International Journal of Social Science Studies
Vol. 4, No. 8; August 2016
ISSN 2324-8033 E-ISSN 2324-8041
Published by Redfame Publishing
URL: http://ijsss.redfame.com

Verification of the Japanese Government’s Level of Utility with Respect to Defense: Creation and Measurement of an MAI-I Model (Note 1)

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Received: June 6, 2016 Accepted: June 22, 2016 Available online: July 4, 2016

doi:10.11114/ijsss.v4i8.1716 URL: http://dx.doi.org/10.11114/ijsss.v4i8.1716

Abstract

In Japan very little empirical security research has been conducted using economic theory. This is because the utility maximization and profit maximization on which economic theory is based are considered to be difficult to apply to security research. The authors have created a model for utilizing economic theory, which so far has been difficult to apply to the economic analysis of security, which they call the MAI-I model.

This model has the following features.

First, when performing analysis using utility functions, it uses government utility functions and assumes the use of cardinal utility which can accurately measure utility levels. The utility function in this paper, therefore, makes it possible to accurately measure the utility level of past Cabinets with respect to defense.

Second, in order to accurately measure utility the precision of utility functions must be increased. In economic theory, for the purpose of greater measurement convenience, utility functions are assumed to be 1st-order homogenous functions. This paper does not make that assumption. Instead, it assumes the function is a μ-order homogenous function and creates a model for use in cardinal utility measurement. The utility function includes μ in its power, but measurement was made possible by using it as an MAI-I model.

This produced the following results.

First, it was possible to measure the μ value of the μ-order homogenous function, necessary to measure the utility level of the Japanese government with regard to defense. It was found that the function was a 1.1079-order homogenous function. This indicated that the Japanese government has, for a long time, implemented security policy with a defense expenditure budget of less than 1% of the GDP, and restrained their utility even though it will largely grow if they will increase defense equipments and personnels.

Second, this utility function could then be used to calculate the government's cardinal utility. This cardinal utility was said to be impossible to measure accurately, but assuming the function is a μ-order homogenous function, it was possible to utilize Japanese defense data to perform measurement. In other words, for the Cabinets which actually focused on security policy, the policies were reflected in actual utility level measurements, indicating that the MAI-I model created in this paper can be used for economic analysis of security. The ability to use the utility functions of this paper to accurately measure utility levels of past Cabinets with regard to defense is a successful quantification of Japan's defense history.

Last, the paper indicated future potential for use of the model in analyzing utility from a variety of perspectives.

Keywords: MAI-I model, Past Cabinets with regard to defense, defense expenditure, Estimating the CES-Utility Function, System-Wide Approach

1. Introduction

1.1 Overview and Objectives

In Japan very little empirical security research has been conducted using economic theory. This is because the utility maximization and profit maximization on which economic theory is based are considered to be difficult to apply to security research. Another reason is that in Japan security studies and economics have been handled as separate research fields. However, research which integrates the two approaches has been gradually developed in the West since the 1960s under the name "defense economics."

The objective of this paper is to use this new perspective of defense economics to connect the security studies and economics approaches. Specifically, in Japanese security policy it has been unclear what exactly utility means, and what profit means, so this paper will create a new Japanese defense indicator that serves as an indicator of utility. Until now Japanese defense indicators have consisted solely of overall figures, limited by simple base 10 restrictions, such as defense expenditures accounting for 1% or less of GDP. This figure, stating that defense expenditure accounts for 1% or less of GDP, has not effectively conveyed to the people the level of defense the government has wished to achieve. This paper will develop a method for calculating Japan's defense indicator, and define a new corresponding indicator. It will serve as a quantitative indicator of how eager the government has been regarding security policy by visualizing how much past Cabinets have focused on security policy.

