The Prisoners' Dilemma and Regime-Switching in the Greek-Turkish Arms Race*

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Abstract

Despite intensive investigation, little evidence has been found for a traditional Richardson style arms race between Greece and Turkey using regression methods. This paper uses an alternative model of the arms race, which treats it as a simple repeated two by two game like Prisoners' Dilemma, in which each country can choose a high or low share of military expenditure. This gives four possible states: both high; Greece high Turkey low; Turkey high Greece low; both low. The strategies of each country, the choice probabilities given the current state, are then estimated using a discrete state regime-switching model, which estimates the transition probabilities between the four states. Various hypotheses about these strategies are tested as restrictions on these transition probabilities. One set of hypotheses is that the countries play 'tit-for-tat' doing what their opponent did in the previous period. This is rejected for both countries. Another hypothesis is that each country plays independently. Each country has its own probabilities of switching between high and low, which do not depend on whether the other country is high or low. This hypothesis is accepted by the data. The estimates of the transition probabilities suggest that the states, high or low shares of military expenditure, are very persistent, with very high probabilities of staying in them. The estimates are not consistent with a traditional 'external' action-reaction explanation of shares of military expenditure, but are more consistent with 'internal' explanations which emphasise bureaucratic and political inertia.

Introduction

The antagonism between the two NATO allies Greece and Turkey has provoked a large amount of defence economics research. Brauer (1999) provides an encyclopaedic survey. However, despite numerous attempts, it has proved difficult to find a robust Richardson type arms-race between the two countries. Regressions estimating dynamic linear reaction functions between the military expenditures of the two countries tend to show wrong signs, lack of cointegration, or extreme sensitivity to minor features of the specification such as the choice of dummy variables or exact definitions of the data, which are themselves subject to serious measurement difficulties. Dunne et al. (1999) contrast the Greece-Turkey case with the India-Pakistan case, where it is fairly easy to get stable, cointegrating reaction functions. As Brauer (1999) points out, the relationship between Greek and Turkish military expenditure shows marked structural changes and this is not suprising because their military expenditures are influenced by many other factors. In principle, one might imagine constructing a well-specified regression equation, which controlled for all these other influences. In practice, this is not an attractive research strategy because all these influences are very difficult to measure precisely. Reflecting this Brauer (1999) says 'Running more single or simultaneous regression equations, even when incorporating all the latest quirks of mathematical statistics, is unlikely to much advance our substantive knowledge'.

Although the Richardson model of the arms race has dominated empirical work, it is not the only model. The natural theoretical starting point is the Prisoners' Dilemma and this is where Sandler & Hartley (1995, section 4.1) start their discussion of arms races. Brauer (1999) notes that the literature on the conflict between Greece and Turkey never addresses it from a game-theoretic view. In this paper we try to remedy that omission and model the process as a simple two by two game. We will treat the arms race as an iterated simple game in which each year, each country can choose either a high or low share of military expenditure for the next period, knowing what the other has chosen this period. We cannot observe the payoffs the countries face but we can observe their strategy: the probabilities with which each country chooses high or low in the next period, conditional on the state in this period. In this paper, we suggest a way to estimate the strategies and test hypotheses about them in the context of such a two by two game. One interesting hypothesis this viewpoint suggests is whether the countries play a tit-for tat strategy: doing in the next period what the other country did this period. This strategy has attracted a lot of attention, since it performs well in iterated Prisoners' Dilemma as long as there is not too much noise, Axelrod (1997). Of course, in this case there is a lot of noise, the impact of other political and strategic factors. Another interesting hypothesis is that the two countries make their decisions independently, i.e. that they are not in fact arms racing. This would be consistent with 'internal' explanations which emphasise bureaucratic or political inertia in military decisions.

We begin by comparing the Richardson and simple game approaches to modelling arms races and providing a non-technical presentation of the estimation method. Then we set out the stochastic specification which we use to estimate the arms-race game, present the estimates and tests and finally make some concluding remarks.

Alternative Approaches to Estimating Arms Races

The Regression Approach

The standard approach to estimating an arms race has been to use linear regression on some variant of the Richardson model. The original Richardson model was a pair of differential equations which simultaneously determined the weapons acquisitions of two countries. Expressing it in discrete time with the addition of stochastic error terms and other determinants the model can be written as:

$$\Delta m_{1t} = a_1 + b_1 m_{2t} + g_1 m_{1t-1} + d_1 z_{1t} + e_{1t} \qquad (1)$$

