Exploring Potential Arms Races

Carlos Seiglie*

Defense spending accounts for a larger share of national output in most countries than many of the other allocative decisions, both public and private, which the majority of economic research aims at explaining. Yet with notable exceptions, most economists have ignored this topic and relegated to political science the task of explaining how resources are allocated to this sector. This paper aims at contributing to this literature by economists.

A theoretical model is developed to explain the dynamics of the arms acquisition process. Within this framework, defense expenditures are governed by the expenditures of potential adversaries if these exist. Then the model is empirically tested using a sample of countries or dyads which have been proposed to be adversaries. The direction of the prima facie causal relationship between the military expenditures of these dyads is investigated using parametric causality tests. The results indicate that some of these country’s expenditures seem to reflect an arms race while other proposed dyads seem not to be adversaries, i.e., their expenditures are independent and therefore, seem to be governed by other than an external threat.

JEL Classification Code: H56, E62

1. Introduction

If one looks at the share of national output accounted for by defense expenditures for a sample of countries, it is not surprising that in some this share has accounted for over 20% of GDP during times of peace and over 50% of Central Government expenditures. These numbers reflect a process of arms acquisition by countries either to deter an attack by an adversary or to be employed offensively by them for various purposes. In other words, countries devote a large share of their resources to accumulate and maintain a stock of weapons and human resources to be used in the event of either internal or external conflicts.

Economists have for the most part delegated to political science the problem of explaining the allocation of such a large share of national income while concentrating on the allocation of resources to private goods. When interested in

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231
public sector activities, those economists working in the area of public choice have generally concentrated on the redistributive role of the State, even though the share of transfers is smaller than that of defense expenditures for the vast majority of countries, especially those in the developing world. Yet there have been a core of economists trying to understand the nature of the armaments process and how the accumulation of weapons can lead to the outbreak of war and with it the destruction of both human and physical capital which necessarily impacts on future production and welfare. Notable examples in this field include Boulding (1962), Brito (1972), Intriligator (1967, 1975), Isard (1988) and McGuire (1965, 1977).

This paper presents a general model of the arming process along the lines of Brito (1972). The motivation to devote resources to the defense sector is governed by national security considerations, i.e., the possibility of conflict with an adversary. This model yields a set of difference equations for each country where their level of military spending is positively related to that of a potential adversary's. This relationship is generally referred to as an arms race.

It has been proposed in previous empirical studies, e.g., by Majeski and Jones (1981), that there exists arms races between particular countries or dyads, in other words, that the military expenditures of certain pairs or groups of countries follow the pattern suggested by an arms race model. It would seem appropriate to empirically investigate whether such countries' military expenditures are governed by such a process and if so to establish the direction of causality between these pairs of adversaries' defense spending. Therefore, this paper investigates whether there exists prima facie Granger causality between the real military expenditures of different adversaries in the world.\(^1\) The adversaries investigated in this paper are: (1) Israel–Arabs, the latter defined as Egypt, Syria and Jordan, (2) Israel–Egypt, Israel–Syria and Israel–Jordan alone, (3) Argentina–Chile, (4) Argentina–Brazil, (5) Turkey–Greece, (6) Pakistan–India and finally, (7) Iran–Iraq.

In the next section, a general theory of the demand for weapons motivated by the desire to provide for national security is presented. Section III empirically tests the relationship implied by this model by examining whether prima facie causality exists between the military expenditure series of these dyads which have been suggested to be involved in arms races. We conclude by emphasizing the complementary nature of structural models of military expenditures with those of time series by reinterpreting the empirical results presented in Section III.

