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JEL Classification: C72, D62, D74, H41

Keywords: Alliances, Public Goods, Burden Sharing, free riding, multi-stage Penrose-Stackelberg equilibrium, NATO

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Hierarchy of Membership and Burden Sharing in a Military Alliance

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1. Introduction

This paper introduces a model of military alliance which consists of several member countries. The members make their voluntary contributions towards alliance budget, which is used for production of the "alliance good" (such as defense, deterrence, and peacekeeping). The members are distinguished on the basis of the following four parameters:

- the level of economic performance, represented by their GDP per capita;
- population size;
- awareness of the alliance;
- the status in the alliance hierarchy.

The first two factors are quite straightforward. The awareness of the alliances for a single member country represents its willingness to contribute towards the alliance good. As in the seminal contribution by Olson and Zeckhauser (1966) (and later, in Weber and Wiesmeth 1991) we differentiate the countries according to their marginal rate of substitution between the alliance and private good.

The (vertical) alliance hierarchy refers to the situation the entire alliance membership is partitioned in several groups that are distinguished on the basis of their status or leadership roles. The sequence of moves in our game respects this hierarchy: the group with the highest leadership status makes its contribution first. The second highest status group takes the decision of the first group as given while correctly anticipating the response by all other members of the alliance. The process continues until, finally, the lowest status group simply responds to the actions by all others. The paradigm described here is called in economics the Stackelberg model and will be followed throughout the paper.

In our setting, in addition to their leadership status, member states differ on the basis of their economic strength, population size, and awareness for an alliance. The latter is the parameter indicating the utility each member derives from the alliance good (defense and deterrence) and the trade-off between the two that impacts countries' contributions. In our aggregation procedure for countries' contribution we adjust for the different country populations by applying Penrose's Square-Root Law (Penrose 1946). While considering the problem of apportioning seats in a global assembly consisting of countries with heterogeneous population sizes, Penrose recommended the method that assigns the voting weights proportional to the square root of each nation's population. Such an apportioning method is based on the fact that the voting power of any voter, as measured by the Penrose-Banzhaf index (cf. Banzhaf 1965), decreases with the size of the voting body as one over its square root. In our setting we utilize the Penrose method with respect to defense spending: an increasing population need not induce similarly increasing expenditures to keep up with the requirements of an adequate defense, which should allay arms racing concerns. Moreover, regarding the countries' contributions to the alliance good, a simple summation of their per capita contributions underrepresents the weight of large countries, whereas the summation of total contributions ignores the role and impact of small countries.

The interaction between the countries is modeled by means of the Penrose-Stackelberg mechanism that yields a unique equilibrium. We then apply our theoretical setting to NATO.

The reason for that is quite obvious. European security has returned to international headlines after years of relative quiet. The rise in geopolitical tensions raises familiar questions of defense contributions and other obligations in NATO, what has been referred to as "the quadrilateral dilemma of transatlantic defense: Europeans fear American abandonment, Americans complain about 'free-riding' Europeans, Americans oppose independent European defense, and Europeans complain about overbearing Americans" (Poast 2019).[1]

Our model allows us to address the sources of state-level variation in meeting (or not) the target of 2% of GDP for defense spending agreed upon at the NATO Summit in Wales in September 2014 and confirmed in July 2018 in Belgium (NATO 2018). Unlike a dues-paying organization, NATO spending targets are what member states spend on their own defense through domestic budgetary processes, which fall outside the purview of both NATO and other member states. Accordingly, some NATO members reach the spending target with vigor while others do not come close. We argue that this variation emerges from idiosyncratic geographical and historical facts of when and how states joined NATO combined with economic issues to produce what we term here "awareness for NATO."

We describe, measure, and empirically estimate "awareness" of the member states for the Alliance and for the associated goods of deterrence and peacekeeping. We integrate awareness into a formal model of decision-making in NATO. We find that in regards to burden sharing, different types of members play different roles within NATO, and that public opinion on NATO is not always congruent with this political awareness, especially for the "older" member states, where the tension with Russia and interest in geopolitics are lower, compared to public opinion in the "new" member states where public opinion corresponds better to political awareness. Finally, we find that interactions between member states based on their roles in the Alliance play a significant role in awareness for NATO, which we find helps explain diverging patterns of behavior among members: even as the U.S. continues to hold a leading role in the organization, new, that is, post-communist and post-Soviet member states exhibit different patterns of behavior regarding their defense expenditures compared to older members of NATO (cf., for example, Hillison 2009, Ch. 2).

As mentioned above, we model the interactions between member states with varying levels of NATO awareness, by considering a multi-stage Penrose-Stackelberg model. The model treats the United States as a "super-leader", the other founding members of NATO as "leaders", and the new, post-Cold War members as "followers" in the sense of the Stackelberg approach. The sequence of moves in our game respects this hierarchy: the super-leader U.S. moves first, leaders make their decisions while taking the U.S. choice as given, while correctly anticipating the optimal response by followers, and, finally, followers act in response to the choices made by the super-leader U.S. and old leaders. Our main theoretical result is the existence and uniqueness of the three-stage Penrose-Stackelberg equilibrium. This outcome is useful in explaining the development of NATO over the last decades. If we contrast our model with the two-stage model, where all new members simply copy the leaders' behavior, our results

[1] https://twitter.com/ProfPaulPoast/status/1128627948721004546

predict, for a given level of NATO awareness, an increase in contributions of the new members and a decline in contributions in old members. Obviously, recent geopolitical events may have impacted the level of NATO awareness for some members. To address this matter, we examine how empirical observations on military expenditure allow an estimation of awareness for NATO for each member state.

The formal conclusions regarding burden sharing show that member states with a higher GDP per capita and higher awareness for NATO tend to have higher military expenditures as a share of GDP. This result relies on both GDP per capita *and* awareness for NATO; a richer country with low awareness can certainly contribute less to the alliance good than a poorer country. Denmark offers an example of a rich country with low awareness, whereas Greece demonstrates high awareness while being much less affluent than Denmark. However, the adjusted levels of contributions are almost the same (cf. Table 4). Moreover, the contribution comparison is dependent on the interaction of the member states because decisions of the leaders do affect contributions of the followers.

The comparison of the empirically derived awareness values with public opinion surveys on NATO shows that in some of the old member states there is a discrepancy between awareness for NATO of the governments and public opinion on NATO. This might help to explain the hesitance of certain old members to increase their contributions. Regarding the new members, government decisions on contributions seem to have more support in the population.

The following section reviews the relevant literature on alliances in general and burden sharing in NATO in particular, followed by the methodology and data. Thereafter we introduce the model, taking into account GDP per capita, population, and "awareness." The interaction between the countries will be modeled by means of the Penrose-Stackelberg mechanism, which allows some degree of independence, although the decisions of the other countries affect individual decision-making. This section also contains the fundamental result on burden sharing in NATO and suggestions for further empirical applications. The paper concludes by evaluating the differences in burden sharing along political, military, and economic dimensions.

2. Literature Review

The literature on alliances, formal documents that record the nature of commitments over time that its participants assume will be honored (Morrow 2000, Leeds and Anac 2005), is understandably voluminous on aspects such as alliance patterns under varying structures (Christensen and Snyder 1990, Fordham and Post 2016), reputational concerns (Gibler 2008, Creszenci et al. 2012, LeVeck and Narang 2017), foreign policy behavior (Kenneth 1959, Walt 1990), and much more. The formation of asymmetric alliances, of which NATO is a classic example, emerges from what LeVeck and Narang (2017, p. 800) explain as a state's decision to accept "a trade-off between security and autonomy. In this view, militarily strong states provide greater security to weaker partners in return for greater policy concessions. Thus, it is

diversity in capabilities that often drives alliance formation and helps explain the prevalence and durability of asymmetric alliances."

