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Burden Sharing in NATO

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Abstract

During the period of cold war, NATO alliance was producing defence commodity to protect its members from the common threat of ex-Soviet Union. The paper examines the problem of burden sharing among NATO allies. It is shown that larger countries are benefited more than smaller countries from the production of the public good i.e defence, if the income elasticity of marginal utility of income is greater than one in absolute value. Complete demand systems are employed for estimating the income elasticity of marginal utility of income.

Keywords: NATO, burden sharing, marginal utility, income elasticity.
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Introduction

Since the seminar paper of Olson and Zeckhauser (1966), (OZ), on the economic theory of alliances, much work on the theoretical and empirical aspects of the allocation behaviour of alliance members appeared in the literature. Two are the main implications of the OZ model; namely, suboptimal provision of the defence commodity and disproportional sharing of the common defence burden. Specifically, in the OZ model the defence commodity is a public good; the cost functions for the production of the defence commodity are linear and the same for all allies; and the alliance members behave noncooperativelly. Then, an unequal burden is inevitable because the larger nations have little barganing power to increase the contributions of the smaller members. Therefore, the smaller nations "free ride" on their defence efforts and the alliance public good is provided because larger nations, mainly the United States, have an interest in it. As a result of this, allies with greater wealth (population etc.) bear a disproportionate share of the common defence burden compared to that of a less wealthy allies. In addition, the free riding hypothesis implies the suboptimal provision of the alliance public good.

Extending the OZ model by relaxing some of its assumptions, many studies showed that the free riding problem was overestimated in the OZ model. Specifically, relaxing the pure assumption of alliance's good, van Yperse de Strihou (1967),

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Sandler and Forbes (1980), Murdoch and Sandler (1982, 1984), proved that as the percentage of private benefits increases as a percentage to total alliance good production, free-rider tendencies will decrease. Thus, the more private benefits alliant nations receive as a result of their contributions to the alliance defence provision. Another aspect of the problem is examined by Boyer (1989), where nations specialize in the production of those alliance goods (economic, political, and military) for which they possess comparative advantage. Finally, Weber and Wiesmeth (1989) emphasize a closer cooperation (stronger integration) among NATO member which implies an optimal provision of the public defence commodity. They present a political environment which allows efficient and equitable burden sharing in NATO.

Among empirical studies, Gonzalez and Mchay (1991) find more support for the cooperative view of ally relationships than that of the OZ noncooperative model. On the other hand, Sandler and Murdoch (1989), using a system of simultaneous equations for a sample of ten NATO allies for the 1956-1987 period, find empirical support for Nash-Cournot behaviour for the NATO members.

In this paper, the NATO decision making process is represented as a cooperative game. Therefore, it is implicitly assumed that stronger integration (cooperation) characterizes more appropriately international military alliances like NATO. A general result is derived and it implies that the disproportionate burden sharing in NATO is explained by the progressiveness of the benefit the NATO members derive from the alliance public good. Larger nations tend to derive more benefit than smaller nations for a given amount of the public good, and therefore, contribute more to the provision of the public commodity. This explains why apparently inequitable alliance military burdens could be acceptable within the alliance.

The remainder of the paper is organized as follows: In Section II, the theoretical framework is developed. In Section III, the empirical model is presented and the empirical findings are analyzed. Finally, concluding remarks follow in the last section.

The Theoritical Framework

We define NATO to be an international regime with n member states, belonging to the set N. In this regime, there is one public good x, defence, and one private good y (income). Each individual member i, $i \in N$, has a preference relation ordering over feasible pairs (x,y). The preference relation is represented by a utility function u_i: $R^2_+ \rightarrow R$. Each member state $i \in N$ is endowed with a positive amount ω_i of the private good (i.e. the endowment may represent a country's gross national product (GNP) etc.). Moreover, each member contributes $t_i \in [0, \omega_i]$ as an input towards the provision of the public good, and the cost functions are linear and the same for all member nations with $x = f(t)$, $t: \sum_{i \in N} t_i$, and $f(0) = 0$. It is assumed that the utility function $u(x,y_i)$ is twice continuously differentiable, strictly monotone and strictly concave. Moreover, the function u_i is the same for each $i \in N$, and u_i is additively separable, $u(x,y_i) = v(x) + h(y_i)$, with $v_x > 0$, $h_y > 0$.