$$\Delta m_{2t} = a_2 + b_2 m_{1t} + g_2 m_{2t-1} + d_2 z_{2t} + e_{2t}$$

where m_{it}, are some measure of military preparedness of country i in year t, (i = 1,2), and $\Delta m_{it} = m_{it} - m_{it-1}$. The z_{it} are other determinants of military expenditure, the e_{it} are disturbances assumed to be independently normally distributed with constant variances. The existence of an arms race implies that either or both of the b_i should be significantly different from zero. The econometric issues involved in estimating such systems are discussed in Smith et al. (2000). For our purposes there are two features to note. Firstly, it is linear. The military expenditure of one country cannot jump or fall sharply unless: the other jumps, or the z_{it} jump, or there is an outlier in the error terms. But jumps are very characteristic of arms race data and tend to have to be dealt with by adding dummy variables to the specification, i.e. including them in the z_{it}. Secondly, the results tend to be quite sensitive to the specification of the z_{it}, different choices give different results. In the case of Greece and Turkey, there are a large number of possible other influences such as domestic politics, including military coups in both countries; the situation in Cyprus; their perceptions of the Soviet threat before 1989 and their perception of the behaviour of the other NATO allies. In addition Greek military expenditure has been affected by events in former Yugoslavia and Turkish military expenditure by the war with the Kurds, Islamic fundamentalism and its relations with its Eastern neighbors. Thus one could specify a large number of possible alternative influences, most of which would be difficult to measure. For a single z_{it} in each equation, the system above has 8 regression parameters and 3 variance-covariance parameters. With longer lags and more other factors, the number of parameters required can grow rapidly. Given this it may be more attractive to regard all these factors as combining stochastically to influence the probabilities of particular choices.

The Game Theory Approach

The alternative game-theory approach imagines each country choosing either high or low military spending, with costs or payoffs which depend on the choice of the other. This gives four possible states, shown in the matrix, with associated costs or payoffs:

		Turkey: High	Turkey: Low
Greece	High	CG_1, CT_1	CG_2, CT_2
	Low	CG_3, CT_3	CG_4, CT_4

So in state 1, both choose high military spending, the payoffs are costs of CG_1 to Greece and CT_1 to Turkey. Given the payoffs, the countries choose a strategy. This is a repeated or iterated game, played every year. One can imagine that during the annual budgetary cycle each country chooses its strategy, high or low military spending for the next year, knowing what its opponent chose for this year, but not what the opponent will do next year. The strategy they choose for the next year will be conditional on the state this year. A familar example of a conditional strategy is Tit for Tat: do in period $t+1$ what your opponent did in t. This is a pure strategy, specifying choosing either high or low for $t+1$ conditional on the state in period t. Countries could also follow mixed strategies, choosing high with some probability p and low with some probability $(1-p)$. Mixed strategies are optimal for quite a wide range of games. We will assume that countries play conditional mixed strategies: choosing a probability of being high or low next year depending on the current state. Our aim is to estimate these strategies and see what light it sheds on the interaction between Greek and Turkish military expenditures. This is the reverse of the usual approach in game theory. The usual approach is to specify the payoffs and then determine the optimal strategy. Here we do not observe the payoffs; but we do observe the strategies the players adopt: whether they choose high or low. This allows us to make inferences about the nature of the game.

This game approach differs from the regression approach in a number of ways. Firstly, this approach naturally handles non-linearities and structural change - jumps from high to low - which the regression approach does not. Secondly, all the other factors, which are treated as deterministic influences in the regression approach are treated stochastically: reflected in the conditional probabilities of choosing high or low. Thirdly, military expenditures are now discrete, taking two values high and low, rather than continuous as in regression models. Obviously, this approach can only be applied where it is sensible to treat the outcomes as dichotomous. Therefore, it could not be applied to military expenditures which are trended upwards and there is no natural classification into high and low. However, it can be applied to shares of military expenditure. Figure 1 plots the share of military expenditure in Greece and Turkey, taken from SIPRI, for the period 1958 1997. It is clear that there have been marked changes both in the level of the Greek and Turkish shares and the relationship between them. To a first approximation the series appear to be well described by variations around distinct high and low levels, so modelling them in terms of a simple high-low choice plus some random errors may not be too unrealistic.

FIGURE 1 ABOUT HERE

Measurement

The choice of the appropriate measure of military preparations in arms race models has been a matter of great controversy. Brauer (1999) discusses the issues in the case of Greece and Turkey and reviews the various choices in the literature. For a country involved in an enduring hostility the focus must be on military capability: the probability of prevailing in a conflict. This will be a function of its levels of forces, measured by military capital (troops, stocks of weapons etc.), relative to those of its opponent. However, capability will also depend on how well those forces are used; a matter of strategy, tactics, training and leadership. Measuring military capability ex ante, before an actual conflict, is inherently problematical. Measuring forces is easier, but the long list of elements which go to make up a force structure cannot be well summarised by a single number. In the case of Greece and Turkey the issue of forces is complicated by the ‘cascading’ of old equipment to them by other NATO countries after the Conventional Forces in Europe Treaty (CFE) treaty. The level of forces reflects depreciated past stocks plus investment paid for by military expenditure. Payment for troops represents investment in human military capital. Again the conversion of military expenditure into effective forces is not a straightforward process, reflecting the efficiency of the arms production industries and personnel policies (e.g. the use of volunteers or conscripts). There are many cases where high military expenditures have not produced capable forces. Governments determine the level of military expenditure by first making a strategic assessment of the threat and of the effectiveness of military spending in meeting the threat. It then balances the strategic assessment against the opportunity costs of the military spending, given available national output. The outcome of that political-economy calculation is the choice of a share of output to devote to military spending. The military may get a smaller share of the pie because the threat is thought to be less; or because military expenditure appears less effective at meeting the threat than alternative measures such as confidence building initiatives; or because the opportunity costs appear greater. While the share of military expenditures in output is clearly a measure of priorities not capabilities, arms races should be reflected in priorities, thus it is an interesting measure in this context.