2. A GENERAL MODEL OF THE ARMAMENT PROCESS

We begin by developing a general model of the consumption, investment and defense spending decisions of a representative (decisive) individual or social

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\(^1\) Majeski and Jones (1981) analyzed a similar problem by specifying the ARIMA representation of a set of military expenditure series.
planner in Country $i$. The individual or social planner has preferences over his level of consumption $c_t$ over time, as well as over the level of national security or defense $d_t$. National security at any moment in time is equal to the difference between the stock of weapons a country has accumulated up to that point $M'_i$, and some proportion of the amount accumulated by an adversary $M'_j$. The reason for adjusting a country's total military capability by that of the adversary's is that some proportion of an adversary's military capability spills over and decreases the effectiveness of the country's military defense, i.e., it reduces its national security (see Seiglie, 1988 and Hirshleifer, 1989 for a discussion of different specifications). Denoting the proportion of Country $j$'s weapon stock that reduces Country $i$'s national security by $a_{ij}$, then

$$d_t = M'_i - a_{ij} M'_j,$$

(1)

with

$$\frac{\partial d_t}{\partial M'_i} = 1 \quad \text{and} \quad \frac{\partial d_t}{\partial M'_j} = -a_{ij} < 0.$$

For countries in an adversarial relationship, national security is declining in the enemy's military expenditures and increasing in own expenditures. The proportion $a_{ij}$ differs for each country depending, for example, on the percentage of military spending directed towards offensive versus defensive purposes. If a country does not perceive the weapon stock of Country $j$ as threatening then we assume $a_{ij} = 0$ for all values of $M'_j$ and therefore, national security, $d_t = M'_i$.

There are several factors not captured explicitly by the model that could lead to a country desiring this minimum amount of weapons even though no threat currently exists. First, the model does not take into consideration other functions of military spending, for example, to quell potential domestic unrest. Second, no other potential enemies besides the main adversary are being considered. Finally, the model does not account for future changes in international relations (uncertainty) from peaceful to adversarial which when faced with the adjustment costs involved in rearming would lead a country to not totally disarm.

More formally, preferences are represented by

$$U = \sum_{t=0}^{\infty} \beta^t u(c_t, d_t) = \sum_{t=0}^{\infty} \beta^t \{ (c_t - \bar{c}_t)^2 + (M'_i - a_{ij} M'_j)^2 \},$$

(2)

where $\beta$ is the discount factor and $\bar{c}_t$ is some minimum subsistence level of consumption.

It is assumed that some fraction of the stock of weapons at time $t$ depreciates, $\gamma$, and so the stock accumulated into the next period to provide national security, $m_t$, is equal to:

$$m_t = M'_{i+1} - (1 - \gamma) M'_i.$$

(3)
Furthermore, the supply of labor (population) is assumed constant over time and for simplicity, is normalized to be equal to unity. Also the commodity and factor markets are competitive. Finally, in period $t$ the country produces output $y$, employing the production function

$$y_t = Ak_t^\alpha,$$  \hspace{1cm} (4)

where $k_t$ is the capital labor ratio available in the country at $t$ and, since labor is normalized to equal unity, $y_t$ corresponds to per capita output as well. This output is allocated amongst consumption, investment, $i_t$, and the accumulation of the weapon stock, $m_t$. Specifically,

$$c_t + i_t + m_t = Ak_t^\alpha,$$  \hspace{1cm} (5)

with

$$i_t = k_{t+1},$$  \hspace{1cm} (6)

i.e., the rate of depreciation of the capital stock is assumed equal to unity.

Substituting for $i_t$ and $m_t$, equation (5) can be rewritten as

$$c_t + k_{t+1} + M_{t+1} - (1 - \gamma)M_t = Ak_t^\alpha,$$  \hspace{1cm} (5')

or as the state equation for the weapon stock,

$$M_{t+1} = Ak_t^\alpha - c_t - k_{t+1} + (1 - \gamma)M_t.$$  \hspace{1cm} (5")

The problem faced by the decisive individual is to maximize equation (2) subject to equation (5'). The Bellman equation for the problem is:

$$V[k_t, M_t^i, t] = \text{Max}[\{(c_t - \bar{c}_t)^2 + (M_t^i - a_y M_t^f)^2 + V[k_{t+1}, M_{t+1}^i, t+1]\}].$$  \hspace{1cm} (7)

The first-order conditions obtained by differentiating with respect to $c_t$ and $m_t$ (military spending) are:

$$2(c_t - \bar{c}_t) - \beta V_{k_{t+1}} = 0,$$  \hspace{1cm} (8)

$$-V_{k_{t+1}} + V_{M_{t+1}^i} = 0.$$  \hspace{1cm} (9)