1.2 The MAI-I Model

The economic model created in this paper is called the "MAI-I model." This model is notable, first, because it makes it possible to apply economic theory to verification and analysis, which has been difficult with actual economic analysis in the past. This model focuses on a perspective which combines security studies and economics approaches. Second, applying this model makes it possible not only to measure ordinal utility, but cardinal utility as well. Accurately measuring utility broadens the range of potential applications to various economic fields, and this model is notable for serving as a model of defense economics. Not only is utility used as existing data, but it can be quantitatively calculated with the MAI-I model. It has been difficult to quantify the mentality and psychology of people and organizations in the past, but this model makes it possible to accurately estimate them. This paper makes it possible to measure the eagerness of the government with respect to defense, which has not been possible in the security research field in the past, and visualizes this eagerness. This paper presents the optimal model for considering the level of government utility with regard to defense.

1.3 Previous Research

Sandler and Hartley (1995) wrote a paper whose objective was to "apply economic analysis tools to issues of defense, arms limitations, conversion of military related technology to civilian use, and peace" (introduction). The essential nature of defense economics is the use of tools such as economics theory and verification analysis to analyze security issues. It is focused on economic issues which are not normally handled in peace research, such as weapon expenditure trends, defense policy, and war (conflict), including military expansion and defense expenditures.

Recent leading research looking at Japanese defense from the perspective of defense economics includes research by Ando (2015) which uses an autoregression distribution lag model (ADL model) to verify, from both short-term and long-term perspectives, whether U.S. defense contributes to Japanese defense. Ando's inferential results are that Japanese defense expenditures have maintained a stable relationship with estimated U.S.-side variables. That is, it does fulfil a role, and Japan did, within the estimated period, cooperate with the U.S. Ando performed econometric analysis of Japanese defense expenditures from a macroeconomics vantage, but did not go as far as indicating "utility" with regard to Japanese defense from a clear economic theory standpoint.

Leading economic theory-based research includes that of Theil (1980a) (1980b). Measurement of cardinal utility requires the elimination of linear homogeneous assumptions from the utility function. However, it is not easy to empirically calculate the value of the elasticity of scale (μ) to substitute for linear homogeneity. Theil's system-wide approach theory made this possible. However, Theil did not realize this development potential, so this paper develops the potential of that characteristics to produce a new model.

Mizuno (1998) applied Theil's system-wide approach theory, actually estimating a cardinal utility function for dietary meat, but did not go as far as extending its scope to a wider range of fields, such as the security research that is examined in this paper. This paper will serve as the first step in applying this theory to other research fields for which it has been difficult to apply economic theory in the past.

2. The MAI-I Model

2.1 Estimating the CES-Utility Function

The MAI-I model assumes that utility is cardinal. Based on this, it creates a utility function for defense, and performs inference with this utility function. This section defines the CES-utility function. One of the features of the MAI-I model is that it does not define a 1st-order homogenous utility function, but a μ-order homogenous utility function. In other words, it can be used with general cases where the elasticity of scale is not 1. A 1st-order homogenous function can only be used to perform formal ordinal utility calculation. A μ-order homogenous utility function can be used to perform cardinal utility calculation, which is considered capable of accurate calculation, such as when utility is gradually increasing or gradually decreasing.

The following utility function is used to calculate utility. It is notable for including μ within the power. A μ-order homogenous function is used for the utility function to make it possible to measure cardinal utility so that psychological degree can be calculated accurately.

$$u = (\alpha_1 q_1{}^{-\beta} + \alpha_2 q_2{}^{-\beta})^{-\frac{\mu}{\beta}} \tag{1}$$

q_1: Defense equipment

In actuality, determined from national defense budget and the costs of personnel and provisions

q_2: Total actual number of self-defense force officials

p_1: Cost of defense equipment

government bond yield

Reason: Actual government funds are paid for by the issuing of government bonds

p_2: Costs of personnel and provisions per person

We do not assume $\alpha_1+\alpha_2=1$, and $\alpha_1<1, \alpha_2<1$.