As in Weber and Wiesmeth (1989), it is assumed that a supranational agency prescribes a proportional burden sharing on NATO. Given this institutional environment, individual members decide upon their contribution towards the provision of the public defence commodity. Then we have to discuss the problem of selecting appropriate outcomes among the feasible allocations. Thus, given that NATO is characterized by a strong integration among its members, its decision making can be represented as a cooperative game.

Let $\Gamma = \{N,L,(u_i)_{i\in N}\}$ be a game, with N the set of the n NATO members as players, L the set of all feasible allocations, and u_i the playoff function of player i, that is $u_i(x) = u_i(f(x), \omega_i - \varphi_i(x))$, $\varphi\in\Phi$ where Φ is the set of all proportional cost sharing methods. For any $a, b\in L$, we say that b S-dominates a if and only if $u_i(b)>u_i(a)$ $\forall i\in S\subset N$. A proposal is a pair (i,x) such that $i\in N$ and $x\in L$. The set of all proposals made by i and not rejected by the other members is defined as follows:

$$\Theta(i,x): = \{(i,x)\in N\times L \,|\, ?\, x'\in L(S) \text{ s.t. } \quad x' \text{ S-dominates } x \forall S\subset N/\{i\}\}$$

Then, the set of "best" proposals for player i is given by:

$$\bar{\Theta}(i,x): = \{(i,x)\in\Theta(i,x) \,|\, \text{argmax. } u_i(x)\}$$

The solution of the game Γ is defined by: $C(i,x) = \bigcup_{i\in N} \bar{\Theta}(i,x)$. That is, the set $C(i,x)$ consists of all maximal not "objectionable" proposals, and, therefore, each one of these proposals has a likelihood to be selected as the final outcome of the decision making by the n NATO members.

Proposition 1 If the decision making in NATO is presented by the game Γ, then $C(i,x) = \varnothing$. Specifically, the unique solution of game Γ is given by $C(i,x^*) = (1,x)$, ..., (n,x^*), where $(f(t^*), t_1^*, ..., t_n^*)$ is a Lindahl allocation, with cost shares $t_i^* = \varphi_i(x^*)$ $\forall i\in N$.

proof

From Mas-Colell and Silvestre (1989, Proposition 1 and 2), it is known that there is one to one correspondence between a linear cost share equilibrium and Lindahl equilibrium. The equivalence theorem of Weber and Wiesmeth (1991) implies that any core allocation is a φ-CSE. Therefore, given the proportionality assumption, the above-mentioned results imply that an allocation is in the core of the game Γ, say $C(\Gamma)$, iff it is a Lindahl equilibrium. Our assumptions on preference and production guarantee the existence of a Lindahl equilibrium (Foley, 1970). By definition $\Theta(i,x)\subseteq C(\Gamma)$, which implies $C(i,x)\subseteq C(\Gamma)$. ∎

This proposition shows that the decision in NATO can cope with the efficiency problem, usually associated with Nash equilibria in noncooperative environments. It is also appropriate to deal with issues of disproportionate burden sharing as we can see in the next proposition.