By the envelope theorem

$$V_{k_t} = \alpha \beta Ak_{t+1}^{\alpha - 1} V_{k_{t+1}},$$  \hspace{1cm} (10)

which when substituted into equation (9) yields

$$V_{M_t^i} = \alpha \beta Ak_{t+1}^{\alpha - 1} V_{M_{t+1}^i}.$$  \hspace{1cm} (11)

Likewise, we also obtain that

$$V_{M_t^f} = 2(M_t^i - a_y M_t^f) + \beta (1 - \gamma)V_{M_{t+1}^f}.$$  \hspace{1cm} (12)
Substituting equation (11) into (12) yields
\[ V_{M_t^i} = 2(M_t^i - a_y M_t^j) + \frac{(1 - \gamma) V_{M_t^i}}{\alpha A k_{t+1}^{\alpha-1}}, \] (13)
or
\[ V_{M_t^i} = \frac{2(M_t^i - a_y M_t^j)}{(1 - (1 - \gamma)/\alpha A k_{t+1}^{\alpha-1})}. \] (13')

Finally, using equation (11) iterated one period forward we get:
\[ \frac{(M_t^i - a_y M_t^j)}{(1 - (1 - \gamma)/\alpha A k_{t+1}^{\alpha-1})} = A \beta k_{t+1}^{\alpha-1} \frac{(M_{t+1}^j - a_y M_{t+1}^j)}{(1 - (1 - \gamma)/\alpha A k_{t+2}^{\alpha-1})}. \] (14)

If a linear technology is assumed \((\alpha = 1)\), then equation (14) simplifies to:
\[ (M_t^i - a_y M_t^j) = A \beta (M_{t+1}^j - a_y M_{t+1}^j), \] (14')

which we rearrange to obtain
\[ M_{t+1}^i = \frac{1}{A \beta} M_t^i + \frac{a_y}{\beta} M_{t+1}^j - \frac{a_y}{A \beta} M_t^j. \] (15)

From equation (15) see that the stock of armaments of Country \(i\) in any given period of time is a function of its level in the previous period and the level of its adversary's in the current and previous periods. Using the state equation (3) we can also express it in the levels of military spending in each country. Given that all the parameters of equation (15) are positive, this equation describes what may be termed an "arms race" between adversarial countries.

3. A STUDY OF THE CAUSALITY OF MILITARY EXPENDITURES

3.1 Data and Methodology

This section employs a parametric test to determine whether there exists a prima facie causal relationship between the military expenditure series of several nations which have been proposed to be adversaries. In terms of the above model, we explore whether \(M_t^j\) and therefore, \(m_t^j\) enters as an argument in equation (15) and its counterpart in levels of spending. The definition of causality employed here is that given by Granger (1969). If we now denote military spending by \(M\), we will say that the military expenditures of Country \(j\), \(M^j\), prima facie causes Country \(i\)'s expenditures, \(M^i\), if and only if we can predict \(M^i\) better by using the past histories of \(M^j\) and \(M^i\) than by not using the \(M^j\) history and relying only on \(M^i\). If \(M^j\) causes \(M^i\) and \(M^i\) does not cause \(M^j\), then it is said unidirectional causality exists from \(M^j\) to \(M^i\). If \(M^j\) causes \(M^i\) and \(M^i\) causes \(M^j\), then it is said that feedback exists between the two series. Finally, if \(M^j\) does not cause \(M^i\) nor \(M^i\) causes \(M^j\), then either \(M^i\) and \(M^j\) are statistically independent (are not adversaries) or are related contemporaneously.