Estimation

Estimation of the strategies in a simple two by two game in which each side choses high or low can be done using the bivariate Hamilton discrete state switching model. This has been widely used in economics (see Hamilton, 1988, 1989, 1990 and 1996; Sola & Driffil, 1994; Ravn & Sola, 1995) to capture movements in time series due, for example, to changes in macroeconomic policies or other shocks. However, to our knowledge the bivariate regime-switching model has not been used to estimate strategies in a simple game or given this game-theoretic interpretation.

Given that the discrete regime-switching technique has not been widely used in peace research, it may be useful to provide a non-technical explanation.

Univariate Case

To begin, consider the univariate case. We could look at the time-series for the Greek share of military expenditure and note that it roughly divides into two regimes or states: high, say above 5%, and low, 5% or below. We could then measure the mean value for the high state (the observations above 5%), m_H and the low state m_L and calculate the variance around these means. From the variance we can calculate the standard error of the means and this would allow us to test whether the two means are significantly different. At any point in time when Greece is in the state of a low share of military spending, there is some transition probability p_L of it staying in that state and some probability $(1-p_L)$ of the share jumping to the high state. We could measure p_L by the number of years that Greece was in the low state in year t and stayed in the low state in year $t-1$ as a proportion of the total number of years it was in the low state. Similarly, if it is in the high state there is some probability p_H of it staying in that state and some probability $(1-p_H)$ of jumping to the low state. We can measure p_H in the same way as p_L This allows us to estimate the two by two transition matrix, which gives the probabilities of moving between states:

		State in t	
		High	Low
State in $t+1$	High	p_H	$(1-p_L)$
	Low	$(1-p_H)$	p_L

If $p_L = p_H$ then half the observations would be in the high state and half in the low state. If p_L were much larger than p_H then one would observe more years in the low state. Notice $p_L + p_H$ do not have to sum to unity. Both states could be very persistent, say $p_L = p_H = 0.9$. Then one would observe, over a long sample equal time in each state, but very few switches between states. If both states were not very persistent, say $p_L = p_H = 0.2$ one would observe equal time in both states but with lots of switches between them. Of course, all this analysis is conditional on our initial choice of a discrete threshold of 5%. However, we do not need a discrete threshold. Given estimates of the high and low means and the variance of the errors around them and assuming normality, one can estimate the probability that a particular observation is in the high state or the low state. Thus each observation has a probability of being in the high state, rather than putting them in the high state with probability one if the share is over 5%. One can then choose estimates of the 5 free parameters (high and low means, the variance of the errors around those means and the associated transition probabilities, p_L and p_H) that are most likely to have generated the observed sample of data. These maximum likelihood estimates are obtained by numerical optimisation. On the basis of those parameter estimates, one can also calculate the filter probabilities for each year, the probability that they are in a high state or a low state. So for instance $\Pr(s_t = H)$ gives the probabilities of being in the high state, given the history of the process. If the two state model is a good description of the process, these filter probabilities should be close to one or zero, indicating a clear separation between the two regimes. Notice these filter probabilities, which differ from year to year are distinct from the transition probabilities, which are constant over time.

Bivariate Case

In the bivariate case there are four states rather than two as in the univariate case. The four states are: (1) both high, (2) Greece high, Turkey low, (3) Greece low, Turkey high and (4) both low. Then in addition to the Greek means for the high and low state and the Greek variance, the Turkish means for the high and low states and the Turkish variance have to be estimated. In addition, the shocks, representing the unmeasured influences, to the two countries are unlikely to be independent, so the covariance between the shocks hitting the two countries needs to be estimated. Since both are members of NATO and faced a common Soviet threat, the shocks are likely to be positively correlated. In the univariate case, the transition matrix has 4 elements, two of which are free. In the bivariate case, the transition matrix has 16 elements, 12 of which are free. The evolution of the series is described by a four by four transition matrix, Π, the elements of which, p_{ij} give the probability of moving from state i in period t to state j in period $t+1$; $i, j = 1,2,3,4$. So p_{11} gives the probability of staying in state 1, both countries having high shares of military expenditure in the next period, given they both have high shares this period. Because the system must move to one of the four states in the next period, each of the four columns of the transition matrix sums to unity, as the columns did in the univariate case above. Thus the unrestricted transition matrix has 12 free probabilities which can be estimated together with the mean shares of military expenditure in the high and low states for each country, the variance of the shocks for each country and the covariance between the shocks to each country. This is 19 free parameters in total. The parameter estimates are obtained by maximising the likelihood function as in the univariate case. On the basis of the estimates, one can calculate the filter probabilities for each year. This gives the probability of being in each of the four states, given the history of the process, for instance $\Pr(s_t = 1)$ gives the probability of both countries being high in a particular year. If the four state model is a good description of the process, these probabilities should be close to one or zero, indicating a clear separation between the four regimes.

