0.0112)
Science and Technology	0.039 (0.0095)	0.0484 (0.0119)
Cabinet Secretary	0.0544 (0.0247)	0.031 (0.0350)
σ	229.1669 (23.2149)	155.7914 (15.1616)
Log Likelihood	610.648	539.2502

Table 3: Comparison of the parameter estimates from the two formulations of the Shapley-Shubik (Party Majority and Parliament Majority).

	Nash	SS (Party)	SS (Parliament)
1	Prime Minister	Prime Minister	Prime Minister
2	Transport	Transport	Construction
3	Construction	Construction	Economic Planning
4	Economic Planning	Economic Planning	Transport
5	Agriculture	Finance	Agriculture
6	Labor	Agriculture	Foreign Affairs
7	Finance	Labor	Finance
8	Defence	Health and Welfare	Labor
9	Cabinet Secretary	Cabinet Secretary	Defence
10	International Trade and Industry	Defence	International Trade and Industry
11	Health and Welfare	International Trade and Industry	Science and Technology
12	Science and Technology	Management and Coordination	Home Affairs
13	Management and Coordination	Education	Education
14	Education	Home Affairs	Health and Welfare
15	Posts and Telecommunications	Science and Technology	Management and Coordination
16	Home Affairs	Justice	Posts and Telecommunications
17	Justice	Posts and Telecommunications	Cabinet Secretary
18	Foreign Affairs	Foreign Affairs	Justice
19	Hokkaido Development	Hokkaido Development	Hokkaido Development
20	National Public Safety	National Public Safety	National Public Safety

Table 4: Comparison of the ministerial ranking reported in the Nash and the two formulations of the Shapley-Shubik (Party Majority and Parliament Majority).

Table 4 shows that the rank of the Minister of Foreign Affairs rises (from the 18th to the 6th) probably because that the Minister was often selected from the pool of senior LDP politicians, and thus its selection may be less affected by the change in the distribution of bargaining power. Table 5 shows the correlation coefficients between the Nash solution and the Shapley-Shubik power index, between the Shapley-Shubik power index and the modified Shapley-Shubik power index, and between the Nash solution and the modified Shapley-Shubik power index. The modified Shapley-Shubik power index coefficients, in particular, are apparently much different in cabinets No.26-28 (Ohira) and No.33-35 (Nakasone).

Cabinet Number	Nash & SS (party)	SS (party) & SS (parliament)	Nash & SS (parliament)
No.1-4	0.993	0.980	0.991
No.5-8	0.998	0.988	0.994
No.9-14	0.998	0.988	0.993
No.15-17	0.997	0.960	0.966
No.18-19	0.999	0.996	0.995
No.20	0.997	0.982	0.969
No,21-25	0.997	0.964	0.959
No.26-28	0.996	0.396	0.439
No.29	0.992	0.891	0.885
No.30-32	0.992	0.891	0.885
No.33-35	0.975	0.269	0.336
No.36	0.949	0.777	0.910
No.37-40	0.947	0.707	0.882
No.41-44	0.960	0.834	0.955

Table 5: The correlation coefficients between two solutions concepts for each cabinet.

5 Concluding Remarks

This paper structurally estimate different cooperative games of government formation. In contrast to the previous results of Adachi and Watanabe (2008) who formulate the problem as a non-cooperative multilateral sequential infinite-horizon bargaining game by Baron and Ferejohn (1989), we consider the Nash solution concept, the Shapley-Shubik power index and its modified version. We obtain estimates of the relative ministerial weights in the period between 1958 and 1993 in Japan. It is found that Adachi and Watanabe's (2008) noncooperative model has the best fit to the observed data, although statistical testing does not reject either formulation. In addition, it is verified that the relative weight for the Prime Minister is estimated lower on the basis of our cooperative bargaining models, although the estimates of the ministerial ranking are similar in Adachi and Watanabe's (2008) non-cooperative model and the three cooperative formulations.

To consider our results from a different angle, Table 6 shows that the estimated relative weights of selected ministers for each cooperative game when the value of the National Public Safety is normalized to be one. $0.0301/0.0154 = 1.9545$

	AW (2008)	Nash	SS (Party)	SS (Parliament)
Prime Minister	16.4	4.4	6.5	24.2
Construction	3.6	4.0	4.3	14.1
Finance	2.8	3.1	3.7	11.2
Foreign Affairs	2.0	1.9	1.5	11.2
National Public Safety	1.0	1.0	1.0	1.0

Table 6: Weights of selected ministers relative to the National Public Safety.