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Since the application of tests for Granger causality assumes that the variables of the system can be represented as stationary time series we induce stationarity using two methods. The first method is the first-differencing of the non-stationary time series. The second method used is to take the logarithm of the military expenditures series and then to detrend by including a trend variable in the equation to be estimated. We use both methods and report the results yielded by each because there is some debate as to the superior method. Formally, the versions of the Granger test employed here are based on ordinary least squares (OLS) estimation of the following:

\[
\Delta M^i_t = \sum_{k=1}^{N} \alpha_k \Delta M^i_{t-k} + \sum_{s=1}^{J} \beta_s \Delta M^i_{t-s} + \delta_0 + \epsilon_t, \quad (16)
\]

\[
\hat{M}^i_t = \sum_{k=1}^{N} \alpha_k \hat{M}^i_{t-k} + \sum_{s=1}^{J} \beta_s \hat{M}^i_{t-s} + \delta_1 t + \delta_0 + \epsilon_t, \quad (17)
\]

where \(M^i_t\) is real military expenditures, \(\hat{M}^i_t\) is the logarithm of \(M^i_t\), \(\Delta M^i_t\) is the first-difference of \(M^i_t\), \(\delta_0\) is a constant and \(t\) is a trend term. The series employed are annual military expenditures in constant 1980 dollars and exchange rates from 1948 to 1991. For some countries the sample period is smaller because of the unavailability of data. The data for the military expenditures of the dyads studied are obtained from various issues of the SIPRI Yearbook.

The hypothesis that \(M^j\) does not cause \(M^i\) is a test that \(\beta_s = 0\) for all \(s = 1, 2, 3, \ldots, J\). The test \(F\) statistic is calculated by estimating the above in both unconstrained and constrained form (i.e., when \(\beta_s = 0\) for \(s = 1, \ldots, J\)) and is distributed with \(J\) and \(T - k\) degrees of freedom, where \(J\) refers to the number of parameters restricted, \(k\) is the number of parameters estimated in the unrestricted regression and \(T\) refers to the number of years in the sample. Finally, in order to test causality from \(M^i\) to \(M^j\) the dependent variable in each of the above regressions is reversed.

Empirically, estimation of equations (16) and (17) requires the selection of the lag lengths \(N\) and \(J\) for each equation. Many studies choose these lag lengths arbitrarily (see e.g., Sargent, 1976; Sims, 1972), but instead we use Akaike's (1974) criterion (AIC) to choose the optimal lag structure. Using a two step approach suggested by Hsiao (1981), we first select the optimal lag length \(N^*\) for the autoregressive (restricted) model. Then, conditional upon this choice we select the optimal lag length \(J^*\). More specifically, the AIC was calculated for \(k = 1, 2, \ldots, 6\), and the optimal lag \(N^*\) was found. Conditional upon this

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2 Stationarity was checked by an Augmented Dickey-Fuller test as well as the Portmanteau test.

3 Nelson and Kang (1984) report that the results derived by using the second method to account for stationarity is sensitive to the method of detrending and conclude the former is superior. For a comprehensive discussion of tests for causality and a comparison of their small sample properties see Guilkey and Salemi (1982).
EXPLORING POTENTIAL ARMS RACES

**Table 1 Granger Test: First Differenced Model**

Regression of $\Delta M'_i = \sum_{k=1}^{N} \alpha_k \Delta M'_{i-k} + \sum_{j=1}^{J} \beta_j \Delta M'_{i-1} + \delta_0 + \epsilon_i$

<table>
<thead>
<tr>
<th>$\Delta M'_i$</th>
<th>$\Delta M'_i$</th>
<th>Lag on $\Delta M'_{i-k}$ ($N^*$)</th>
<th>Lag on $\Delta M'_{i-1}$ ($J^*$)</th>
<th>$F$-statistics on $\beta_{i-1} = 0$ for all $s$</th>
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<td>2</td>
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<td>1</td>
<td>1</td>
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<tr>
<td>Egypt</td>
<td>Israel</td>
<td>5</td>
<td>4</td>
<td>2.49*</td>
</tr>
<tr>
<td>Israel</td>
<td>Jordan</td>
<td>1</td>
<td>2</td>
<td>3.42*</td>
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<td>Jordan</td>
<td>Israel</td>
<td>1</td>
<td>4</td>
<td>3.71*</td>
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<td>0.67</td>
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<td>3</td>
<td>6</td>
<td>2.26</td>
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<td>Iran</td>
<td>Iraq</td>
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<td>2</td>
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<td>1</td>
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<td>0.51</td>
</tr>
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</table>

NOTES: *Significant at the 5% level.

