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Le Désarmement pour le Développement
ARES, Défense et Sécurité
Grenoble, Lyon, 1986

Summary : Econometric model have been widely used to analyse both arms races and the economic impact of military expenditure, in order to provide quantitative estimates, hypothesis tests and analysis clarification. The main problem is the validation of the hypothesis, the quality and availability of data, and the model pertinence. It is particularly difficult to cover all the influences of arms, to show the real dynamic of the process. Econometric model needs to be conducted with caution, but it is an essential method of investigation. It reveals further complications and factors that need to be taken into account, leading to more sophisticated explanations able to cover a wider variety of instances.

Les modèles économétriques ont été largement utilisés pour analyser à la fois les courses aux armements et l'impact économique des dépenses militaires, afin de fournir des estimations quantitatives, des tests d'hypothèses et des clarifications d'analyse. La validation de l'hypothèse, la qualité et la disponibilité des données et la pertinence du modèle sont les principaux problèmes à résoudre. Il est particulièrement difficile de couvrir toutes les influences économiques et politiques des armes, pour montrer la vraie dynamique du processus. Le modèle économétrique doit être conduit avec prudence, mais il s'agit d'une méthode d'investigation essentielle. Il révèle d'autres complications et facteurs qui doivent être pris en compte, conduisant à des explications plus sophistiquées capables de couvrir une plus grande variété de solutions.

Econometric model, military expenditures, race models
Modèles économétriques, dépenses militaires, modèles de course aux armements

THE USE OF ECONOMETRIC MODELS IN THE ANALYSIS OF ARMS RACES AND DISARMAMENT

by J. FONTANEL and R.P. SMITH (*)

1. Introduction

Econometric models have been widely used to analyse both arms races and the economic impact of military expenditure. If used with care, they can play an important role in providing quantitative estimates, testing hypotheses, and clarifying the analysis. Care is required because there are a range of problems in the specification, estimation and validation of the models. These problems, which often appear highly technical, make interpretation of the results rather difficult. For instance, there has been a large amount of quantitative work on the question of whether military expenditure increases or reduces growth in developing countries. Papers include: Deger & Smith (1983), Faini et al (1984), Ball (1983) and Fontanel (1982). This econometric analysis has made an important contribution to our understanding of the processes involved. But its main contribution has not been to provide a simple yes-or-no answer to the question, but to show that the question needs to be posed more precisely.

A second problem arises because the models are scattered widely through the economics, peace research, international relations and political science literature and tend to differ in the type of data used, the statistical procedures employed, and the theoretical structure adopted. These differences make comparison difficult. This paper discusses some of the econometric issues involved in the specification of military models, the economic issues are discussed in more detail in Fontanel & Smith (1985) and Fontanel (1984).

In modelling terms analysis of arms-races poses less problems, because most of the models in the literature share a common theoretical basis, derived from the Richardson Equations. Section 2 discusses the estimation of these. Modelling the economic impact of military expenditure is more difficult because of the large variety of theories available. Section 3 discusses this problem in terms of theory, data and models.

2. Arms races

Just as Supply and Demand Curves have structured thinking about markets, most recent analytical work on arms races has been structured by two equations proposed by Lewis Fry Richardson (1960). The Richardson equations relate the evolution, over time (t), of the level of Arms, $Ai(t)$, for countries $i = 1,2$; by an action-reaction process of the form:

$$dA1\,(t)\,dt = a1 + b1.A2(t) - c1.A1(t)$$

$$dA2\,(t)\,dt = a2 + b2.A1(t) - c2.A2(t)$$

The lower case letters denote parameters. The a's measure the exogenous increases in arms in each country; the b's the feedbacks as increases in the arms of one country stimulate the other to increase its arms; the c's the stabilising fatigue effect by which larger stocks of arms reduce further increases. This model is in continuous time, but it can also be presented in discrete time and given a familiar economic stock-adjustment interpretation, where

$$Ai^*_t = di + ei.Aj_t \quad ; \text{ and}$$

$$Ai_t - Ai_{t-1} = fi\,(Ai^*_t - Ai_{t-1})$$

$$i = 1,2$$

with Ai^* being target levels or arms in period t and fi being adjustement coefficients.

This simple framework, with its analogies to mechanical and ecological models, has proved tremendously powerful in organising thought about military interactions; raising research questions and allowing systematic discussion and comparison of the results. Estimation and testing are made easier because we start from a clearly specified theoretical framework, and since we are dealing with a dynamic process it is obvious that time series data are required.