Proposition 2 Let $(t_1^*, ..., t_n^*)$ be a solution of game Γ. Then for any two member nations i and j with $\omega_i > \omega_j$ we have: $\frac{t_i^*}{\omega_i} > \frac{t_j^*}{\omega_j}$ if and only if $|\sigma| > 1$, where σ is the elasticity of marginal utility of income with respect to income.

proof

From the assumption on utility functions and proposition 1, we know that: $t_i = px$, where $p = \frac{v_x}{h_y}$. Let $B_i = \frac{t_i}{y_i}$, then

$$\frac{\partial B_i}{\partial y_i} = -\frac{x}{y_i^2}\left[\frac{v_x}{h_y}\left(\frac{y_i h_{yy}}{h_y} + 1\right)\right]. \tag{1}$$

Since $\sigma = \frac{y_i h_{yy}}{h_y}$, equation (1) becomes:

$$\frac{\partial B_i}{\partial y_i} = -\frac{x}{y_i^2}[p(\sigma + 1)]. \tag{2}$$

Therefore, relation (2) implies: $\frac{\partial B_i}{\partial y_i} > 0$ if $\sigma < -1$. ■

Thus, proposition 2 implies that if the decision making among NATO members is described by game Γ, then cost-burden, as proportion of income, rises with income if the elasticity of marginal utility of income is greater than one in absolute terms. This provides an explanation of disproportionate burden sharing since the benefits from the public good as a proportion of income rise with income whenever $|\sigma| > 1$, which may nullify the tax progressivity.

Estimation and Results

Empirical consumer demand studies provide estimates of the parameter ψ, which is called the "money (or income) flexibility" (Frisch, 1959). Its reciprocal is the income elasticity of marginal utility of income, i.e. $\sigma = 1/\psi$. Frisch has speculated on the welfare implications of ψ. However, Sato (1972) has shown that ψ has no intrisic cardinal properties.

To obtain estimates of ψ, a cross-country demand model is used; namely, the Working-Preference Independence (WPI) model, as parameterized by Theil et al. (1989). Given m-goods and n-countries, the WPI model is given by:

$$w_{ij} = A + B + C \tag{3}$$

where:
$A = a_i + b_i q_j$ (real-income term),

$$B = (\alpha_i + \beta_i q_j)\left[\log\frac{p_{ij}}{\bar{p}_i} - \sum_{k=1}^{m}(\alpha_k + \beta_k q_j)\log\frac{p_{kj}}{\bar{p}_k}\right] \text{ (pure price term),}$$

$$C = \psi(\alpha_i + \beta_i q_j^*)\left[\log\frac{p_{ij}}{\bar{p}_i} - \sum_{k=1}^{m}(\alpha_k + \beta_k q_j^*)\log\frac{p_{kj}}{\bar{p}_k}\right] \text{ (substitution term),}$$

w_{ij} is the budget share of good i for country j; q_j is the logarithm of real income per capita of country j, $q_j^* = 1 + q_j$, and $\log \bar{p}_i = \sum_{j=1}^{n} \log p_{ij}$ is the geometric mean of prices across countries for good i. The α's and β's satisfy the following constraints: $\sum_i \alpha_i = 1, \sum_i \beta_i = 0$.

The NATO members are: the United States, Canada, Germany, Luxembourg, Belgium, Denmark, France, Netherlands, United Kingdom, Norway, Italy, Spain, Greece, Portugal, Iceland and Turkey. Since consumption expenditures in different countries are expressed in different currencies, these can be converted into a common currency, say U.S. dollars. However, this method has serious disadvantages (see Theil et al., 1989). To avoid this problem, Kravis and his colleagues at the University of Pennsylvania, applied the Geary-Khamis method (Theil et al., 1989)to obtain data for the countries included in the International Comparison Project (ICP) at various phases. These data sets are reported in Theil et al. (1989). Due to lack of data Iceland and Turkey have been omitted. The data for the remaining fourteen countries were obtained from Theil et al. (1989). The WPI model on years 1980 and 1986 was estimated using four and six aggregated commodity groups. The six good categories are: (1) food, including food, beverages and tobacco, (2) clothing and footwear, (3) rent, (4) housing, including furniture, furnishing and household equipment and operation, (5) travel and leisure, including transport, communication, recreation, entertainment, education and culture services, and (6) other goods and services. In the four-goods case the aggregated categories are: (1) food, (2) rent and housing, (3) travel and leisure, and (4) other goods and services.