The unrestricted case allows unlimited dependence in the decisions of the two countries. We also consider three restricted transition matrices. The first assumes that each country determines its share of military expenditure independently. If two events A and B are independent, the probability of both happening is the product of the probabilities of each of them happening: $P(A \cap B) = P(A)P(B)$. Similarly, the probability of staying in state 1, both high, is just the product of the probability of Greece staying in the high state and the probability of Turkey staying in the high state: $p_{11} = p_{GH} p_{TH}$. With independence, there are only four free probabilities: that of Greece staying in a high state, p_{GH}, Turkey staying in the high state, p_{TH}; Greece staying in a low state, p_{GL} and Turkey staying in the low state, p_{TL}. In the independent case the transition matrix Π^{indep} takes the form:

$$\begin{bmatrix} p_{GH}p_{TH} & p_{GH}(1-p_{TL}) & (1-p_{GL})p_{TH} & (1-p_{GL})(1-p_{TL}) \\ p_{GH}(1-p_{TH}) & p_{GH}p_{TL} & (1-p_{GL})(1-p_{TH}) & (1-p_{GL})p_{TL} \\ (1-p_{GH})p_{TH} & (1-p_{GH})(1-p_{TL}) & p_{GL}p_{TH} & p_{GL}(1-p_{TL}) \\ (1-p_{GH})(1-p_{TH}) & (1-p_{GH})p_{TL} & p_{GL}(1-p_{TH}) & p_{GL}p_{TL} \end{bmatrix} \quad (2)$$

The second and third restricted versions assume that one or other country plays tit-for-tat and follows the leader. That is that Greece (Turkey) is always in the state that Turkey (Greece) was one period ago. In this case there are only two free probabilities, that of the leader staying in the high state or of the leader staying in the low state. Suppose Greece leads and Turkey plays tit-for-tat, then Turkey will always be in the state Greece was one period ago. There are then only two free probabilities, that represent Greek strategy, p_{GH} and p_{GL} and the transition matrix $\Pi^{G/T}$ is given by:

$$\begin{bmatrix} p_{GH} & p_{GH} & 0 & 0 \\ 0 & 0 & 1-p_{GL} & 1-p_{GL} \\ 1-p_{GH} & 1-p_{GH} & 0 & 0 \\ 0 & 0 & p_{GL} & p_{GL} \end{bmatrix} \quad (3)$$

If Greece is high this period, Turkey will be high next period, so any state with Turkey low has zero probability. What drives the system is the probabilities of Greece staying in the high or low states. Similarly if Turkey leads Greece, the transition matrix $\Pi^{T/G}$ is:

$$\begin{bmatrix} p_{TH} & 0 & p_{TH} & 0 \\ 1-p_{TH} & 0 & 1-p_{TH} & 0 \\ 0 & 1-p_{TL} & 0 & 1-p_{TL} \\ 0 & p_{TL} & 0 & p_{TL} \end{bmatrix} \quad (4)$$

Stochastic Representation

Consider a vector $x_t = [G_t, T_t]'$ (where G_t and T_t denote respectively the shares of military expenditure in Greece and Turkey) which is generated by a vector stochastic process given by:

$$x_t = m_{s_t} + u_t, \quad (5)$$

$$m_{s_t} = m_1 s_{1t} + m_2 s_{2t} + m_3 s_{3t} + m_4 s_{4t}, \quad (6)$$

where:

$s_{it} = 1,$ if the state is i at time t,

$s_{it} = 0,$ otherwise.

Accordingly, the means of the series are modelled as:

$$m = \left(m_{S=1} = \begin{bmatrix} G_H \\ T_H \end{bmatrix}, m_{S=2} = \begin{bmatrix} G_H \\ T_L \end{bmatrix}, m_{S=3} = \begin{bmatrix} G_L \\ T_H \end{bmatrix}, m_{S=4} = \begin{bmatrix} G_L \\ T_L \end{bmatrix} \right), \quad (7)$$

where the indices H and L refer to 'high' and 'low'. The four-state Markov process can be generated by assuming that each series, G_t and T_t follows a two-state Markov process. Define $x_t = [G_t, T_t]'$ with a state-dependent mean, m_s, given by

$$m_{s_t} = \begin{bmatrix} a_0 + a_1 s_t' \\ b_0 + b_1 s_t'' \end{bmatrix}, \tag{8}$$

where s_t' can take the value 0 or 1, and s_t'' can take the values of 0 and 1, where s_t' and s_t'' are independent of u_t Thus the Greek mean is a_0 in the low state and $a_0 + a_1$ in the high state. We assume that the errors are independent and normally distributed: $u_t \sim N(0, \Sigma)$ and $x_t \mid (s_t = s) \sim N(m_s, \Sigma)$ for $s = 1,2,3,4$ with Σ being the associated variance-covariance matrix, which does not change between regimes. The regime is indexed by s_t and the states are modelled as the outcome of an unobserved discrete-time, discrete-four-state first-order Markov process independent of u_{t-i} for all $i \neq 0$.