*The critical value of $F_{5,24}$ at the 5% level is 2.78.

selection, $J^*$ was obtained by calculating the AIC for $s = 1, \ldots, 6$, and choosing the length which minimized it.

4. RESULTS

Tables 1 and 2 present the results from these tests for prima facie causality. Note that the lag structures for the model under consideration ($N^*, J^*$) are given in columns 3 and 4 in the tables. The $F$-statistic for the null hypothesis of no causality, that is, that the $\beta_j$ are not jointly significantly different from zero in the respective model is reported in the final column.

These models yield similar findings in three cases. First, the results show unidirectional prima facie causality for the Arab-Israeli and Pakistani-Indian dyads. The direction of causality of military spending is from Israel to the Arabs and India to Pakistan. Another common result which emerges is that Brazilian and Argentine military expenditures are either independent or they respond contemporaneously. Theoretically, the implication of the above conclusions are

*Holmes and Hutton (1988, 1990) report that parametric causality tests are not robust over the procedure used to transform the variable and the functional forms employed.

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that these countries are not engaged in what is generally termed an arms race, i.e., responding to an external threat, but are instead influenced by domestic or idiosyncratic forces. Recall in our theoretical model that if a country does not perceive the weapon stock of Country $j$ as threatening, then $a_{ij} = 0$ for all values of $M^t_j$ and therefore, $d_i = M^t_i$.

Furthermore, first-differencing the time series yields that two-way causality exists for Israeli-Jordanian military spending and unidirectional causality for two other dyads. We find that Argentina Granger-causes Chilean military spending and that Greece causes Turkey's expenditures. It is interesting to find that Greek and Turkish military spending are related since both are members of NATO. Military coordination and planning within the alliance for these countries presumably varies, and both being member countries would tend to dampen or constrain any potential arms race between them.

As for the results when the series is detrended, we find two-way causality between Israeli-Syrian military spending and unidirectional prima facie causality from Israel's expenditures to Egypt's and from Iran to Iraq. Again, for both models it is found that Israel causes Arab expenditures and that India causes Pakistani spending. These results are consistent with our description of the arming process in these countries as being generated by an arms race.

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**Table 2: Granger Test: Detrended Model**

<table>
<thead>
<tr>
<th></th>
<th>$\tilde{M}^t_i$</th>
<th>Lag on $\tilde{M}^t_i$ ($N^q$)</th>
<th>Lag on $\tilde{M}^t_{i-s}$ ($J^q$)</th>
<th>$F$-statistics on $\beta_{i-s} = 0$ for all $s$</th>
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Notes: *Significant at the 5% level. **Significant at the 1% level.
5. CONCLUDING REMARKS

No attempt has been made to explain the underlying structural process generating the military expenditure series of these adversarial nations. It is quite possible, that if we look at world business cycles and economic growth some country's economy may be more responsive to changes in global economic conditions than others. For example, this may be the case for the Israeli and Indian economies. Using the results derived in Seiglie (1992) the process may operate somewhat as follows. A positive economic shock would be experienced by these economies first, leading to an increase in demand for military weapons and therefore expenditures, since they have been shown to be normal goods. Their adversaries react to this higher spending by immediately increasing their expenditures, and this is reinforced later when they experience the benefits of the positive shock and they react by making further increases. This appears in the military expenditures series as unidirectional causality from the more responsive economies to the less responsive ones.

A similar process could be operational as a result of grants from foreign donors which lead to increases in the demand for normal goods by the recipient nation. For example, an increase in foreign aid (military or non-military since they are partially fungible) by the U.S. to Israel leads to an increase in aid to Israel's opponents by other large donor Arab nations such as Saudi Arabia and the former U.S.S.R. Or transfers to India by the former U.S.S.R. are met by transfers from the U.S. to Pakistan. Again, these two cases would show up in the series as unidirectional causality. These examples highlight the need for theoretical models which account for the effects that economic, political and institutional changes have on the military spending of a nation.

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