The provision of public goods – and the "alliance good" considered in this paper has characteristics of a public good – emerges from this trade-off between security and autonomy in which the United States largely provides security to other members of NATO, who cede strategic autonomy to the United States in return for the public goods under question (cf., for example, Samuelson's "pure theory of public expenditures" (Samuelson 1954), Olson's "logic of collective action" (Olson 1965), or "the private provision of public goods" (Bergstrom et al. 1986) among many others.

The literature on burden sharing within NATO emerged within a decade of the Alliance's founding in 1949, with papers on the "economic aspects of coalition diplomacy," (Gordon 1956) "economic problems of alliance," (Hoag 1957) and "on NATO pooling" (Hoag 1958) published in top journals. In the policy world, U.S. presidents as far back as Dwight Eisenhower have complained about Europeans failing to provide sufficiently for their own defense. In their history of American officials complaining about insufficient burden-sharing, Cresswell and Gavin (2017) quote Eisenhower exclaiming that "All I ever get from [Secretary of State John Foster] Dulles are favorable reports, but the French are getting their asses kicked. Blackmailing bastards! Damn them! They have ten divisions bogged down in Vietnam, and every time I ask the sons of bitches to put more troops into NATO they kiss me off unless I promise to bail them out. The French have got themselves into this. They ought to get themselves out of it."[2]

A seminal contribution by Olson and Zeckhauser (1966) on the economic theory of alliances, characterized by publicness of defense and non-cooperative behavior of the alliance members, triggered a large number of theoretical and empirical investigations (cf., for example, Avenhaus et al. 1991, and Weber and Wiesmeth 1991, 1991a and the papers cited therein). Until the 1990s, a great deal of the literature focused on empirical validations of the Olson and Zeckhauser model (cf., for example, Sandler and Murdoch 1990), on impure public good properties in this context in general (Murdoch and Sandler 1982), and on imperfect substitutability of defense contributions in particular (McGuire 1989). Weber and Wiesmeth (1991) introduce a class of utility functions, which allow marginal cost differentials among member nations. This latter model allows the basic conclusions obtained in the non-formal framework of Olson and Zeckhauser 1966): (i) smaller members of NATO devote smaller percentages of their incomes to defense than do larger members, and (ii) the defense efforts are suboptimal. Hillison (2009) provides an extensive review of the literature and an empirical investigation of burden sharing since the founding of NATO.

The one-parametric approach in Olson and Zeckhauser (1966) assumes a particular variation of the marginal rate of substitution between a public defense commodity and a private good with the size of a member nation, which does not leave much room for differences in

[2] https://warontherocks.com/2017/08/a-history-of-vexation-trumps-bashing-of-nato-is-nothing-new/

awareness (cf. also Wiesmeth and Weber 1991a). Nevertheless, the goal of defense contributions of 2% of GDP is still an important political aspect of NATO policy in view of "improving the balance of sharing the costs and responsibilities" (cf. NATO 2018, No. 3.). As we investigate below the extent to which awareness affects this goal of an equal burden sharing, we note that Olson and Zeckhauser (1966) stressed that nations that place a higher absolute value on the public good of deterrence will end up supporting a disproportionate share of the common burden. Accordingly, they predicted the inevitability of an unequal burden borne by the dominant states because the larger nations have little bargaining power to increase the contributions of the smaller members, a theoretically predicted result demonstrated empirically by Thies (1987), Oren (1990), and, in an intriguing single-country case study on the Netherlands, Van Staden (1995).

The free-riding in NATO, therefore, emerges from the differing security needs and alliance awareness, in which those who "feel" relatively less pressure from Russia pay less, regardless of the time period. In effect, some states may feel pressure at certain times, but the U.S. feels pressure from Russia all the time as the leading power of the Alliance, hence the intemperate outburst of President Eisenhower. Even following the conclusion of the Cold War, the debate over whether to bring NATO to an end or expand it was decided conclusively in favor of the latter (Goldgeier 1999, Shifrinson 2016), extending the same issue of free-riding under different structural political conditions (Sandler and Shimizu 2014).

All these issues generated a variety of publications in the post-Cold War period addressing the economic future of the alliance (cf. Sandler and Hartley 1999, Hartley and Sandler 1999, Sandler and Hartley 2001). Sandler and Hartley (2001), Table 2, calculate defense burdens and average benefit shares for NATO members. Moreover, they point to the fact that "with the tenfold increases in crisis management spending in the last decade, an exploitation concern exists where the large, rich nations in both the UN and NATO shoulder much of the burden of peacekeeping. Peacekeeping is anticipated to possess a smaller share of excludable benefits than defense spending and, consequently, is prone to more disproportionate burden sharing" (Sandler and Hartley 2001, p. 886).

Nevertheless, following the conclusion of the Cold War and the break-up of the Soviet Union, the membership of NATO increased from 14 to its current size of 29 countries. The new members are drawn from previously communist (or even formerly Soviet) states from the Baltic Sea to Southeastern Europe, and are mostly small states without large military capabilities. Each of the states underwent substantial reforms to qualify for NATO membership, with the official criteria noting: "the applicant countries should consent to further the principles of NATO and must also demonstrate their ability to meet the obligations and commitments of possible future membership. The requirements a country must fulfill to seek NATO membership are a functioning democratic political system based on a regular market economy, the fair treatment of minority populations, a commitment to the peaceful resolution of conflicts, the ability and willingness to make a military contribution to NATO operations and a commitment to democratic civil-military relations and institutional

structures." (cf. Tavana and O'Connor 2014, p. 792 for these and further details on NATO enlargement).

The currently greater importance of "awareness" is rooted in the origins of these enlargements. As many of the new member states were allied to the former Soviet Union (or, for the Baltic states of Latvia, Lithuania, and Estonia, were in the Soviet Union), they believe they are, or could, face Russian security pressure, which in the case of conflict, would force other members of the Alliance, both the U.S. super-leader and the European leaders, to defend. Hillison (2014) thus finds that due to a normative component to burden sharing, "it is not surprising that new members feel compelled to bear a greater relative share of the collective burden than older members" (Hillison 2009, p. 9), given the differential desires to confront security risks within a suddenly heterogenous organization. Larger membership could also lead to financial risks and a more difficult and more time-consuming decision-making process (cf. Tavana and O'Connor 2014, p. 792).

This observation raises the question whether the older members of NATO, in particular the founding members, can be considered as "leaders", which provide guidance to the younger member states, or whether the "leaders" diverge from the "super-leader," generating a tacit sub-alliance of super-leader and followers, meaning the U.S. and the post-communist states versus Western Europe. This view is to some extent supported by empirical investigations (cf. Oneal and Elrod 1989), suggesting that NATO members deviated from the predictions of Olson's collective action theory (cf. also Hillison 2009, p. 25, and, in particular, Hillison 2014, Ch. 4 and 5), as well as a previous U.S. Secretary of Defense Donald Rumsfeld, who, when asked about NATO unity, provided a memorable contribution to the debate:

> What do I think about it? Well, there isn't anyone alive who wouldn't prefer unanimity. I mean, you just always would like everyone to stand up and say, Way to go! That's the right thing to do, United States. Now, we rarely find unanimity in the world. I was ambassador to NATO, and I – when we would go in and make a proposal, there wouldn't be unanimity. There wouldn't even be understanding. And we'd have to be persuasive. We'd have to show reasons. We'd have to – have to give rationales. We'd have to show facts. And, by golly, I found that Europe on any major issue is given – if there's leadership and if you're right, and if your facts are persuasive, Europe responds. And they always have. Now, you're thinking of Europe as Germany and France. I don't. I think that's old Europe. If you look at the entire NATO Europe today, the center of gravity is shifting to the east. And there are a lot of new members. And if you just take the list of all the members of NATO and all of those who have been invited in recently – what is it? Twenty-six, something like that? – you're right. Germany has been a problem, and France has been a problem (U.S. Department of Defense, 2003).

This variation in capabilities and proximity to external security threats make decision-making in NATO and contributions to NATO contingent on awareness for NATO, which we explore in the following formal model and then provide empirical estimates and relate the findings to public opinion surveys.