In the general case the transition matrix will be given by a 4×4 matrix, Π, with elements p_{ij}, where $p_{ij} = \Pr(s_t = i \mid s_{t-1} = j)$, $i, j = 1,2,3,4$, and each column of the transition matrix sums to unity and all elements are nonnegative. The unrestricted model allows for correlation between the states s_t' and s_t''. We can impose the various restrictions discussed in the last section on the transition matrix to test particular hypotheses about the strategies the countries follow. The model assuming independence involves 8 restrictions, since only four free probabilities, p_{GH}, p_{GL}, p_{TH} and p_{TL} are required rather than the twelve free probabilities required in the unrestricted model which allows for correlation between the states. The two tit-for tat models involve 10 restrictions since only two free probabilities are required.

The restrictions can be tested with a likelihood ratio test statistic $LR = 2(MLL_U - MLL_R)$, where MLL_U is the unrestricted maximised log-likelihood and MLL_R the restricted. Under the null hypothesis that the restrictions are true LR is asymptotically distributed as a $c^2(r)$ where r is the number of restrictions. We can also compare models using selection criteria which weight fit, measured by the maximised log-likelihood for a particular model, say i, MLL_i and the complexity measured by the number of parameters, k_i. As one removes restrictions (adds variables to the model) the maximised log-likelihood, like R^2 in linear regression models, always increases. We need to adjust for the loss in degrees of freedom in estimating extra parameters, just as $\overline{R}^2$ does in the linear regression model. Two popular criteria are the Akaike Information Criterion, $AIC_i = MLL_i - k_i$, and the Schwarz Bayesian Criterion, $SBC_i = MLL_i - 0.5k_i \ln(T)$ where T is the sample size. These are widely used for problems like selecting lag orders in ARIMA models or VARs. For nested models these are equivalent to likelihood ratio tests using different critical values. For instance, for a likelihood ratio test with one restriction the 5% critical value is 3.88. One would reject the restricted model if *LR* was greater than that. For the *AIC* the critical value would be 2. For the *SBC* the critical value would be ln(T) which for 40 observations is 3.69. As the sample size grows the *SBC* penalises the extra parameters more strongly. One attraction of model selection criteria is that, like $\overline{R}^2$ they can be used even when some of the models are non-nested. In this case none of the restricted versions are nested within each other, although all the restricted models are nested within the general model.

Empirical Results

In this section we apply the technique outlined above to SIPRI annual data on Greek and Turkish shares of military expenditure 1958-1997. First, the unrestricted Markov structure is estimated, which allows for twelve free probabilities in the transition matrix. The first column of Table I gives the estimates of the other parameters for the general, unrestricted, model. The Greece Low state has a mean military expenditure of 4.37% of GDP, the Greece High state has a mean 2.16 percentage points of GDP higher, and this shift is very significant, with a t ratio over 15. The variance of the Greek shocks is 0.182. The Turkey Low state has a mean share of military expenditure of 3.86% with the Turkey High state 1.44 percentage points higher, again the difference between the high and low means is very significant. Turkey shows a higher variance around its means than does Greece, the standard deviations of the shocks, square roots of the variances, are 0.43 for Greece and 0.55 for Turkey. Thus the variations in the share of military expenditure around the means are about a half a percent of GDP. There is a positive covariance between the shocks to the two countries, that is on the margin of significance at the 5% level.

TABLE I AND II ABOUT HERE

To describe the process we can calculate the filter probabilities of being in each state conditional on the history of the process: $\Pr(s_t = s \mid x_t, x_{t-1}, ..., x_1)$, where $x_t = [G_t, T_t]'$ and $s = 1,2,3,4$. Figure 2 plots the filter probabilities of being in each state of the four regimes from the unrestricted, general, model. For instance, the top left quadrant of Figure 2, gives the probability in each year of being in state 1, both high. This probability is zero, up to 1973, jumps to about 0.7 in 1974 (the invasion of Cyprus) and to one in 1975. It stays at one or close to one till 1983, drops to 0.1 in 1984, and then is zero for the remainder of the period. Table II gives the dates of the regimes based on a division at $\Pr(s_t = s \mid x_t, x_{t-1}, ..., x_1) = 0.5$. The separation into regimes is very clear-cut, the probabilities are close to zero or one, and matches the impression of the time series. The series starts with both being low (state 4); switches in 1961 (about the time of a Turkish military coup) to Greece low, Turkey high (state 3); stays in that state till 1967 (the year of the Greek military coup), when it switches back to both low (state 4) until 1973. With 1974 (the invasion of Cyprus) it switches to both high (state 1) until 1983 (the end of a period of military rule in Turkey). From 1984-1988 Greece is High, Turkey Low (state 2). From 1989 (the end of the Cold War) to 1997 shares of military expenditure are in state 4 (both low). Although there is some correspondence, it is interesting that the division into states does not match up neatly with military rule: 1967 to 1974 for Greece and 1960-61, 1971-73 and 1980-1983 for Turkey.