Since Theil et al. (1989), provide data for the fourteen country-members of NATO only in 1980, the data for the 1986 year have been estimated by extrapolation. Specifically, an implicit deflator for each good category was obtained simply by dividing the 1986 expenditure in current prices by the expenditure in 1980 prices. In some cases, the constant price series was based on a year other than 1980, and the series had first to be shifted to the 1980 base for this purpose. Then, each 1986 price for the goods, was extrapolated from its 1980 counterpart by multiplying the 1980 good price by the price change between 1986 and 1980 as indicated by the implicit deflator in the appropriate good category. The per capita expenditures was obtained by dividing expenditure on current prices in each category by population figures.

For the statistical estimation of the WPI model, an error term, ε_j, added at the end of each one of the demand equations. Since $\sum_i \varepsilon_{ij} = 0$ for each j, one of the m

equations can be disregarded, say the last. Then the system of $m-1$ equations, given by the WPI model, is estimated using the maximum likelihood procedure (Theil et al., 1989). In all cases, the per capita real income is normalized so that the 1980 (1986) United States per capita real income is equal to one.

The estimated parameters of the WPI demand model for the years 1980 and 1986 are reported in Tables 1 and 2 respectively. The estimates of ψ are all negative, as we expert them to be (since $1/\psi$ has the interpretation as the income elasticity of the marginal utility of income) and statistical significant at 5% level of significance. In all cases the absolute value of ψ is less than one. Then the empirical evidence supports the hypothesis that $|\sigma| > 1$, which implies, in the light of proposition 2, that more wealthy countries derive greater benefit than less wealthy countries from the provision of the public commodity.

Table 1: *Estimates of WPI model in 1980*

	Parameters estimated		
	a_i	β_i	ψ
		Four goods	
Food	0.158	–0.247	–0.594
	(0.010)	(0.024)	(0.098)
Rent/Housing	0.252	0.063	
	(0.008)	(0.020)	
Travel/Leisure	0.296	0.131	
	(0.007)	(0.017)	
Other	0.294	0.053	
	(0.020)	(0.046)	
		Six goods	
Food	0.157	–0.251	–0.530
	(0.010)	(0.024)	(0.067)
Cloth/Foowear	0.067	–0.025	
	(0.005)	(0.009)	
Rent	0.167	0.045	
	(0.009)	(0.020)	
Housing	0.085	0.015	
	(0.005)	(0.010)	
Travel/Leisure	0.296	0.129	
	(0.007)	(0.016)	
Other	0.228	0.087	
	(0.022)	(0.048)	

Asympotic standard errors are in parentheses.

Table 2: *Estimates of WPI model in 1986*

	Parameters estimated		
	a_i	β_i	ψ
		Four goods	
Food	0.146	–0.224	–0.720
	(0.009)	(0.017)	(0.168)
Rent/Housing	0.312	0.126	
	(0.015)	(0.029)	
Travel/Leisure	0.246	0.035	
	(0.014)	(0.027)	
Other	0.296	0.063	
	(0.024)	(0.047)	
		Six goods	
Food	0.148	–0.219	–0.676
	(0.008)	(0.017)	(0.111)
Cloth/Foowear	0.073	–0.008	
	(0.004)	(0.007)	
Rent	0.220	0.099	
	(0.015)	(0.030)	
Housing	0.084	0.006	
	(0.005)	(0.030)	
Travel/Leisure	0.241	0.022	
	(0.014)	(0.025)	
Other	0.234	0.100	
	(0.024)	(0.045)	

Asympotic standard errors are in parentheses.