3. Methodology and Data

The formal approach of the paper is to apply the Penrose-Stackelberg model, based on Olson's logic of collective action (Olson 1965). In contrast to a pure public good, our alliance good combines features of a public good (deterrence) and of a private good (defense), thereby adhering to the consideration of ``impure public goods'' (Lepgold 1998) or “joint products” (Murdoch and Sandler 1991). As contributions towards alliance expenditure should therefore increase with a higher population in order to take adequately care of the defense aspect, we apply Penrose’s Law to adjust for differences in population sizes.

The Cobb-Douglas utility functions used to model the government decisions on NATO expenditure allow a straightforward characterization of awareness for NATO, and of the relationship between awareness, GDP per capita and burden sharing. Empirical estimates of the awareness for NATO of the member states parameters can then be obtained from the first-order conditions of the Penrose-Stackelberg equilibrium. These estimates seem to mirror the situation regarding burden sharing in NATO reasonably well for the period of the Cold War and after the enlargement with an obviously different behavior of the newer member states (cf., for example, Hillison 2009, 2014). It is possible to relate these awareness values to those obtained from public opinion surveys on NATO.

We collect data on GDP, GDP per capita, and population from the World Bank; on military expenditure from the Stockholm International Peace Research Institute; and, on public opinion surveys from the Transatlantic Trends Survey and European Values Survey.

4. Leaders and Followers: A Penrose-Stackelberg Model

This section presents the basic assumptions of the model, the mechanism of decision-making in a multi-stage Penrose-Stackelberg model, and the results on equilibrium allocations and burden sharing in such a context. The conclusions will be applied to empirical investigations in the next section.

The central concept of the model refers to “awareness for NATO”, meaning the extent NATO membership is appreciated from both governments in terms of military expenditures and, perhaps differently, the citizens of the member states through public opinion polling. How can we formally introduce awareness for NATO and to what extent is it theoretically related to military expenditure? We consider in this section how to evaluate the method by which NATO member states derive utility from a private good and an alliance good, which has features of both a public good (deterrence) and a private good (defense). The choice of the Cobb-Douglas utility functions allow us to derive an explicit analytical solution.

4.1 Assumptions

The member states of NATO differ with respect to GDP, population, geographic location and, sensitivity to geopolitical affairs or “awareness” for the Alliance. These differences, in combination with strategic interactions among the member states, manifest themselves in

observable military expenditures. Modeling decision-making in an alliance has to respect, therefore, that the member states, usually considered as the decision-makers, have some degrees of freedom to select their level of involvement. Other forms of interactions, leading, for example, to egalitarian-equivalent allocations or core allocations, require more intense cooperation among the partner countries, which, in general, can only be guaranteed by a supranational institution endowed with sufficient administrative power.

The most important commodities provided by a military alliance are defense, deterrence, and peacekeeping, which are characterized by different levels of external effects, by properties of both private and public commodities. This is reflected in the following basic assumptions:

Assumption [Basic Concepts]. *This assumption characterizes countries as members and decision makers of an alliance, the relevant commodities and production possibilities:*

- $N = \{1, \dots, n\}$ *denotes an alliance (NATO) with* n *member states;* P_i *denotes the population,* W_i *the GDP, and* $w_i := W_i/P_i$ *the GDP per capita of member state* $i, i \in N$.
- *In each member state ,* $i \in N$*, one unit of the private good* W_i *can be turned into one unit of alliance expenditure* T_i*, such as defense, deterrence, or peacekeeping activities;* $t_i = T_i/\sqrt{P_i}$ *denotes Penrose-adjusted per capita expenditure of member state* i.
- *The alliance good* t*, representing the benefits of the alliance and characterized by external effects, is given by* $t = t_1 + t_2 + \cdots + t_n$.
- *With* $\widehat{w}_i := w_i\sqrt{P_i}$*, the Penrose-adjusted GDP per capita, utility* $u_i(\widehat{w}_i - t_i, t) := (\widehat{w}_i - t_i) \cdot t^{\alpha_i}$ *of member state* $i, i \in N$*, depends on per capita consumption* $\left(w_i - t_i/\sqrt{P_i}\right)$ *of the private good and on consumption of* t *units of the alliance good;* $\alpha_i > 0$ *denotes the awareness parameter.*

The concept of the “alliance good” needs some explanation. As already mentioned, alliance expenditure refers to defense, deterrence, and peacekeeping. Whereas the latter two have properties of public commodities, defense has also characteristics of a private commodity. Contributions towards alliance expenditure should therefore increase with a higher population to address adequately the defense aspect. This leads to the aggregate production of the alliance good in the member states. In order to respect externalities of alliance spending, combined contributions are then taken into account in defining the total amount of the alliance good available to the member states.

The question is, to what extent the size P_i of the population of member state $i \in N$ affects the defense aspect of this country’s military expenditures. We propose to apply Penrose’s Square-Root Law. Penrose considered the problem of apportioning seats in a global assembly consisting of countries with heterogeneous population sizes (cf. Penrose 1946). The recommended method should assign a voting weight somewhere between an equal weight to each country (which undervalues the importance of large countries) and an equal weight to each citizen (which makes small counties almost irrelevant). Penrose argued that the voting weights should be proportional to the square root of each nation's population. Such an

apportioning method is based on the fact that the voting power of any voter, measured by what later became known as the Penrose-Banzhaf index (cf. Banzhaf 1965), is decreasing with the size of the voting body as one over its square root.[3]

In our setting we utilize the Penrose method first of all with respect to defense spending: an increasing population need not induce similarly increasing expenditures in order to keep up with the requirements of an adequate defense, which should allow for other states to observe whether military buildups conform to expectations set by others, or whether military expenditures are rising proportional to population increase, such as China's past decade of military spending. Moreover, regarding the countries' contributions to the alliance good, a simple summation of their per capita contributions underrepresents the weight of large countries, whereas the summation of total contributions ignores the role and impact of small countries. Therefore, we consider t_i as country's $i, i \in N$, decision variable, leading to $t = t_1 + t_2 + \cdots + t_n$ units of the alliance good.

Of course, to some extent military spending is comprised of investments in weaponry and technical equipment. Nevertheless, in the context considered here it is assumed that military spending of NATO member states is focusing on consumption commodities. This is in line with the still relevant aspect of deterrence and the increased spending for peacekeeping purposes in the last decades. Sandler and Hartley (2001) point to this aspect (cf. p. 886). The benefits of NATO, the consumption of the alliance good, thus result through military expenditure, as introduced above.

The parameter α_i is closely related to the marginal rate of substitution between the private and the alliance good. In fact, considering $\mathrm{u_i}(\mathrm{x_i}, \mathrm{y}) = \mathrm{x_i} \cdot \mathrm{y}^{\alpha_i}$ yields:

$$\mathrm{MRS_i}(\mathrm{x_i}, \mathrm{y}) = \frac{\mathrm{u_{iy}}(\mathrm{x_i}, \mathrm{y})}{\mathrm{u_{ix}}(\mathrm{x_i}, \mathrm{y})} = \alpha_i \cdot \frac{\mathrm{x_i}}{\mathrm{y}}$$

for an arbitrary consumption bundle $(\mathrm{x_i}, \mathrm{y}) \in \mathbb{R}_+^2$. Therefore, a higher value of α_i indicates a higher "willingness to pay" for an additional unit of the alliance good.[4] In this sense, parameters α_i, $i \in N$, can be considered as indicators of "awareness" for the alliance good, or, more generally, of NATO (cf. again Sandler and Hartley 2001 in this context).

The Nash mechanism is certainly among the most prominent approaches towards describing the interactions of the countries regarding the provision of a public good. Regarding NATO, Olson and Zeckhauser (1966) remark that "in an alliance, the amount a nation spends on defense will be affected by the amount its allies provide." This continues to hold true in view of the external effects associated with alliance spending. Moreover, member states usually

[3] For applications of Penrose's Square-Root Law see Kirsch (2013).