Notice that the weight of the Minister of Foreign Affairs is estimated high in the modified Shapley-Shubik power index, which has the least log likelihood value. Tables 7-9 compare the same selected ministers with each other for each of the three formulations. Table 7 shows that if the weight of the Minister is normalized to be one, the relative weight of the Prime Minister is 2.4 and that of the Minister of Construction is 2.1. However, Table 8 illustrates that the relative weight of the Prime Minister is 1.5 with the Shapley-Shubik power index. As Table 9 depicts, by modifying the Shapley-Shubik power index, we have the weight of the Minister of Foreign Affairs close to that of the Minister of Finance. The weight of the Minister of Construction remains high: 1.3 times the weights of the Ministers of Foreign Affairs and Finance. The Prime Minister has a value 1.7 times that of the Minister of Construction.

	PM	C	F	FA	NPS
Prime Minister	1.0	1.1	1.4	2.4	4.4
Construction	-	1.0	1.3	2.1	4.0
Finance	-	-	1.0	1.7	3.1
Foreign Affairs	-	-	-	1.0	1.9
National Public Safety	-	-	-	-	1.0

Table 7: Comparison of relative weights of selected ministers (Nash).

	PM	C	F	FA	NPS
Prime Minister	1.0	1.5	1.7	4.4	6.5
Construction	-	1.0	1.1	2.9	4.3
Finance	-	-	1.0	2.5	3.7
Foreign Affairs	-	-	-	1.0	1.5
National Public Safety	-	-	-	-	1.0

Table 8: Comparison of relative weights of selected ministers (Shapley-Shubik (Party Majority)).

	PM	C	FA	F	NPS
Prime Minister	1.0	1.7	2.2	2.2	24.2
Construction	-	1.0	1.3	1.3	14.1
Foreign Affairs	-	-	1.0	1.0	11.2
Finance	-	-	-	1.0	11.2
National Public Safety	-	-	-	-	1.0

Table 9: Comparison of relative weights of selected ministers (Shapley-Shubik (Parliament Majority)).

Finally, the remaining issues include: applying other solution concepts such as the nucleolus to estimation, and using other data from other parliamentary democracies. These and other interesting issues on government formation are left for future research.

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Appendices

A.1 Proof of Proposition 1

Notice first that

$$\begin{aligned} & \max_v \prod_{i=1}^{n} (v_i - c_i)^{p_i} \\ \Leftrightarrow \quad & \max_v \sum_{i=1}^{n} p_i \log(v_i - c_i). \end{aligned}$$

Using the normalization $\sum_{i=1}^{n} v_i = 1$, we can rewrite expression (1) as

$$\max_v \sum_{i=1}^{n-1} p_i \log(v_i - c_i) + p_n \log(1 - \sum_{i=1}^{n-1} v_i - c_n)$$

By solving this maximization problem, we have

$$\frac{\partial}{\partial v_i}\left(\sum_{i=1}^{n-1} p_i \log(v_i - c_i) + p_n \log(1 - \sum_{i=1}^{n-1} - c_n)\right) = 0,$$

which leads to the desired result:

$$\frac{v_i - c_i}{p_i} - \frac{v_n - c_n}{p_n} = 0$$

for each $i = 1, .., n - 1$.

A.2 Data

For the allocation data, see the dataset that is to be available online.

Faction	Number of Members	Nash	SS (party)	SS (parliament)
Sato->Tanaka	42	0.14094	0.13700	0.13294
Ikeda	38	0.12752	0.13056	0.12698
Ohno	44	0.14765	0.15198	0.15079
Ishida	21	0.07047	0.07698	0.07341
Kishi	56	0.18792	0.19841	0.18651
IB	15	0.05034	0.05198	0.03770
Kono	36	0.12081	0.11627	0.12698
Miki	35	0.11745	0.11270	0.12698
X	11	0.93691	0.02341	0.03771