Finally, the pooled estimates and their asymptotic standard errors are shown in Table 3. Not surprisingly, the estimates tend to be between those of the 1980 and 1986 years' estimates. Again, the pooled estimator of ψ implies that the income elasticity of marginal utility of income is greater than one in absolute value. Therefore, wealthy countries have an incentive to bear a disproportionate burden sharing since their benefits depend positively on the amount of the public defence commodity produced.

Also, estimates of the parameter ψ are derived, using time-series data for NATO countries. The time-series version of the WPI-model is given by:

$$\Delta w_{it} = \beta_i \Delta(\log Q_t) + \bar{w}_{it}\left[\Delta(\log p_{it}) - \sum_{j=1}^{m} \bar{w}_{jt}\Delta(\log p_{jt})\right] + \\ + \psi(\bar{w}_{it} + \beta_i)\left[\Delta(\log p_{it}) - \sum_{j=1}^{m}(\bar{w}_{jt} + \beta_i)\Delta(\log p_{jt})\right] \quad (4)$$

where Δ stands for the first (backward) differences. Q is the real income, and $\bar{w}_{it} = \frac{w_{it} + w_{it-1}}{2}$. The log-change in real income is given by the index: $\Delta(\log Q_t) = \sum_{i=1}^{m} \bar{w}_{it}\Delta(\log q_{it})$.

Table 3: *Pooled Estimates of WPI model*

	Parameters estimated		
	a_i	β_i	ψ
	Four goods		
Food	0.150	-0.240	-0.624
	(0.009)	(0.020)	(0.066)
Rent/Housing	0.253	0.057	
	(0.007)	(0.014)	
Travel/Leisure	0.300	0.126	
	(0.006)	(0.012)	
Other	0.297	0.057	
	(0.018)	(0.037)	
	Six goods		
Food	0.149	-0.240	-0.573
	(0.009)	(0.020)	(0.046)
Cloth/Foowear	0.068	-0.019	
	(0.003)	(0.006)	
Rent	0.167	0.041	
	(0.007)	(0.014)	
Housing	0.084	0.011	
	(0.003)	(0.007)	
Travel/Leisure	0.299	0.120	
	(0.006)	(0.012)	
Other	0.233	0.087	
	(0.019)	(0.039)	

Asympotic standard errors are in parentheses.

The Rotterdam model, developed by Theil (1965), and Barten (1968), provides a first order approximation to the demand functions (4). The "relative price" version or the Rotterdam model (RRP) is given by the following equations:

$$\bar{w}_{it}\Delta(\log q_{it}) = \gamma_i \Delta(\log Q_t) + \sum_{j=1}^{m} \delta_{ij}\left[\Delta(\log p_{it}) - \sum_{k=1}^{m} \gamma_k \Delta(\log p_{kt})\right] \qquad (5)$$

The conditions which are required to make the model (5) consistent with the theory of demand are:

(i) adding-up: $\sum_{i=1}^{m} \gamma_i = 1$

(ii) symmetry: $\delta_{ij} = \delta_{ji}$

(iii) homogeneity: $\sum_{i=1}^{m}\sum_{j=1}^{n} \delta_{ij} = \psi$

The above restrictions are not sufficient to ensure the identifiability of the RRP-model (Theil, 1975). The assumption of preference independence solves this problem. To account for that, the following restriction is also imposed on the parameters:

(iv) additivity: $\delta_{ij} = 0 \; \forall \; i \neq j$ and $\delta_{ii} = \psi\gamma_i, i = 1, ..., m$

Annual time series data for the period 1960-1989 on personal consumption expenditures and prices were used to estimate the WPI and RRP models. All data are based on official estimates of OECD statistics. Implicit price indices were derived by dividing expenditures in current prices by expenditures in constant prices. The quantity q_{it}, is the per capita expenditurre on i^{th} commodity divided by its price at year t. Following the OECD classification, the eight aggregated commodity groups are: (1) food, beverages and tobacco, (2) clothing and footwear, (3) gross rent, fuel and poweer, (4) furniture, furnishings and household equipment and operation, (5) medical care and health expenses, (6) transport and communication, (7) recreation, education and cultural services, and (8) miscellaneous goods and services.