[4] The idea of differentiating the countries according to their marginal rate of substitution has already been applied by Olson and Zeckhauser (1966) and Weber and Wiesmeth (1991). However, in contrast to their model, countries in our approach are characterized by additional parameters. Moreover, our utility functions differ from those in Weber and Wiesmeth (1991).

defend their degree of independence regarding their military expenditure, making the Nash mechanism, in principle, appropriate for modeling decision-making in an alliance.

However, NATO's distinction is that it is dominated by a single state that is itself marked by an unusual amount of institutional self-binding to prevent unilateral action (Ikenberry 2001), a feature which helped NATO maintain coherence and relevance following the conclusion of the Cold War and institutional expansion thereafter (Sarotte 2009). An analysis of NATO decision-making should therefore account for differences in American leadership before and after expansion beginning in 1990 with the incorporation of East Germany into West Germany and continuing from the induction of the "Visegrad countries" of Czech Republic, Hungary, and Poland in 1999 onwards throughout the rest of Europe.[5] If the U.S. was the "leader" to the European "followers" during the Cold War, the United States should continue to occupy that role to the pre-1990 members of NATO, but then have a deeper leader-follower relationship with the post-1990 members of NATO. However, those same post-1990 members also followed the pre-1990 members in other organizations, such as the European Economic Community, meaning that the new members, probably in view of their inexperience and their lower levels of economic welfare, seem to follow the decisions the "super-leader," but also of the other founding member states, the "leaders". The new member states, which joined NATO after 1990, are therefore considered as "followers" of both the "leaders" and the "super-leader." The pre-1990 members of NATO are there somewhere in between: they are followers of the super-leader, and they are leaders for the new member states.

In fact, empirical evidence (cf. Section 5) shows that neither the Nash mechanism, nor the Stackelberg model with the U.S. as leader and all other member states as followers capture all relevant features of decision-making in NATO, in particular after the enlargement from 1999 onwards.

These considerations lead to the application of a multi-stage Penrose-Stackelberg model in order to better explain more recent developments in NATO. The following assumptions detail decision-making in this context.

Assumptions [Decision-Making]. *We consider an alliance model with the "super-leader"* $S = \{1\}$*, the "leaders"* $L = \{2, \dots, m\}$*, and the "followers"* $F = \{m+1, \dots, n\}$*. Thus,* $N = S \cup L \cup F$ *with decision variables* $t_1, \dots, t_n$*.*

[Super-Leader] *The super-leader* $i = 1$ *assumes that all other member states take into account* t_1*, following the decision of country 1:* $t_j = t_j(t_1)$ *for* $j \in L \cup F$*. The super-leader then maximizes*

$$(\widehat{w}_i - t_1) \cdot \left(t_1 + t_2(t_1) + \cdots + t_n(t_1)\right)^{\alpha_1}$$

by selecting an appropriate level of t_1*.*

[5] The Slovak Republic was part of the original Visegrad Group, but its accession was delayed by NATO until 2004 due to actions of its then-Prime Minister Vladimir Meciar being considered undemocratic by the organization.

[Leaders] *The leaders $i \in L$ assume that all followers $j \in F$ take into account their decision t_i. Thus, $t_j = t_j(t_i)$ for $j = m+1, \dots, n$. Hence, leader $i \in L$ chooses the optimal response t_i, maximizing*

$$(\widehat{w}_i - t_i) \cdot \left(t_1 + \cdots + t_m + t_{m+1}(t_i) + \cdots + t_n(t_i)\right)^{\alpha_i}$$

given t_k, $k \in S \cup L$, $k \neq i$.

[Followers] *The followers $i \in F$ react optimally on the decisions of all other member states. Follower $i \in F$ thus chooses the optimal response t_i, maximizing*

$$(\widehat{w}_i - t_i) \cdot (t_1 + \cdots + t_n)^{\alpha_i}$$

given t_j, $j \in N$, $j \neq i$.

With these basic assumptions on decision-making we consider next the first-order conditions for utility maximization. The following subsection contains main features of the Penrose-Stackelberg equilibrium. Thereafter, the results on burden sharing in equilibrium will be presented. Relevant steps of the proofs are provided in the Appendix.

4.2 Multi-Stage Penrose-Stackelberg Equilibrium

We analyze the Penrose-Stackelberg equilibrium model with three stages: a super-leader, leaders, and followers.

Theorem 4.1 [Penrose-Stackelberg Equilibrium]. *There exists a unique Penrose-Stackelberg equilibrium. The equilibrium contributions of member states are given by:*

$$\mathrm{t}_\mathrm{f}^\star = \widehat{\mathrm{w}}_\mathrm{f} - \frac{\widehat{\mathrm{W}}}{\alpha_\mathrm{f}(1+\mathrm{A_F})(1+\mathrm{A_L})(1+\mathrm{A_S})} \quad \text{for all } \mathrm{f} \in \mathrm{F} \qquad (1)$$

$$\mathrm{t}_\mathrm{l}^* = \widehat{\mathrm{w}}_\mathrm{l} - \frac{\widehat{\mathrm{W}}}{\alpha_\mathrm{l}(1+\mathrm{A_L})(1+\mathrm{A_S})} \quad \text{for all } \mathrm{l} \in \mathrm{L} \qquad (2)$$

$$\mathrm{t}_1^* = \widehat{\mathrm{w}}_1 - \frac{\widehat{\mathrm{W}}}{\alpha_1(1+\mathrm{A_S})} \quad \text{for the super-leader,} \qquad (3)$$

with $\mathrm{A_F} = \sum_{\mathrm{f}\in\mathrm{F}} \frac{1}{\alpha_\mathrm{f}}$, $\mathrm{A_L} = \sum_{\mathrm{l}\in\mathrm{L}} \frac{1}{\alpha_\mathrm{l}}$, $\mathrm{A_S} = \frac{1}{\alpha_1}$, and $\widehat{\mathrm{W}} = \sum_{\mathrm{i}\in\mathrm{N}} \widehat{\mathrm{w}}_\mathrm{i}$.

Note also that the total equilibrium contribution $t^* = \sum_{i \in N} t_i^*$ can be derived from (1) – (3):

$$\mathrm{t}^* = \frac{\widehat{\mathrm{W}}}{(1+\mathrm{A_F})(1+\mathrm{A_L})(1+\mathrm{A_S})}. \qquad (4)$$

It will also be useful to directly link the individual and total contributions in equilibrium:

$$\mathrm{t}^* = \alpha_\mathrm{f}(\widehat{\mathrm{w}}_\mathrm{f} - \mathrm{t}_\mathrm{f}^*) \quad \text{for all } \mathrm{f} \in \mathrm{F} \qquad (5)$$

$$t^* = \frac{\alpha_l(\widehat{w}_l - t_l^*)}{1+A_F} \text{ for all } l \in L \qquad (6)$$

$$t^* = \frac{\alpha_1(\widehat{w}_1 - t_1^*)}{(1+A_F)(1+A_L)} \text{ for the super-leader.} \qquad (7)$$

A closer analysis of the equations (1) - (7) allows us to derive a series of comparative statics results that evaluate the impact of changes in individual member states´ characteristics on their contributions as well as on the total alliance contribution.