Here, u is interpreted as follows. The leading element in the utility function is the government. In other words, with regard to defense the government consumes defense equipment and personnel. The utility derived here does not refer to citizens' utility but government utility. The utility level determined with these calculations indicates the utility of the government with respect to defense.

u: Utility of the government with respect to defense

2.2 Procedure for Estimating the CES-Utility Function

The first step in estimating the CES-utility function is estimating the following demand function. The figures needed to derive the estimated values for each CES-utility function parameter function can be calculated. The following formula can be used to calculate values other than μ for the μ-order homogenous function.

$$\boldsymbol{\frac{p_2}{p_1} = a\left(\frac{q_2}{q_1}\right)^{b}} \tag{2}$$

Data and estimation period: 1986 to 2013

This demand function estimates by converting Formula (2) into a log function.

$$\ln\frac{p_2}{p_1} = \ln a + b\ln\frac{q_2}{q_1} \tag{3}$$

The estimation results of Formula (2)' are as follows.

$$\ln\frac{p_2}{p_1} = 0.1105 + 0.1090\ln\frac{q_2}{q_1} \quad \text{-(2)''}$$

$$(14.3688) \quad (3.7405)$$

$$R^2 = 0.3498$$

Formula (2)" produces persuasive estimation results, although the coefficient of determination is not high. Looking at the t value in parentheses, the level of significance for each variable is 1%, indicating that each result is also persuasive.

Parameters a and b for Formula (2) can therefore both be determined. Using these values to perform calculations while indicating the correspondence relationships for each CES-utility function parameter produces the following results.

$$a = 1.1168$$

$$b = 0.1090$$

$$\alpha_1 = 1/(b+1) = 0.9017$$
$$\alpha_2 = a/(b+1) = 1.0070$$
$$\beta = -(b+1) = -1.1090 \tag{3}$$

Estimate values for the majority of the parameters in Formula (1) have now been determined.

2.3 System-Wide Approach Estimation (=Estimation of Elasticity of Scale)

The only missing parameter required for calculation using Formula (1), parameter μ (elasticity of scale, μ-order homogenous function) is determined using the system-wide approach theory described in Theil (1980a) (1980b). The theoretical demand formula is expressed as a differential demand equation relative price formula.

$$w_1 \mathrm{dln} q_1 = \theta_1 \mathrm{dln} Q + \phi\theta_{11} \mathrm{dln}\frac{p_1}{p_F} + \phi\theta_{12} \mathrm{dln}\frac{p_2}{p_F}$$
$$w_2 \mathrm{dln} q_2 = \theta_2 \mathrm{dln} Q + \phi\theta_{21} \mathrm{dln}\frac{p_1}{p_F} + \phi\theta_{22} \mathrm{dln}\frac{p_2}{p_F} \tag{4}$$

In Formula (4) $\mathrm{dln}p_F=\theta_1\ \mathrm{dln}p_1+\theta_2\ \mathrm{dln}p_2$ is the Frish price index and dlnQ is the Divisia quantity index, expressed as $\mathrm{dln}Q=w_1\ \mathrm{dln}q_1+w_2\ \mathrm{dln}q_2$.Φ represents income elasticity. Here, w_i (i=1,2) represents the budget share (the percentage share of each good of the total budget) and θ_{ij} (i=1,2, j=1,2) represents the limit share (the ratio of increase of the percentage share of each good when the budget increases). Limitations include the fact that, as shown below, these values must add up to 1.

$$w_1 + w_2 = 1$$
$$\theta_1 + \theta_2 = 1$$

With regard to budget share, each item must be greater than 0 and smaller than 1, but when interest is used as a value, given past negative interest rates, this limitation may not always apply (Note 2). The limit share does not have the same limitation as the budget share, requiring each value to be greater than 0 and less than 1, so negative values may also exist.

Actual estimation is performed using the following absolute price form. This has the same value as the relative price.

$$w_1 \mathrm{dln} q_1 = \theta_1 \mathrm{dln} Q + \pi_{11} \mathrm{dln} p_1 + \pi_{12} \mathrm{dln} p_2$$
$$\Leftrightarrow \ w_1 \mathrm{dln} q_1 = \theta_1 \mathrm{dln} Q + \pi_{11}(\mathrm{dln} p_1 - \mathrm{dln} p_2) \tag{5}$$

Here, the following limitation applies to $\pi 11$ and $\pi 12$ in Formula (5).

$$\pi_{11} + \pi_{12} = 0$$
$$\pi_{21} + \pi_{22} = 0$$
$$\pi_{12} = \pi_{21} \tag{6}$$

Due to this limitation, there is no need to use the equation to perform estimation for two goods, and all included parameters can be calculated based on this limitation.