Despite the advantages of starting from a clearly specified theory and data type, advantages that we will not have when we come to examine the economic impact of military expenditure, there are still a number of problems in making this theory operational, that is putting it in a form suitable for estimation. Firstly, it is not clear how the Ai should be measured. They could be physical stocks (number of missiles, warheads, battleships, etc) or monetary flows of military expenditure, or perhaps shares of military expenditure in output.

Whichever measure is chosen, the data are likely to be measuread subject to substantial errors. The secrecy surrounding security matters, the difficult definitional problems involved, and the incentives for misrepresentation by the Governments concerned means that the data are likely to be unreliable. The problems with the data are discussed in a number of reports by the UN group of experts on the measurement of military expenditure, e.g. the paper by Cars & Fontanel in Blackaby and Schmidt (1986). This problem is severe both in the case of arms race models and measuring the economic impact of military expenditure. Measurement errors raise a number of very difficult statistical problems, and there are no simple solutions.

Secondly, the dynamics of the process need to be elaborated. How rapidly do the two countries react. There are perception lags, before one country recognises what the other has done and decision delays before it makes its mind up what to do. The countries also form expectations (rational or adaptive), and there is the possibility of deception of one country by another (1). All these features have to be represented in a specific adjustment process, with distributed lags and expectations formation mechanisms.

Thirdly, the model clearly does not cover all the influences on arms. Domestic politics, alliance interactions, the machinations of the military industrial complex all interact with the action-reaction feedback processes. There are a variety of ways in which these other influences could be represented. However, even after these extra variables have been included, there will remain an equation residual, a component of the dependent variable that has not been explained (2).

Fourthly, the relationships above, were assumed to be linear and symmetrical, that is with the same form of equation in each country. But it may be necessary to examine alternative functional forms, and different specifications for each country equation. There is also a difficulty that the parameters of the model, arising from game-theory or strategic calculations by the countries concerned, are unlikely to be stable over time. Thus it is clear that there are a variety of possibilities for the specification of data, equations, dynamics, and residuals. The estimates that are obtained will be very sensitive to the choices made. In certain circumstances the model may not even be identified, in which case it becomes impossible to infer the values of the parameters from the data. To a certain extent, the quality of the results can evaluated by a range of specification tests (3).

Although specification tests are very useful it may be the case that the data available do not distinguish between rival models. The econometric results in McGuire (1977 & 1981) and Desai & Blake (1981), provide a good example. These papers are all concerned with the arms race in nuclear weapons between the US and USSR, and use the same data. The only real difference between the models is in their dynamic specification, yet they give very different equilibrium solutions and have very different implications.

Arms races appear a pervasive phenomena, from the competitive accumulation of nuclear and conventional weapons by the super-powers to the regional competitions between countries like Greece and Turkey; Israel and the Arab States; and India and Pakistan. Arms races, thus, seem to be a characteristic form of international interaction. However, in general the quantitative

evidence for the Richardson type action-reaction model has not been compelling, except perhaps for the relatively rare cases where there has been an explicit matching policy, such as the pre 1914 Anglo-German naval competition. Otherwise, the variety of complicating factors make econometric application and testing problematic. Despite the empirical difficulties associated with the model it remains the focus of intensive theoretical research, examples of "state of the art" research in this area can be found in the papers by Intriligator & Britto, Lambelet, Shubik and others in Blackaby and Schmidt (1986).

3. The économic effects of military expenditure

(a) Theory

A change in military expenditure will have direct effects on the employment of soldiers, purchases of weapons, financing of the budget and so on. The direction and size of these effects will depend on contingent circumstances: whether the economy is demand or supply constrained, the specific forms of economic organisation prevailing, exactly how the military expenditure is changes, and the concurrent political and economic policies followed. As these direct effects feed through the system they will interact with each other causing multiplier and feedback reactions. The long-run impact when these reactions have worked through the system may be very different from the immediate direct impact.

To trace through these linkages, in order to evaluate the long run effect of military expenditure, requires a model or theory about how the economy operates. Since, there are a variety of different theories, we shall get different estimates of the economic impact of military expenditure depending on which model we use. Sometimes the data will be sufficiently informative to allow us to reject one particular theory or model in favour of another. But in economics, unfortunately, such clear results are quite rare.

A further problem is that most theoretical models used by economists do not include an explicit role for military expenditure, distinct from other forms of government expenditure.

Except among defence specialists, relative neglect of military expenditure tends to be the rule. This is surprising given the size of the expenditures involved, and the amount of attention which gets directed to other parts of the government budget. However, the consequence is that the theory of how military expenditure, interacts with other economic processes is not well developed.