Corollary 4.1 [Comparative Statics]. *Suppose that awareness α_i of country $i, i \in N$, increases, while all other characteristics of the member states remain the same. Then:*
or the adjusted initial endowment $\widehat{w}_i$:

1. *The contribution of country i increases.*
   1.1. If $i = 1$, the contributions of all other countries decrease.
   1.2. If $i \in L$, the contributions of all other countries, except the super-leader, decrease. The contribution of the super-leader does not change.
   1.3. If $i \in F$, the contributions of all other followers decrease. The contributions of the leaders and the super-leader remain the same.
2. *The total equilibrium amount of the alliance good t^* increases. That is, the increase of the contribution of country i is sufficient to compensate for the drop-off in the contributions of other countries.*

Suppose now that the adjusted initial endowment $\widehat{w}_i$ of country $i, i \in N$, increases, while all other characteristics of the member states remain the same. Then:

3. *The contribution of country i increases.*
4. *The contributions of all other countries decrease.*
5. *The total equilibrium amount of the alliance good t^* increases. That is, the increase of the contribution of country i is sufficient to compensate for the drop-off in the contributions of other countries.*

The hierarchy of interactions among the member states might change over time. In particular, the post-1990 enlargements of NATO brought in countries that had been allied with or part of the Soviet Union deserves closer investigation. We therefore analyze their military expenditure decisions in light of diverging examples of the U.S. as super-leader and the European leaders in Section 5. The following corollary to Theorem 4.1 reveals potentially observable consequences resulting from the shift in a mode of interactions.

For this end, we first introduce a two-stage Penrose-Stackelberg model with one super-leader and all other countries as followers. This corresponds to the aftermath of the NATO enlargement when the new members simply imitated the behavior of the “old” members, except the U.S. We then contrast those values with the equilibrium levels derived in the three-

stage setting in Theorem 4.1. In addition, we compare the three- and two-stage Penrose-Stackelberg equilibria with the Nash model where all members make their decision simultaneously. While we do not believe that the Nash paradigm is (or was) a proper framework for NATO decision making, the Nash equilibrium nevertheless represents an important benchmark, in special in lieu of the seminal contribution of Olson and Zeckhauser (1966).

We therefore consider two additional scenarios:

- a two-stage Penrose-Stackelberg model with one super-leader $S = 1$ and the rest of the alliance as followers: $\tilde{F} = L \cup F = \{2, \dots, n\}$. We will denote the equilibrium contributions of the individual members under this scenario by $\tilde{t}_i, \mathrm{i} \in N$, and the total contribution by $\tilde{t}$;
- a Nash-Penrose model, where all countries make their contribution decisions simultaneously. That is, the set of followers is the entire alliance: $F^{\mathrm{NP}} = N$. We will denote the equilibrium contributions of individual members under this scenario by $t_i^{\mathrm{NP}}, i \in N$, and the total contribution by t^{NP}.

We then compare individual and total contributions in the three scenarios under consideration. In particular, we show that a finer partition of members into different groups, followers, leaders and the super-leader, leads to a higher contribution of the followers, a lower contribution of the super-leader, and a lower total alliance contribution. Moreover, by shifting from the two-stage to the three-stage Stackelberg-Penrose equilibrium, followers increase their contribution, leaders reduce theirs, whereas the contribution of the super-leader remains unchanged. The total contribution declines, implying that the raise of contribution by followers is outweighed by the drop of leaders' contributions.

Corollary 4.2 [Comparison of Three Scenarios]. *The following inequalities, summarized in Table 1, are satisfied:*

a) For each country $f \in F$, its contribution is highest under the three-stage Stackelberg-Penrose equilibium and is lowest under the Nash-Penrose equilibrium:

$$\mathrm{t}_{\mathrm{f}}^{*} > \tilde{\mathrm{t}}_{\mathrm{f}} > \mathrm{t}_{\mathrm{f}}^{\mathrm{NP}} \quad \text{for all} \quad \mathrm{f} \in \mathrm{F}.$$

b) For each country $l \in L$, its contribution is highest under the two-stage Penrose-Stackelberg equilibrium:

$$\mathrm{t}_{\mathrm{l}}^{*} < \tilde{\mathrm{t}}_{\mathrm{l}} > \mathrm{t}_{\mathrm{l}}^{\mathrm{NP}} \quad \text{for all} \quad \mathrm{l} \in \mathrm{L}.$$

c) For the super-leader, its contribution is the highest under the Nash-Penrose equilibrium, and is the same under both variants of the Penrose-Stackelberg equilibrium:

$$t_1^* = \tilde{t}_1 < t_1^{NP} \text{ for the super-leader.}$$

d) The total equilibrium contribution is lowest under the three-stage Penrose-Stackelberg equilibrium and is highest under the Nash-Penrose equilibrium:

$$t^* < \tilde{t} < t^{NP}.$$

	Three-stage PS equilibrium	Two-stage PS equilibrium		Nash equilibrium
Followers	t_f^*	$>$	$\tilde{t}_f$ $>$	t_f^{NP}
Leaders	t_l^*	$<$	$\tilde{t}_l$ $>$	t_l^{NP}
Super-leader	t_1^*	$=$	$\tilde{t}_1$ $<$	t_1^{NP}
Total contribution	t^*	$<$	$\tilde{t}$ $<$	t^{NP}

Table 1: Comparison of the contribution levels under three scenarios.

The following subsection addresses the central issue of burden sharing in the multi-stage Penrose-Stackelberg equilibrium.

4.3 Burden Sharing in the Multi-Stage Penrose-Stackelberg Equilibrium

This subsection turns to the issue of burden sharing. With respect to the contributions of the various countries in relation to the parameters characterizing these countries, we obtain the following theorem, whose proof is given in the Appendix. The theorem shows, first of all, that in equilibrium a proportional burden, usually considered to be fair in view of the balance of sharing the costs and the responsibilities, is the exception, at least without any further coordination through a supranational body. Moreover, a proportionally higher share of the burden arises not only from GDP. The effect of awareness has to be taken into account. Thus, it is possible that despite of a high GDP or GDP per capita value, a proportionally lower share of the burden results from low awareness for NATO. Moreover, in order to compare the contributions across different groups in the alliance, say, followers and leaders, we also take into account the composition of the alliance and the characteristics of members of each of the three groups, followers, leaders and the super-leader. It is useful to consider the equilibrium alliance expenditure as a fraction of the member's endowment for every $i \in N$:

$$r_i = \frac{t_i^*}{\widehat{w}_i}.$$

Theorem 4.2 [Burden Sharing].

a) (Intra-group comparison). For any two members i, j, that belong to the same group (either both are followers or both are leaders):

$$r_i > r_j \text{ if and only if } \alpha_i \widehat{w}_i > \alpha_j \widehat{w}_j.$$

b) (Inter-group comparison). Put

$$\beta_f = \alpha_f \text{ for all } f \in F,$$

$$\beta_l = \frac{\alpha_l}{1+A_F} \text{ for all } l \in L,$$

$$\beta_1 = \frac{\alpha_1}{(1+A_F)(1+A_L)} \text{ for the super-leader.}$$

Then for any two members $i, j \in N$:

$$r_i > r_j \text{ if and only if } \beta_i \widehat{w}_i > \beta_j \widehat{w}_j.$$

The following section focusses on empirical investigations combining the theoretical findings with observations regarding the military expenditure of NATO members in various stages of the development of the alliance.

5. Empirical Analysis

The first subsection considers the first stage of NATO, the period of the Cold War, and analyzes decision-making on military expenditure of the founding members. These are the member states, which joined NATO before 1990. In the context of our multi-stage Penrose-Stackelberg model, we are, thus, left with the U.S., the super-leader, and the other founding members, which are now just followers of the U.S.

5.1 Empirical Results for the Founding Members of NATO

The empirical values of awareness for NATO can be consecutively obtained from the first-order conditions and the observable, or computable parameters w_i, t_i and t. We assume that besides the leader, the U.S., all other older members of NATO are followers, thus:

$$\alpha_i = \frac{t}{\widehat{w}_i - t_i} \text{ for } i \in \tilde{F} = \{2, \dots, n\}, \text{ and } \alpha_1 = \frac{1}{\widehat{w}_1 - t_1} \cdot (1 + A_L).$$

Then we derive the empirical values of awareness for NATO among the member states. In Table 2 we obtain the ranking with respect to awareness for NATO in the context of the two-stage Penrose-Stackelberg equilibrium with data from 1990.