The following formulas also hold.

$$\pi_{11} = \phi(\theta_{11} - \theta_1^2)$$
$$\pi_{12} = \phi(\theta_{12} - \theta_1\theta_2)$$
$$\pi_{21} = \phi(\theta_{21} - \theta_2\theta_1)$$
$$\pi_{22} = \phi(\theta_{22} - \theta_2^2) \tag{7}$$

Given the limitations that apply to Formulas (6) and (7), as with Theil (1980b), assuming a standard distribution of error values, Formula (5) is estimated using OLS (Note 3).

The estimation results of Formula (5) are as follows. The estimation period is 1986 to 2013(Note 4).

$$w_1 \mathrm{dln} q_1 = \underset{(2.8213)}{0.2478} \mathrm{dln} Q - \underset{(-1.9206)}{0.0923}(\mathrm{dln} p_1 - \mathrm{dln} p_2)$$
$$R^2 = 0.5189$$

$$\theta_1 = 0.2478$$
$$\pi_{11} = -0.0923$$

Calculating each parameter, using the above limitations and an income elasticity value of ϕ=-0.5 produces Table 1 below (Note 5).

Table 1. System-Wide Approach Parameter Estimated Values

$\theta_2 = 1 - \theta_1 = 0.7522$			
π_{11}	-0.0923	θ_{11}	0.2460
π_{12}	0.0923	θ_{12}	0.0018
π_{21}	0.0923	θ_{21}	0.0018
π_{22}	-0.0923	θ_{22}	0.7504

From Table 1 it is possible to determine elasticity of scale μ, which corresponds to n for the n-th order homogeneous CES-utility function.

$$\mu = (\beta + 1)\frac{\theta_{12}}{\theta_1\theta_2} - \beta = 1.1079$$

The value of the elasticity of scale, μ, was 1.1079. In other words, this shows that Japan's defense utility can be expressed as a 1.1079-order homogenous function. The utility in this paper refers to government utility, so this indicates that the Japanese government has, for a long time, implemented security policy with a defense expenditure budget of less than 1% of the GDP, and restrained their utility even though it will largely grow if they will increase defense equipments and personnels (Note 6).

3. Visualization of a New Indicator

3.1 Calculation of Cardinal Utility

The government's past cardinal utility with regard to defense was calculated by substituting the data used for estimation into the CES-utility function. The growth rate was also calculated (Note 7). Figure 1 shows the government's cardinal utility with regard to defense, and Figure 2 shows the growth rate. Looking at Figure 1, the government's cardinal utility with regard to defense rose until 2003, fell slightly from 2004 to 2009, and rose thereafter. Figure 2 shows that the growth rate has repeatedly risen and fallen, with its peak in 1987. In recent years it has risen from 2011 to 2013.