The time series estimates of ψ for the NATO countries are given in Table 4. All estimates are negative, but for Italy they are statistically insignificant for both models. As it can be seen from Table 4, the absolute value of all income flexibilities, for the NATO countries, is less than one. Finally, a pooled time series cross sectional data consisting of 14 NATO countries for a four-year period 1970-1973 has been assembled. The real expenditure and income data are constant 1970 dollars. The time series cross section estimates of the WPI and RRP models are given in Table 5. As it can be seen, the time series cross section estimates of the income flexibility, in both models, tend to provide evidence supporting the hypothesis that $|\sigma| > 1$.

Table 4: *Income Flexibilities*

Country	RRP-model ψ	WPI-model ψ
United States	–0.7778	–0.6291
	(0.0632)	(0.0583)
Canada	–0.04741	–0.4080
	(0.0647)	(0.0648)
Germany	–0.5416	–0.4925
	(0.0877)	(0.0834)
Luxembourg	–0.5408	–0.5266
	(0.0851)	(0.0811)
Belgium	–0.4082	–0.4481
	(0.0518)	(0.0541)
Denmark	–0.6311	–0.6166
	(0.0654)	(0.0646)
France	–0.5898	–0.5349
	(0.0513)	(0.0437)
Netherlands	–0.1318	–0.0613
	(0.0602)	(0.0654)
United Kingdom	–0.3264	–0.3393
	(0.0719)	(0.0731)
Norway	–0.7883	–0.7640
	(0.0856)	(0.0823)
Italy	–0.0646	–0.0869
	(0.0552)	(0.0555)
Spain	–0.3043	–0.3438
	(0.0381)	(0.0396)
Greece	–0.3140	–0.2808
	(0.0621)	(0.0582)
Iceland	–0.8886	–0.8131
	(0.0627)	(0.0742)

Standard errors are in parentheses.

Table 5: *Time series-cross section estimates*

	RRP-model	
	γ_i	ψ
Food	0.1784	–0.3173
	(0.0149)	(0.0670)
Clothing	0.0860	
	(0.0093)	
Rent/Fuel	0.1035	
	(0.0106)	
Housing	0.1506	
	(0.0096)	
Health	0.0715	
	(0.0101)	
Transportation	0.1969	
	(0.0140)	
Recreation	0.0955	
	(0.0073)	
Other	0.1176	
	WPI–model	
	γ_i	ψ
Food	–0.1216	–0.4149
	(0.0130)	(0.0549)
Clothing	–0.0118	
	(0.0086)	
Rent/Fuel	–0.0504	
	(0.0109)	
Housing	0.0487	
	(0.0086)	
Health	0.0155	
	(0.0078)	
Transportation	0.0688	
	(0.0125)	
Recreation	0.0284	
	(0.0051)	
Other	0.0224	

Standard errors are in parentheses.

Final Remarks

In this paper, the problem of burden sharing for the defence commodity in NATO was examined. Assuming a stronger integration among NATO members, the NATO decision making process was represented as a cooperative game. Then, it has been shown that NATO obtains an efficient production level of the public commodity. Furthermore, under the assumption of separable utility functions for NATO members, it was proven that larger countries benefit more than smaller countries from the production of the public good if the income elasticity of marginal utility of

income is greater than one in absolute value. Therefore, empirical estimates of the income elasticity of marginal utility of income using cross-sectional, time-series and pooled estimates were derived. The empirical results found to be robust, indicating a value for the income elasticity of marginal utility of income greater than one in absolute terms. This provides an explanation of disproportionate burden sharing in NATO since the benefits from the public commodity, as proportion of income, rise with income, thus favoring the more wealthy nations.

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