Table A1: Cabinets 1 to 4

Faction	Number of Members	Nash	SS (party)	SS (parliament)
ST	46	0.15333	0.16071	0.15556
Ikeda	54	0.18000	0.19246	0.17341
Ohno	28	0.09333	0.09087	0.09603
Ishida	18	0.06000	0.05873	0.04643
Kishi	45	0.15000	0.15754	0.15556
FJ	34	0.11333	0.10952	0.11786
IB	5	0.01667	0.00913	0.02063
Kohno	34	0.11333	0.10952	0.11786
Miki	28	0.09333	0.09087	0.09603
X	8	0.02667	0.02063	0.02063

Table A2: Cabinets 5 to 8

Faction	Number of Members	Nash	SS (party)	SS (parliament)
Sato	46	0.15646	0.16190	0.15437
Ikeda	50	0.17007	0.17698	0.16825
Ohno	29	0.09864	0.09206	0.10079
Ishida	14	0.04762	0.04048	0.03929
Kishi	25	0.08503	0.08254	0.09286
KW	20	0.06803	0.06508	0.07500
FJ	20	0.06803	0.06508	0.07500
Kohno	46	0.15646	0.16190	0.15437
Miki	36	0.12245	0.12619	0.12262
X	8	0.02721	0.02778	0.01745

Table A3: Cabinets 9 to 14

Faction	Number of Members	Nash	SS (party)	SS (parliament)
Sato	53	0.18929	0.20692	0.19398
Ikeda	44	0.15714	0.16496	0.19398
Ohno	14	0.05000	0.04642	0.03893
MR	10	0.03571	0.03231	0.02933
Ishida	16	0.05714	0.05450	0.04095
Kishi	28	0.10000	0.09822	0.09398
KW	18	0.06429	0.06172	0.04347
FJ	16	0.05714	0.05450	0.04095
Kohno	24	0.08571	0.08029	0.08489
MO	14	0.05000	0.04642	0.03893
Miki	37	0.13214	0.13174	0.19398
MT	4	0.01429	0.01460	0.00559
X	2	0.00714	0.00739	0.00104

Table A4: Cabinets 15 to 17

Faction	Number of Members	Nash	SS (party)	SS (parliament)
ST	53	0.17667	0.19246	0.17833
IK	44	0.14667	0.15339	0.14550
Ohno	14	0.04667	0.04423	0.05087
MR	10	0.03333	0.02991	0.03320
Ishida	16	0.05333	0.04946	0.05939
Kishi	38	0.12667	0.12919	0.11621
KW	19	0.06333	0.05873	0.06999
FJ	6	0.02000	0.01829	0.02461
Kohno	35	0.11667	0.11703	0.10206
MO	13	0.04333	0.04012	0.04734
Miki	40	0.13333	0.13705	0.12732
MT	3	0.01000	0.00909	0.01577
X	7	0.02333	0.02103	0.02890

Table A5: Cabinets 18 to 19

Faction	Number of Members	Nash	SS (party)	SS (parliament)
Sato/Tanaka	44	0.14667	0.14935	0.13860
IK	43	0.14333	0.14776	0.13860
Ohno	10	0.03333	0.02951	0.02471
MR	16	0.05333	0.04935	0.05527
Ishida	12	0.04000	0.03506	0.03027
Kishi	65	0.21667	0.24141	0.27471
KW	17	0.05667	0.05173	0.05804
FJ	2	0.00667	0.00411	0.00725
Kohno	34	0.11333	0.11284	0.09138
Miki	38	0.12667	0.12157	0.11082
X	19	0.06333	0.05729	0.07035

Table A6: Cabinet 20

Faction	Number of Members	Nash	SS (party)	SS (parliament)
ST	48	0.16901	0.17763	0.20985
IK	45	0.15845	0.16136	0.20985
Ohno	9	0.03169	0.02565	0.02334
MR	13	0.04577	0.04390	0.03128
Ishida	9	0.03169	0.02565	0.02334
Kishi	56	0.19718	0.21255	0.20985
KW	18	0.06338	0.04787	0.03128
FJ	2	0.00704	0.00898	0.01818
Kohno	38	0.13380	0.13795	0.10985
Miki	37	0.13028	0.13279	0.10985
X	9	0.03169	0.02565	0.02333