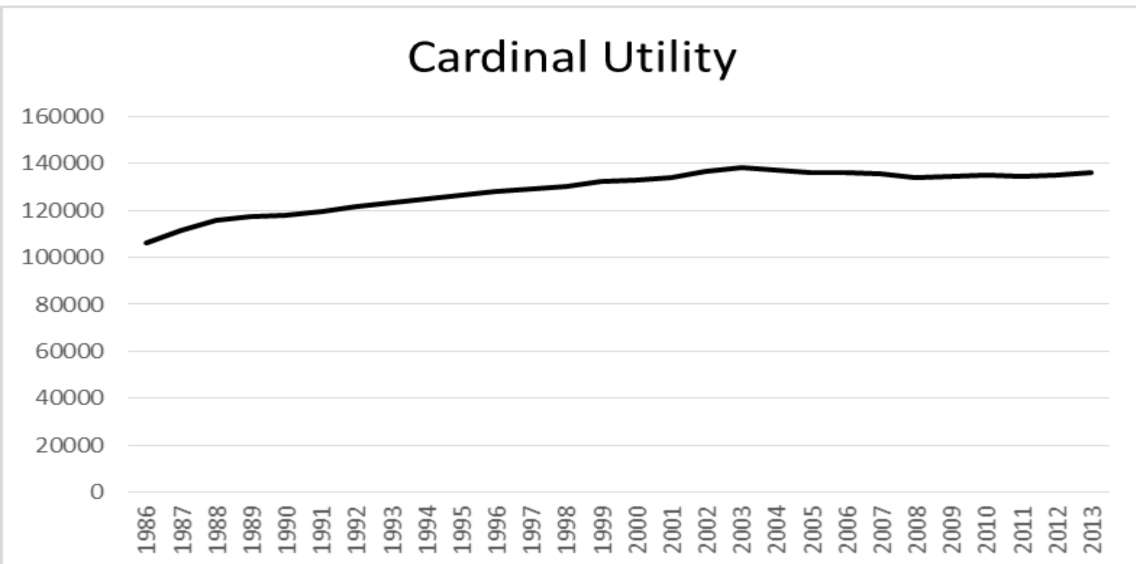

Figure 1. Government's Cardinal Utility with Regard to Defense

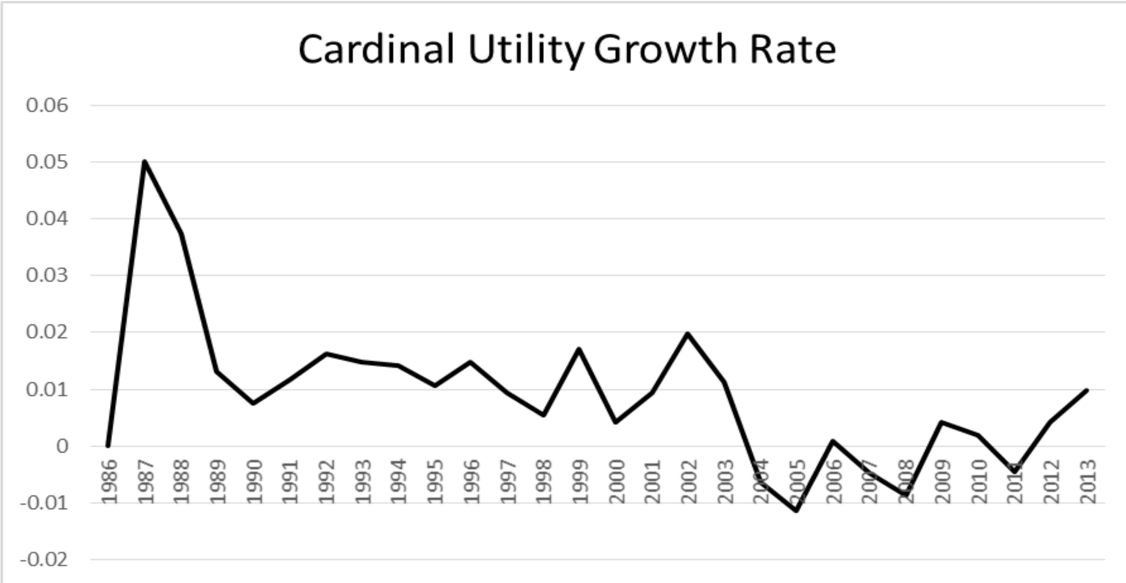

Figure 2. Growth Rate of Government's Cardinal Utility with Regard to Defense

3.2 Analysis Based on Calculation Results

The calculation results for the government's cardinal utility with regard to defense indicated in Figures 1 and 2 can be used to analyze the attitude towards defense of past Cabinets.

Tables 2a and 2b show changes in Cabinet attitudes during the late 1980s, 1990s, and 2000s. Figures 1 and 2 show the results of numerical analysis of attitudes towards defense each year (Note 8). Many of Japan's prime ministers have been called soft-liners, but Tables 2a and 2b show the Cabinets which exhibited a high degree of eagerness with regard to defense, and the backgrounds behind them.