Country:	w_i	α_i	Country:	w_i	α_i
U.S.	23,954	3.449	Netherlands	21,019	0.618
Turkey	2,794	2.485	Spain	13,767	0.585
Luxembourg	34,645	2.309	Canada	21,371	0.444
Portugal	7,885	2.018	UK	19,095	0.352
Greece	9,600	1.655	Italy	20,757	0.320
Norway	28,243	0.868	France	21,691	0.306

Denmark	26,891	0.821	Germany	22,220	0.254
Belgium	20,711	0.768			

Table 2: Two-Stage Penrose-Stackelberg Equilibrium: Ranking of NATO members 1990 with respect to awareness; GDP per-capita w_i in current (1990) US-$. Sources: data compiled from http://data.worldbank.org/ for GDP and http://www.sipri.org/ for NATO expenditure.

Without assuming the U.S. to be a leader, the Nash mechanism would assign the U.S. an awareness level of 0.136, the lowest among the old NATO members. This is not plausible and allows us to disregard the Nash mechanism for decision-making in NATO, also for the earlier years of the alliance.

Table 2, based on the two-tier Penrose-Stackelberg model, reveals the clear leadership of the U.S., and leaves the impression that in 1990 the awareness levels of most of the founding members, thus excluding Turkey (1952), Greece (1952), Germany (1955), and Spain (1982) – and with the further exemption of the U.S., Luxembourg and Portugal – are focused, with a standard deviation of 0.220. Thus, in view of Theorem 4.2, as awareness levels are close together, the share of the burden tends to increase with Penrose-adjusted GDP per capita. Many studies investigating the earlier years of NATO (cf., for example, Hillison 2009, 2014, for a review of the relevant literature) observe some dependence on GDP per capita, affected also by the size of the country, the "Penrose-adjustment". We obtain the following result:

Result 5.1. *In the early decades of NATO, burden sharing among various founding members was more affected by GDP per capita and the size of the population due to similar levels of awareness for NATO given the common concern over the security challenge posed by the Soviet Union. As all NATO members were concerned by potential Soviet land invasion or nuclear attack (as were the Warsaw Pact members of the same from their adversaries in NATO), a higher level of economic welfare together with a higher population tended to induce higher per capita military expenditure in 1990. For the U.S., as leading NATO decision-making in these years, both a high level of GDP per capita, the high population, and a high level of awareness determined the outstanding per capita military expenditure.*

For the following analysis of decision-making in NATO after the extensions in the 1990s and 2000s, we turn to the three-stage Penrose-Stackelberg model, which shows how the "leaders" of Europe, which used to be the "followers" of the United States during the Cold War, began to downgrade their own awareness for NATO as their concerns over Russia and other land-based security challenges decreased. For the newer states of NATO, they are not only followers of the existing NATO members, but given their closer appreciation of Russian security challenges, began to adopt the security preferences of the United States and its hyper-awareness of NATO. Hillison (2009, 2014) suggests that the socialization of new members in NATO helped them "to more closely reflect NATO's burden sharing norms" from the super-leader, to show "that new members are able to overcome the rational incentives to free-ride in order to prove their credibility" (Hillison 2014, p. 180). Thus, the newer members of NATO seem to "follow" the older ones prior to the Western European downshifting of the

Russian security challenge. In order to investigate this issue, we consider them as Stackelberg followers, whereas the member states, which joined NATO before 1990, are assumed to be Stackelberg leaders with the U.S. as super-leader.

5.2 Empirical Results for the Enlargement of NATO

For the empirical analysis we classify NATO member states as leaders, followers, and a super-leader. Observe that NATO members Iceland and Montenegro are not considered: Iceland still does not have armed forces, and Montenegro became a member of NATO only in 2017:

S: The U.S. is considered as a super-leader: S := {U.S.}.
L: The founders and those countries, which joined NATO before 1990, are considered as leaders: L := {Belgium, Canada, Denmark, France, Germany, Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Turkey, UK}.
F: The followers are those countries, which joined NATO after 1990: F := {Albania, Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia}.

Corollary 4.2 provides one hint to investigate the structural interactions in view of the new member states. According to the statement of this corollary, as followers, the new members should gradually reveal (cet. par.) increasing military expenditure, a view, which is also empirically supported by various studies: regarding burden sharing, Hillison (2014) also found that – with some caveats – new members "will share greater relative proportion of burdens than old members" and that they "have been more willing to take on additional responsibility and burdens" (Hillison 2014, p. 166).

Year	Country i	T_i 2008	T_i 2017	t_i 2008	t_i 2017
1999	Poland	6,883	9,871	1,115	1,602
1999	Hungary	1,460	1,463	461	468
1999	CzechRep.	2,406	2,078	747	638
2004	Estonia	461	537	398	468
2004	Lithuania	494	812	276	483
2004	Latvia	507	509	344	366
2004	Romania	2,366	3,622	522	818
2004	Bulgaria	905	824	331	310
2004	Slovakia	1,263	1,049	544	450
2009	Croatia	1,068	784	514	386
2009	Albania	219	144	128	85

Table 3: Military expenditure of "new" NATO member states in 2008 and in 2017; measured in absolute expenditure T_i (constant (2017) mil. US-$) and corresponding Penrose-adjusted expenditure $t_i = T_i/\sqrt{P_i}$. Source: http://www.sipri.org/ and http://data.worldbank.org.

In order to investigate these statements in our context, we consider the military expenditures of old and new NATO members in 2008 and compare them with those in 2017 in Table 3 and Table 4 below.

First, the numbers in Table 3 show that total absolute contributions of the new member states increase from 18,734 mil. US-$ in 2008 to 22,168 mil. US-$ in 2017. The Penrose adjusted contributions increase from 5,873 mil. US-$ in 2008 to 6,403 mil. US_$ in 2017. Again, a variety of other effects, such as economic growth, and the likelihood of shifts in the awareness values, are influencing these numbers, but a certain tendency towards relatively higher military expenditure of the new member states is recognizable, as postulated by Corollary 4.2.

Secondly, the numbers in Table 4 show that total absolute contributions of the old member states decrease from 977,256 mil. US-$ in 2008 to 873,087 mil. US-$ in 2017. The Penrose adjusted contributions decrease from 83,050 mil. US-$ in 2008 to 74,129 mil. US_$ in 2017. Of course, again a variety of other effects, such as economic growth, and possible changes in the awareness values, are also influencing these numbers, but nevertheless, there seems to be tendency towards lower military expenditures of the old member states, as postulated by Corollary 4.2, too.

Result 5.2. *The fact that military expenditures of the new NATO members increased over the last years, whereas those of the older members decreased supports the hypothesis that the new members are, to some extent, following the decisions of the older members in the sense of the Penrose-Stackelberg model (cf. Corollary 4.2).*

Empirical estimates of awareness for NATO can be obtained from the first-order conditions of the three-stage Penrose-Stackelberg model. These first-order conditions are provided in Theorem 4.1 with the member states of NATO classified as super-leader (U.S.), leaders (countries, which joined before 1990) and followers (all other NATO members).

Year	Country i	T_i 2008	T_i 2017	t_i 2008	t_i 2008
1949	Belgium	5,572	4,485	1,703	1,330
1949	Canada	18,156	21,343	3,149	3,531
1949	Denmark	4,145	3,764	1,768	1,568
1949	France	54,907	60,417	6,843	7,389
1949	Italy	31,387	26,448	4,092	3,399
1949	Luxembourg	207	358	297	463
1949	Netherlands	10,786	9,581	2,660	2,315
1949	Norway	5,211	6,466	2,386	2,815
1949	Portugal	4,046	3,647	1,245	1,136
1949	UK	54,983	46,433	6,994	5,713
1949	U.S.	707,151	605,803	40,552	33,596
1952	Greece	8,675	5,094	2,606	1,553

1952	Turkey	12,482	17,824	1,487	1,979
1955	Germany	40,819	45,382	4,505	4,992
1982	Spain	18,730	16,044	2,763	2,350

Table 34: Military expenditure of "old" NATO member states in 2008 and in 2017; measured in absolute expenditure T_i (constant (2016) mil. US-$) and corresponding Penrose-adjusted expenditure $t_i = T_i/\sqrt{P_i}$. Source: http://www.sipri.org/ and http://data.worldbank.org.