Table A7: Cabinets 21 to 25

Faction	Number of Members	Nash	SS (party)	SS (parliament)
Sato/Tanaka	45	0.17308	0.18214	**0.11111**
Ikeda	39	0.15000	0.15754	**0.11111**
Ohno	8	0.03077	0.02421	**0.11111**
MR	11	0.04231	0.03373	**0.11111**
Ishida	4	0.01538	0.01230	**0.00001**
Kishi/Fukuda	53	0.20385	0.22421	**0.11111**
KW	11	0.04231	0.03373	**0.11111**
Kohno	39	0.15000	0.15754	**0.11111**
Miki	32	0.12308	0.12659	**0.11111**
X	18	0.06923	0.04802	**0.11111**

Table A8: Cabinets 26 to 28

Faction	Number of Members	Nash	SS (party)	SS (parliament)
Sato/Tanaka	52	0.20155	0.20667	**0.10910**
Ikeda/Ohira	50	0.19380	0.20072	**0.10909**
Ohno	4	0.01550	0.00786	**0.10909**
MR	5	0.01938	0.01144	**0.10909**
Ishida	2	0.00775	0.00390	**0.00909**
Kishi/Fukuda	49	0.18992	0.19834	**0.10909**
NG	10	0.03876	0.02215	**0.10909**
KW	2	0.00775	0.00390	**0.00909**
Kohno	41	0.15891	0.16144	**0.10909**
Miki	31	0.12016	0.16144	**0.10909**
X	12	0.04651	0.02215	**0.10909**

Table A9: Cabinet 29

Faction	Number of Members	Nash	SS (party)	SS (parliament)
Sato/Tanaka	64	0.22300	0.22381	0.19048
Ikeda/Ohira/Suzuki	63	0.21951	0.22381	0.19048
MR	3	0.01045	0.02857	0.00000
Kishi/Fukuda	46	0.16028	0.15714	0.19048
NG	11	0.03833	0.02857	0.02380
Kohno	47	0.16376	0.15714	0.19048
Miki	32	0.11150	0.11905	0.19048
X	21	0.07317	0.06190	0.02380

Table A10: Cabinets 30 to 32

Faction	Number of Members	Nash	SS (party)	SS (parliament)
Sato/Tanaka	68	0.25468	0.29286	**0.12500**
Ikeda/Ohira/Suzuki	52	0.19476	0.18095	**0.12500**
Kishi/Fukuda	43	0.16105	0.14048	**0.12500**
NG	6	0.02247	0.02143	**0.12500**
Kono/Nakasone	49	0.18352	0.17143	**0.12500**
Miki	21	0.07865	0.10000	**0.12500**
SJ	8	0.02996	0.02857	**0.12500**
X	13	0.04869	0.06428	**0.12500**

Table A11: Cabinets 33 to 35

Faction	Number of Members	Nash	SS (party)	SS (parliament)
Sato/Tanaka	87	0.28065	0.30000	**0.25000**
Ikeda/Ohira/Suzuki	59	0.19032	0.16667	**0.25000**
Kishi/Fukuda	56	0.18065	0.16667	**0.25000**
Kono/Nakasone	60	0.19355	0.16667	**0.25000**
Miki	28	0.09032	0.10000	**0.00000**
SJ	6	0.01935	0.00000	**0.00000**
X	14	0.04516	0.10000	**0.00000**

Table A12: Cabinet 36

Faction	Number of Members	Nash	SS (party)	SS (parliament)
Sato/Tanaka/Takeshita	87	0.28065	0.30000	**0.25000**
Ikeda/Ohira/Suzuki	59	0.19032	0.16667	**0.25000**
Kishi/Fukuda	56	0.18065	0.16667	**0.25000**
Kono/Nakasone	60	0.19355	0.16667	**0.25000**
Miki	28	0.09032	0.10000	**0.00000**
X	20	0.06452	0.10000	**0.00000**

Table A13: Cabinets 37 to 40

Faction	Number of Members	Nash	SS (party)	SS (parliament)
ST	69	0.24126	0.25714	0.23333
NK	4	0.01399	0.00714	0.00000
IK	62	0.21678	0.20714	0.23333
Kishi/Fukuda	61	0.21329	0.20714	0.23333
Kohno/Nakasone/Uno	48	0.16783	0.12381	0.23333
Miki/Kaifu	26	0.09091	0.12381	0.03334
X	16	0.05594	0.07381	0.03334

Table A14: Cabinets 41 to 44