First, looking at Table 2a, the third Nakasone Cabinet had a high utility growth rate. Yasuhiro Nakasone became prime minister in 1982. He was known as a hard-liner polemicist, and showed right wing tendencies within the LDP from an early age. When he became prime minister the economy was in the midst of a bubble, and he was very close to U.S. President Ronald Reagan. Needless to say, given the defense requests from the U.S. as well, the Nakasone Cabinet implemented defense strengthening policies. The decision made by the Takeo Miki Cabinet in 1976 to restrict defense expenditures to 1% or less of the GNP was revoked in December 1986. Defense expenditures exceeded 1% of the GNP for three successive years starting in 1987. The high rate of utility level growth can be considered a reflection of the mentality of the Nakasone Cabinet.

Table 2a. Analysis of Attitude toward Defense by Past Cabinets (1986 – 1999)

Year	Cabinet Changes	Cardinal Utility	Utility Growth Rate
1986	(Third term) Yasuhiro Nakasone	106225	-----
1987	(Third term) Nakasone -> Noboru Takeshita	111543	0.0501
1988	Takeshita -> Sosuke Uno	115727.2	0.0375
1989	Uno -> (First cabinet) Toshiki Kaifu	117250.7	0.0132
1990	(First cabinet) Kaifu -> (Second term) Kaifu	118145	0.0076
1991	(Second term) Kaifu -> Kiichi Miyazawa	119524.6	0.0117
1992	Miyazawa	121472.2	0.0163
1993	Miyazawa -> Morihiro Hosokawa	123264.1	0.0148
1994	Hosokawa -> Tsutomu Hata -> Tomiichi Murayama	124999.3	0.0141

1995	Murayama	126322.2	0.0106
1996	Murayama -> (First cabinet) Ryutaro Hashimoto	128188.5	0.0148
1997	(Second term) Hashimoto	129394.7	0.0094
1998	(Second term) Hashimoto -> Keizo Obuchi	130106.2	0.0055
1999	Obuchi	132322	0.0170

Next, looking that the attitudes towards defense by Cabinets in the 2000s, shown in Table 2b, shows that utility rose from 2001 to 2003, when Koizumi was in office. In 2001 the Junichiro Koizumi Cabinet was formed. With the exception of the immediately preceding Mori Cabinet there were no cabinets from the 1970s onwards since the Nakasone Cabinet which focused on defense. The three laws related to emergency legislation – the Armed Attack Situations Response Act, which permitted the dispatching of the Japan self-defense forces overseas, the Amendment to the Self-Defense Forces Law, and the Amendment to the Act for Establishment of the Security Council of Japan -- were passed in 2003. This stance was reflected in the utility levels, and utility growth rose from 2001 to 2002.

This table also shows that utility rose for the second term Abe Cabinet from 2012 onwards. The second term Abe Shinzo Cabinet was created in December 2012. This Cabinet showed a focus on defense, passing the Bill for the Development of Legislation for Peace and Security in 2015. This Cabinet stance is reflected in the utility level growth rate in 2013 reaching roughly 1%, a high growth rate. This shows the Cabinet's eagerness with regard to defense.

Table 2b. Analysis of Attitude toward Defense by Past Cabinets (2000 -2013)

Year	Cabinet Changes	Cardinal Utility	Utility Growth Rate
2000	Obuchi -> (First cabinet) Yoshiro Mori -> (Second cabinet) Mori	132886.3	0.0043
2001	(Second cabinet) Mori -> (First cabinet) Junichiro Koizumi	134150.7	0.0095
2002	(First cabinet) Koizumi	136802.9	0.0198
2003	(First cabinet) Koizumi -> (Second cabinet) Koizumi	138352.9	0.0113
2004	(Second cabinet) Koizumi	137468.4	-0.0064
2005	(Second cabinet) Koizumi -> (Third cabinet) Koizumi	135903.4	-0.0114
2006	(Third cabinet) Koizumi -> (First cabinet) Shinzo Abe	136013.6	0.0008
2007	(First cabinet) Abe -> (First cabinet) Yasuo Fukuda	135359.1	-0.0048
2008	Fukuda -> Taro Aso	134176.2	-0.0087
2009	Aso -> Yukio Hatoyama	134757.1	0.0043
2010	Hatoyama -> Naoto Kan	135008.4	0.0019
2011	Kan -> Yoshihiko Noda	134412.6	-0.0044
2012	Noda -> (Second cabinet) Abe	134975.8	0.0042
2013	(Second cabinet) Abe	136313	0.0099