FIGURE 2 ABOUT HERE

The first restriction tested is that the probability of switching between states in each country is independent. Each country has its own probabilities of switching, which does not depend on the state the other country is in. This reduces the number of free parameters in the transition matrix from 12 to 4, two for each country. This would be the case if each was responding to its own domestic political economy or strategic concerns, which determined the probability of staying in the high state or the low state, without regard for whether the other was in a high or low state. Imposing independence reduces the maximised log-likelihood from 15.2

to 10.6, see Table III, which is not a significant reduction at any conventional level. The Likelihood ratio test would give $LR = 2(15.2 - 10.6) = 9.2$ whereas the 5% critical value for $c^2(8)$ is 15.51. Both the *AIC* and the *SBC* agree with the Likelihood Ratio test in choosing the model with independence relative to the general model. The estimates of the coefficients and the assignment of the sample into the four states are hardly changed by the restriction of independence, so are not reported. Furthermore, the estimates of the transition probablities appear to be persistent and highly significant with values respectively given by $p_{GH} = 0.96$, $p_{GL} = 0.95$, $p_{TH} = 0.86$ and $p_{TL} = 0.93$. If the two countries get into state 4 (low-low), there is a high probability of them staying there: $p_{44} = p_{TL} p_{GL} = 0.95 \times 0.93 = 0.88$. It should be noted that, as Ravn & Sola (1995) point out, independence of the two countries transition probabilities does not imply that the two series are independent or that they cannot change regime simultaneously; it simply means that the unobserved states that generate the changes in means can be modelled as independent Markov chains. In this case, there will be positive covariance through the error terms for instance, shocks (e.g. Cyprus or, in the past, increased Soviet threat) will hit them both in the same way.

TABLE III ABOUT HERE

The second and third restrictions tested were that one country determined its state independently and the other played tit-for-tat, playing what the leader had played in the previous period. The Greece leads Turkey or Turkey leads Greece restrictions lead to a large reduction in the maximised log likelihood. Using Likelihood Ratio tests both restrictions are rejected at the 1% level. For the hypothesis Turkey leads Greece, the test statistic is 40.2 compared to a 1%

$c^{2}(10)$ of 23.21. For the hypothesis Greece leads Turkey the test statistic is 30.9 with the same critical value. The *AIC* and *SBC* also suggest that the independent model is preferred to the leader-follower models. Even though they are rejected, the restricted estimates are of some interest. The estimates for the Greece leads Turkey case are given in the second column of Table I and the state probabilities are given in Figure 3. In addition to rejection on the test there are a number of other features which suggest the model is unsatisfactory. Firstly, the allocation into regimes is less clear cut. If we allocate years to regimes on the basis that the probability is greater than 0.5, only two states are predicted: both high or both low. They are in the both high regime 1975-1988 and in the both low regime otherwise. Secondly, under the Greece leads Turkey restriction, the difference between the high and low state for Turkey is only just on the margin of significance, rather than clearly determined as it was in the unrestricted and independent models. Thirdly, the covariance between the errors is not significantly different from zero. On all criteria the independent decision model is clearly superior.

FIGURE 3 ABOUT HERE

Conclusions

The simplest possible model for an arms race is one in which each country chooses either a high or a low share of military expenditure in output. Usually, in such games the payoffs are assumed to be those of the Prisoners' dilemma. While we cannot observe the payoffs, we can estimate the countries' strategies in such a game: the probabilities that each country will choose a high or a low share of military expenditure for next year, conditional on the current state, the shares of military expenditure of them and their opponent in this year. The estimation method is the widely used bivariate Hamilton regime-switching model. In this paper we have used this method to estimate the strategies played by Greece and Turkey over the period 1958-1997. Despite its simplicity, this model seemed to capture the data reasonably well, with the difference between the high state and the low state being very significantly different from zero in both countries and the division of the sample into the four possible states very clearly defined. The simplicity of the model allows us to test sharp hypotheses suggested by game theory, which is difficult to do in a regression framework. For instance, it is known that tit-for-tat, which involves doing what the other side did in the previous period, is a very robust strategy in repeated Prisoners' Dilemma games. Two cases were considered. In one case Greece leads and Turkey follows, playing tit-for-tat, in the other Turkey leads and Greece follows. The tit-for-tat hypotheses are rejected by Likelihood Ratio tests both for Turkey leads Greece and Greece leads Turkey. Another interesting special case is where the two countries play a mixed strategy in the game, but determine their probabilities of high or low shares of military spending independently, ignoring the information in the current choice of the other. This restriction reduces the number of free parameters in the transition matrix from 12 to 4 (the probabilities of each country staying in the high state or the low state). This hypothesis is accepted by a Likelihood Ratio test. Model selection criteria also suggest this is the best of the four models estimated. The independence restriction can be interpreted either as the switches are determined by other factors than the Greece-Turkey antagonism or each country plays a mixed strategy which does not condition on the other side's behaviour. Neither interpretation provides much support for a traditional action-reaction type arms-race in which military expenditure is a response to an external threat represented by the other countries military spending. Instead the estimates of the transition probabilities are more consistent with an internal explanation in which political or bureaucratic inertia mean that once either country gets into a particular state, high or low, there is a high probability that it will stay there. Currently, this is quite an optimistic conclusion. By historical standards (though not by comparison with other NATO countries) both Greece and Turkey are spending a low share of output on the military. The estimates suggest that this relatively low equilibrium has a high probability of persisting, just under 90% a year. This low-low state may reinforce the recent confidence building measures between the countries.