Table 5 represents these estimates. The results point again to the definition of awareness for NATO. These empirically estimated levels of the awareness parameter indicate the marginal willingness to pay for an additional unit of the alliance good in the equilibrium situation.

Country i	α_i	Country: i	α_i	Country: i	α_i
U.S.	17.081	Estonia	3.660	Slovakia	1.996
Albania	10.664	Belgium	3.610	Canada	1.940
Greece	8.782	Norway	3.062	Hungary	1.839
Portugal	7.843	Croatia	3.022	Romania	1.724
Luxembourg	6.517	Lithuania	2.983	France	1.696
Turkey	5.635	Spain	2.754	UK	1.649
Denmark	3.910	Netherlands	2.650	Germany	1.308
Latvia	3.793	Slovenia	2.411	Czech. Rep.	1.235
Bulgaria	3.757	Italy	2.134	Poland	0.967

Table 5: Penrose-Stackelberg Mechanism: Ranking of NATO member states regarding "awareness" in 2017. Sources: Data compiled from http://data.worldbank.org/ for GDP and http://www.sipri.org/ for NATO expenditure.

It is then interesting to analyze the situation of the U.S. in this context. The estimated value of 17.081 for awareness for NATO points to the role this country has always played in NATO as the vehicle by which it engages in international politics as a superpower. Among the other founding members of NATO, only Greece, Portugal, Luxembourg, Turkey, and Denmark show relatively high awareness levels. Thus, the leadership role combined with responsibility with respect to the new member states is not mirrored in the awareness levels of all old member states. In particular, Canada, France, UK, and Germany are characterized by low values.

One must, however, not forget that these awareness levels refer to the attitude of the decision-makers, in our model the governments of the member states. The question arises, whether these levels of awareness are always in agreement with public opinion on NATO in the member states.

5.3 Public Opinion on NATO

There have always been efforts to evaluate and measure the support, NATO receives in the populations of the member states. Of course, this support can be, for some time at least, different from awareness for NATO, influencing the activities of the governments regarding military expenditure. The following public opinion ratings are taken from panel survey data across NATO:

Country:	Rating	Country:	Rating	Country:	Rating
U.S.	58.9	Estonia	50.9	Slovakia	53.6
Albania	78.9	Belgium	73.8	Canada	57.0
Greece	27.6	Norway	69.2	Hungary	47.3
Portugal	63.2	Croatia	23.8	Romania	57.4
Luxembourg	64.6	Lithuania	64.7	France	53.8
Turkey	33.7	Spain	33.2	UK	47.5
Denmark	69.5	Netherlands	53.6	Germany	38.6
Latvia	47.4	Slovenia	55.4	Czech. Rep.	42.6
Bulgaria	44.4	Italy	57.5	Poland	52.5

Table 6: Public opinion on NATO in 2008. (Sources: Kennedy et al., 2008 and European Values Survey 2011).

Table 6 presents public opinion on NATO as surveyed in 2008, which was an interesting point in geopolitics given the renewed concerns about Russia and dissatisfaction with the Iraq War, but prior to the global financial crisis and the high tensions of events in Ukraine. The order of the member states coincides with those of Table 5 showing the awareness levels in descending order. Clearly, awareness for NATO as relevant for decisions on military expenditure does not really coincide with public opinion. The question is, whether there are remarkable differences between old and new members of NATO.

Interestingly, there is a huge discrepancy between old and new members of NATO regarding the correspondence between awareness levels and public opinion ratings. For the old member states, which have joined NATO before 1990, the correlation coefficient between the awareness levels (resulting from the Penrose-Stackelberg equilibrium (cf. Table 5) turns out to be 0.024, whereas the correlation coefficient referring to the new members is 0.557.

How can this difference be interpreted? The small value 0.024 of the correlation coefficient for the old members means that public opinion and awareness for NATO in these countries do not coincide, are not in harmony. In particular, those old member states, such as Turkey and Greece with their military expenditure above 2% of GDP, experience a rather low public opinion on NATO. And, on the other hand, Belgium and Denmark with high public ratings, reveal low shares of military expenditures on GDP.

Regarding the new members, there is with a value of 0.557 of the correlation coefficient the opposite situation. Government decisions on military expenditure seem to have more support in the populations of these member states, which implies that a difference between old and

new members regarding NATO is that populations in the newer members are keeping their governments aware of NATO while their counterparts in the older members are not exerting the same pressure.

6. Concluding Remarks

This paper examines economic motives of NATO decision making in single member states. We identify the source of variation for spending behavior between the super-leader, the leaders from the pre-1990 states of NATO, and the followers from the post-1990 states of NATO. The last point is addressed through examination of different models for the interactions among the member states. Whereas the Nash mechanism, mirroring Olson´s "logic of collective action" (Olson 1965), seems to be applicable to NATO decision-making in the earlier decades of the treaty, roughly until the end of the Cold War, the Penrose-Stackelberg mechanism seems to be better suited for the more recent period of NATO existence. However, introducing Stackelberg leaders and followers in an empirical context is not straightforward, and we argue that the old member states should be viewed as leaders, providing guidance to the newer members.

A central concept of this paper is "awareness for NATO" in the governments of the member states. This awareness determines decision making and helps investigate the issue of proportional burden sharing, which has always been a fundamental issue in NATO. It turns out that proportional burden sharing (2% goal) is not much less the rule than the exception in NATO decision making.

Finally, there is the question of public support for NATO. Results from public opinion surveys yield an interesting conclusion: there does not seem to be much of a harmony between governments of the old member states and their populations regarding NATO, whereas the populations in the new member states provide more support regarding NATO to their governments, perhaps because their entry into NATO, ongoing concerns about external security, and assuaging the concerns of the super-leader are more closely linked in the public imagination.

Further studies should more carefully and more intensively investigate the empirical issues raised and touched in this paper. Only then will it be possible to answer the question about leaders and followers in NATO in greater detail.

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Appendix

With the exemption of the proof of Corollary 4.2, all proofs will be given for the simple case of only three countries: country 1 the super-leader, country 2 the leader, and country 3 the follower. The general cases can be dealt with in analogous ways.

Proof of Theorem 4.1: Denote by t_j^i the partial derivative of the contribution of country j with regard to the choice of country i.

The first order conditions for each country $f \in F$ yield: $\alpha_f\left(\widehat{w}_f - t_f\right) = t$. Differentiation with respect to $t_l, l \in L$, generates the following expression for each pair $f \in F, l \in L$:

$$-\alpha_f t_f^l = 1 + \sum_{i \in F} t_i^l.$$

Notice that, for a given $l \in L$, the right-hand side of the above equality does not depend on f. Thus, there exists a positive value x such that for every $f \in F$ and $l \in L$

$$t_f^l = -\frac{x}{\alpha_f}.$$

By substituting this expression into the previous equation, we obtain

$$x = 1 - xA_F \text{ or } x = \frac{1}{1 + A_F}.$$

Thus, we obtain for each $f \in F$ and each $l \in L$:

$$\mathrm{t}_{\mathrm{f}}^{\mathrm{l}} = -\frac{1}{\alpha_{\mathrm{f}}(1+\mathrm{A_F})} \qquad (8)$$

By using (8), we obtain for each $l \in L$

$$\alpha_{\mathrm{l}}(\widehat{\mathrm{w}}_{\mathrm{l}} - \mathrm{t}_{\mathrm{l}})\left(1 + \sum_{\mathrm{f}\in\mathrm{F}} \mathrm{t}_{\mathrm{f}}^{\mathrm{l}}\right) = \mathrm{t}, \text{ or}$$

$$\alpha_{\mathrm{l}}(\widehat{\mathrm{w}}_{\mathrm{l}} - \mathrm{t}_{\mathrm{l}})\left(1 - \frac{\mathrm{A_F}}{1+\mathrm{A_F}}\right) = \alpha_{\mathrm{l}}(\widehat{\mathrm{w}}_{\mathrm{l}} - \mathrm{t}_{\mathrm{l}})\frac{1}{1+\mathrm{A_F}} = \mathrm{t}.$$