4. Conclusion

This paper considered utility as an indicator of Japanese security policy, and defined a new Japanese defense indicator. This new indicator was used to quantify the attitude of past Cabinets towards defense, and to visualize how much past Cabinets focused on security policy.

First, when performing analysis using the utility function, in order to measure cardinal utility, which is considered capable of being used to accurately calculate attitudes, the government utility function was assumed to be a μ-th order homogenous function, and a measurement model was created. The utility function includes μ in its power, but measurement was made possible by using it as an MAI-I model. The results of the measurement indicated that the government utility function was roughly a 1.1079-order homogenous function.

Second, the calculation results for the government's cardinal utility with regard to defense indicated in Figures 1 and 2 were used to analyze the attitude towards defense of past Cabinets. The analysis results showed that defense utility levels were high for the Nakasone Cabinet, the Koizumi Cabinet, and the second Abe Cabinet, said to be focused on defense. In other words, for the Cabinets which actually focused on security policy, the policies were reflected in actual utility level measurements, indicating that the MAI-I model created in this paper can be used for economic analysis of security. The ability to use the utility functions of this paper to accurately measure utility levels of past Cabinets with regard to defense is a successful quantification of Japan's defense history.

However, this paper is just the first step in the creation of the MAI-I model. One of the key features of the MAI-I model is that it produces cardinal utility calculation results with great potential for other applications. Indifference curve analysis, residual analysis, etc., can be used to provide defense-related policy recommendations. These will be areas for future research.

Appendix

Data sources and processing methods (in form of annual data)

Defense equipment:

Calculated as "national defense budget - cost of personnel and provisions"

Source: Defense Yearbook

National defense budget (100 million yen)

Cost of personnel and provisions (100 million yen)

Labor: Actual number of self-defense force officials

Source: Defense Yearbook

Price:

Defense equipment: (1+ New 10 year government bond distribution yield)

Source: Ministry of Finance website Interest information – Year-end figures for 1974 to 1990 9 year government bonds for 1985 onwards

Self-defense official:

Cost of personnel and provisions (100 million yen)

Source: Defense Yearbook

Costs of defense equipment and of personnel and provisions was actualized using the government final consumption calculation deflator (2005 prices). The government final consumption calculation deflator was based on Cabinet Office national economic accounting.

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Notes

Note 1. This work was supported by JSPS KAKENHI Grant Number 15K13024. Any remaining errors are the author's responsibility.

Note 2. There was no negative inflation at the time of the Theil (1980a) (1980b) research, so budget share was seen as 0 or greater and 1 or less.

Note 3. The maximum-likelihood method was applied to estimates, but assuming error follows standard deviation, estimates were determined by applying OLS.

Note 4. See appendix regarding data.

Note 5. Income growth of -0.5 was used for estimates for Theil (1980a) (1980b) and Mizuno (1998).

Note 6. As indicated later, the 1% of GNP limitation on defense expenditures was revoked, but defense expenditures remain at roughly 1% of the GNP.

Note 7. Utility growth calculation was performed by substituting defense equipment and cost of personnel and provisions for each year.

Note 8. The list of past cabinets on the website of the Prime Minister of Japan and His Cabinet website was used for the terms of office of past Cabinets. http://www.kantei.go.jp/jp/rekidainaikaku/

Note 9. Utility growth calculation was performed by substituting defense equipment and cost of personnel and provisions for each year.