We are not aware that the regime switching model has been used to estimate strategies in simple games before. However, in cases such as this where there are two players, the choice variable is stationary and the values the choice variable takes can be approximated by high and low regimes, it seems a useful procedure. It is also interesting that a very simple theoretical model translates into quite a complicated empirical model. To apply the simple unrestricted two by two game to data on observed choices requires 19 free parameters. However, these parameters can be related to game theory strategies in a straightforward way, which is not the case with regression based arms race models. Theories about the possible strategies followed by the players, such as independence or tit-for-tat, can reduce the parameter space substantially. Of course, different problems require different models and there are other arms races where the traditional Richardson regression approach will be more appropriate than the simple game approach.

References

Axelrod, Robert, 1997. *The Compexity of Cooperation*. Princeton: Princeton University Press.

Brauer, Jurgen, 1999. 'Turkey and Greece: A comprehensive review of the defense economics literature', forthcoming in Christos Kollias and G Gunluk-Senesen eds, Greece and Turkey in the 21st Century, available on www.aug.edu/ ˜ sbajmb. A shorter version will appear as: 'Survey and Review of the Defense Economics Literature on Greece and Turkey: What have we learned', *Defence and Peace Economics*.

Dunne, J. Paul, Eftychia Nikolaidou & Ron P. Smith, 1999. 'Arms Race Models and Econometric Applications', mimeo Middlesex University Business School.

Hamilton, James D., 1988. 'Rational expectations econometric analysis of changes in regimes: An investigation of the term structure of interest rates', *Journal of Economic Dynamics and Control* 12(2): 385-423.

Hamilton, James D., 1989. 'A new approach to the economic analysis of nonstationary time series and the business cycle', *Econometrica* 57(2): 357-384.

Hamilton, James D., 1990. 'Analysis of time series subject to changes in Regime', *Journal of Econometrics* 45(1-2): 39-70.

Hamilton, James D., 1996. 'Specification testing in Markov-switching time series models', *Journal of Econometrics* 70(1): 127-157.

Ravn, Morten O. & Martin Sola, 1995. 'Stylized facts and regime changes: Are prices procyclical?', *Journal of Monetary Economics* 36(3): 497-526.

Sandler Todd & Keith Hartley, 1995. *The Economics of Defense*. Cambridge: Cambridge University Press.

Smith, Ron P., J. Paul Dunne & Eftychia Nikolaidou (2000). ‘The Econometrics of Arms Races’, *Defence and Peace Economics* 11(1): 31-43.

Sola, Martin & E. John Driffil, 1994. ‘Testing the term structure of interest rates from a stationary Markov-switching VAR’, *Journal of Economic Dynamics and Control* 18(3-4): 609-628.

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TABLES and FIGURES

Table I. Parameters of the Models for Greece, G, and Turkey, T

	General Model	Greece leads Turkey
Low Mean of G	4.371	4.398
	(39.233)	(45.146)
Difference L-H of G	2.164	2.112
	(15.299)	(12.830)
var (G)	0.182	0.184
	(2.844)	(3.575)
Low Mean of T	3.857	4.264
	(27.088)	(19.279)
Difference L-H of G	1.443	0.566
	(8.580)	(1.930)
var (T)	0.304	0.506
	(2.701)	(3.223)
cov (G, T)	0.161	0.027
	(1.919)	(0.299)

Note: t ratios in parentheses

Table II. Dating of Regimes

	General Model	Greece leads Turkey
State 1	1974-1983	1975-1988
State 2	1984-1988	-
State 3	1961-1967	-
State 4	1958-1960	1958-1974
	1968-1973	1989-1997
	1989-1997	

Table III. Complexity-penalized Likelihood Criterion

MODEL	MLL	k	AIC	SBC
General	15.184	19	-3.816	-19.860
Independent	10.621	11	-0.379	-9.668
GlT	-0.279	9	-9.279	-16.879
TlG	-4.914	9	-13.914	-21.514