Next, we turn to the partial derivatives of all other players with respect to actions of the super-leader. For each $f \in F$ we have

$$-\alpha_f t_f^1 = 1 + \textstyle\sum_{i\in F} t_i^1 + \sum_{j\in L} t_j^1, \qquad (9)$$

and for each $l \in L$ we obtain:

$$-\alpha_l t_l^1\left(1 + \textstyle\sum_{i\in F} t_i^l\right) = -\alpha_l \frac{t_l^1}{1+A_F} = 1 + \textstyle\sum_{i\in F} t_i^1 + \sum_{j\in L} t_j^1. \qquad (10)$$

To solve equations (9) and (10), note that the right-hand side in both equations is the same and that it is independent of l and f. Thus, there is a positive value of y such that

$$t_l^f = -\frac{y}{\alpha_f} \text{ for all } f \in F \text{ and } t_l^1 = -\frac{y(1 + A_F)}{\alpha_l} \text{ for all } l \in L.$$

By substituting those expressions into equation (9), we obtain

$$y = 1 - y(A_F + A_L + A_F A_L), \text{ or } y = \frac{1}{(1 + A_F)(1 + A_L)}.$$

Thus, for each $f \in F$

$$t_f^1 = -\frac{1}{(1 + A_F)(1 + A_L)\alpha_l}.$$

and for each $l \in L$

$$t_l^1 = -\frac{1}{(1+A_L)\alpha_f}.$$

We then obtain

$$\sum_{f\in F} t_f^1 = -\frac{A_F}{(1+A_F)(1+A_L)}$$

and

$$\sum_{l\in L} t_l^1 = -\frac{A_L}{1+A_L}.$$

Since we have

$$\alpha_f\left(\widehat{w}_f - t_f\right) = t \text{ for all } f \in F$$

$$\frac{\alpha_l(\widehat{w}_l - t_l)}{1+A_F} = t \text{ for all } l \in L$$

$$\frac{\alpha_1(\widehat{w}_1 - t_1)}{(1+A_F)(1+A_L)} = t \text{ for the super-leader,}$$

it follows that

$$t_f = \widehat{w}_f - \frac{t}{\alpha_f} \text{ for all } f \in F$$

$$t_l = \widehat{w}_l - \frac{t(1+A_F)}{\alpha_l} \text{ for all } l \in L$$

$$t_1 = \widehat{w}_1 - \frac{t(1+A_F)(1++A_L)}{\alpha_1} \text{ for the super-leader.}$$

By summing up all those contributions, we conclude that the total equilibrium contribution t^* is given by

$$t^* = \widehat{W} - t^*\left(A_F + A_L(A_F+1) + A_S(1+A_F+A_L+A_FA_L)\right),$$

and we obtain:

$$t^* = \frac{\widehat{W}}{(1+A_F)(1+A_L)(1+A_S)}.$$

The individual equilibrium contributions of the member states are given by

$$t_f^* = \widehat{w}_f - \frac{\widehat{W}}{\alpha_l(1+A_F)(1+A_L)(1+A_S)} \text{ for all } f \in F$$

$$t_l^* = \widehat{w}_l - \frac{\widehat{W}}{\alpha_l(1+A_L)(1+A_S)} \text{ for all } l \in L$$

$$t_1^* = \widehat{w}_1 - \frac{\widehat{W}}{\alpha_1(1+A_S)} \text{ for the super-leader.}$$

This proves Theorem 4.1. □

Proof of Corollary 4.1: Suppose first that awareness α_i of country $i \in N$ goes up, while all other parameters of the model remain unchanged.

Note first that $\alpha_f(1+A_F)$ is increasing in α_f for $f \in F$. So are $\alpha_l(1+A_L)$ in α_l for $l \in L$ and $\alpha_1(1+A_S)$ in α_1. Thus, equations (1) – (3) imply that for each $i \in N$ an increase in α_i leads to an increase in t_i^*, proving assertion 1. Moreover, equations (1) and (2) guarantee that the increase in α_1 yields a decline in the equilibrium contributions of all other countries, proving 1.1. For each $l \in L$, (1) and (2) show that an increase in α_l leads to a decline of t_i^* for i $\neq 1$. By (3), the contribution of the super-leader remains unchanged, yielding 1.2. By (1), for each $f \in F$ an increase in α_f leads to declining contributions of all other followers. By (2) and (3), the contributions of leaders and the super-leader remain unchanged, proving 1.3. The increase of the total contribution of the alliance, assertion 2., follows immediately from equation (4).

Suppose now that the adjusted initial endowment $\widehat{w}_i$ of country $i \in N$ goes up, while all other parameters of the model remain unchanged. Note that the denominator in equations (1) - (3) is greater than one. Then the contribution of country i goes up which proves 3. Since the contributions of single countries have an inverse relationship with initial endowments of other countries, this yields 4. Finally, equation (4) implies that the total contribution of the alliance goes up, proving 5. □

Proof of Corollary 4.2: It easy to derive individual and total contributions for the two-stage Stackelberg-Penrose and Nash-Penrose equilbrium. For the first case, recall that the set of followers, $\tilde{F}$, is given by $L \cup F$. Thus, we have

$$\tilde{t}_i = \widehat{w}_i - \frac{\widehat{W}}{\alpha_i(1+A_{\tilde{F}})(1+A_S)} = \widehat{w}_i - \frac{\widehat{W}}{\alpha_i(1+A_F+A_L)(1+A_S)} \text{ for all } i \neq 1,$$

$$\tilde{t}_1 = \widehat{w}_1 - \frac{\widehat{W}}{\alpha_1(1+A_S)} \text{ for the super-leader,}$$

$$\tilde{t} = \frac{\widehat{W}}{(1+A_F+A_L)(1+A_S)}.$$

In the Nash case, the set of followers F^{NP} consists of the entire society. Thus,

$$t_i^{\mathrm{NP}} = \widehat{w}_i - \frac{\widehat{W}}{\alpha_i(1+A_{F^{\mathrm{NP}}})} = \widehat{w}_i - \frac{\widehat{W}}{\alpha_i(1+A_F+A_L+A_S)} \text{ for all } i \in N,$$

$$t^{\mathrm{NP}} = \frac{\widehat{W}}{1 + A_F + A_L + A_S}.$$

By comparing those expressions with equations (1) - (4), we conclude that

$$t_f^* > \tilde{t}_f > t_f^{\mathrm{NP}} \text{ for all } f \in F,$$

$$t_l^* < \tilde{t}_l > t_l^{\mathrm{NP}} \text{ for all } l \in L,$$

$$t_1^* = \tilde{t}_1 < t_1^{\mathrm{NP}} \text{ for the super-leader,}$$

$$t^* < \tilde{t} < t^{\mathrm{NP}},$$

This proves Corollary 4.2. □

Proof of Theorem 4.2: Note that equations (5) - (7) can we rewritten as

$$t^* = \alpha_f \widehat{w}_f(1 - r_f) = \beta_f \widehat{w}_f(1 - r_f) \text{ for all } f \in F,$$

$$t^* = \frac{\alpha_l \widehat{w}_l(1 - r_l)}{1 + A_F} = \beta_l \widehat{w}_l(1 - r_l) \text{ for all } l \in L,$$

$$t^* = \frac{\alpha_1 \widehat{w}_1(1 - r_1)}{(1 + A_F)(1 + A_L)} = \beta_1 \widehat{w}_1(1 - r_1) \text{ for the super-leader.}$$

Then the assertions a) and b) follow immediately. □