Note: k = number of estimated parameters

Figure 1. Greece and Turkey: shares of military expenditure, percent

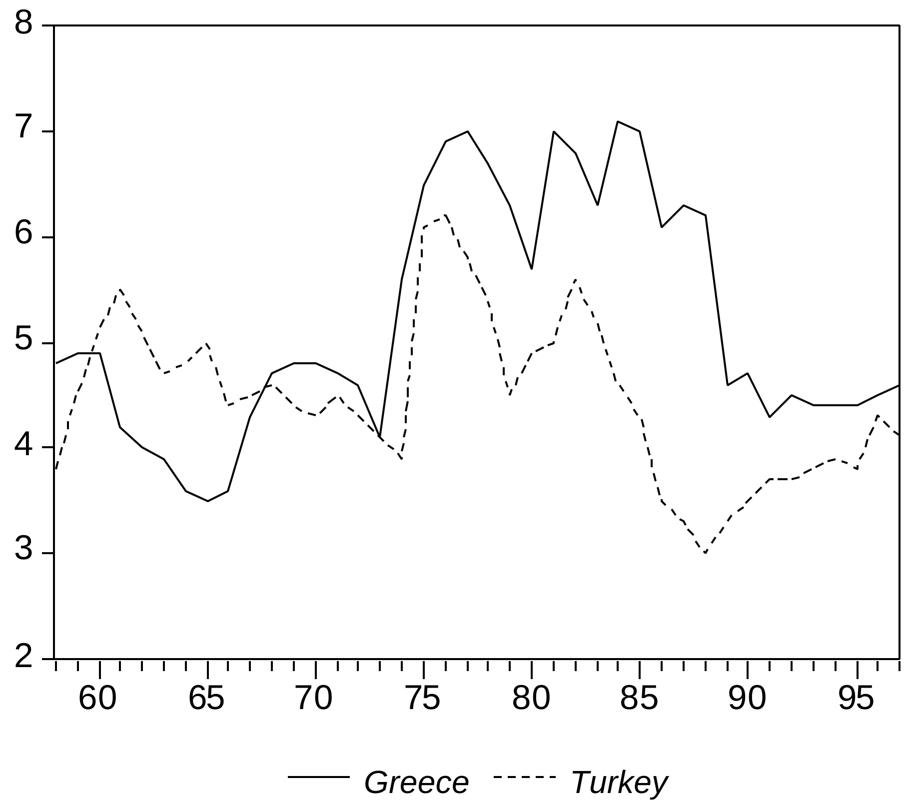

Figure 2. Filter Probabilities for each State in the General Model

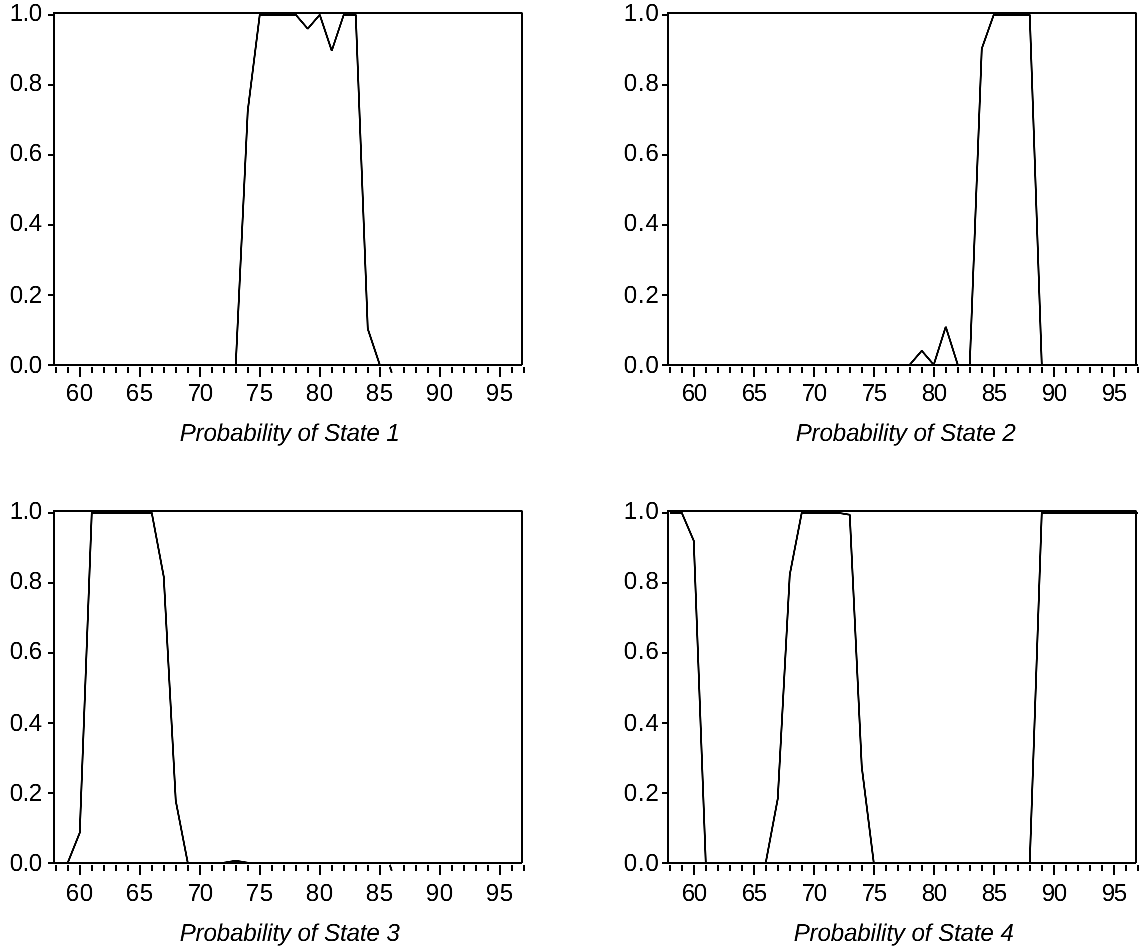

Figure 3. Filter Probabilities for each State in the GIT Model