Given the difficulties with the theories which are available, some econometricians would reject theory completely, and merely "let the data speak for themselves". This is not satisfactory and is likely to produce nonsense regressions and spurious correlations. Without a formal analytical structure organized thought about the problem becomes impossible; the logic of the links in the argument cannot be checked and inferences cannot be made from the empirical and historical evidence available. If we could conduct controlled experiments it might, perhaps, be different. But we cannot and theory is necessary to organise our interpretation of the statistics history provides us.

Although we distinguish theory and the data, they are not independent: theoretical developments are motivated by observation of data, and the data are constructed within a theoretical framework. However, the limitations of both theory and data mean that it is impossible to demonstrate conclusively that a particular hypothesis is true, or false. Of course, this does not preclude the presumption of improvements in knowledge by reasoned observation and rational reconstruction, but it means that no methodology can claim a guaranteed route to truth. Economic analysis thus proceeds in an eclectic fashion, alternating induction and deduction interspersed with attempts at prediction and falsification.

b) Data

Macro-economic national time-series data are the primary source of evidence used to estimate and test most economic models. There are a number of studies which use such data to estimate the impact of military expenditure on the economy. Examples are Fontanel, Martin and Smith (1985) which estimates the impact of military expenditure on growth, investment and unemployment in France and Britain and Kormendi (1983) which examines the effect of military

expenditure on US private saving. One difficulty is that for many Third World Countries it is difficult to obtain the long consistent time-series which are needed to estimate well-specified models. Another difficulty is that in industrial countries peacetime military expenditures have shown relatively little variance around trend. This means that time-series estimates of its impact will tend to exhibit large standard errors. This lack of variation in military expenditure means that it is difficult to measure its effect with any precision. This lack of variation is usually compounded by the difficulty that military expenditure is likely to be correlated with other possible explanatory variables, such as total public expenditure. Thus, as is discussed in Fontanel (1982), military expenditure may play two roles in the equation: as a proxy for public expenditure, a positive effect, and capturing its specific negative influence. The sign of the coefficient will then depend on the net impact.

The main source of variation in military expenditure is associated with wars. However, these call into question the assumption of structural stability - parameters which are constant over time - on which most time series estimation is based. It is also difficult to know if the changes observed are associated with the increased military expenditure or other changes in regulation and political arrangements associated with war. It is possible to test whether the parameters are constant over time, and if they do change some of the variation can be allowed for by including additional variables. Of course, the estimate of the impact of military expenditure will change depending on which other variables are included in the equation. Ideally, one would wish to have "robust" results where coefficient estimates and tests are relatively insensitive to the inclusion or exclusion of other variables. In practice, it is very difficult to judge how sensitive published estimates are to changes in specification, data or estimation technique.

Many of the effects associated with military expenditure are difficult to quantify: war-time political arrangements, patriotism, technological spin-offs, influence of the military on government, and the like. For instance, fear of nuclear war may have important economic effects. If people attach a high probability to nuclear

destruction, then their discount rate should be higher and, according to standard life-cycle models of consumption, they should save less. To test this hypothesis some measure of fear of nuclear war is required. This might be obtained from expert judgements or opinion polls, but there will always be some doubt about how good an approximation the available measure provides to the desired variable.

In fact, in order to allow for any of these potentially important, but difficult to quantify effects, in a regression some type of proxy variable is required. The simplest form is a "dummy" variable, which takes the value zero during peace and unity during war, for instance. But many political phenomena do not take this simple on-off form, and more elaborate scales have to be constructed, often from subjective data or judgements by the investigator. Kormendi and Meguire (1985) discuss the measurement of "civil liberties", Zuk and Thompson (1982) the measurement of military government. Choice of a particular measure will influence the results. But it is important to make an effort to obtain measures, otherwise econometric analysis can be criticised for concentrating on the unimportant factors which can be easily measures, rather than the more important influences which resist simple quantification.

Because of the lack of variation in time-series data on military expenditure and the short lengths which are often available, international cross sections are a very popular way of investigating the questions. Countries differ substantially in the share of output that they devote to military expenditure, from Japan who spends less that one percent, to the US and UK which have spent over five percent. In consequence, cross-sections usually provide much more precise estimates of the parameters, in the sense that the coefficients have smaller standard errors and covariances, than time-series.

The difficulty with cross-sections is that countries differ in many ways other than are captured by the variables included in the equation. The danger is that, to the extend that the omitted variables are correlated with those included, the effect of the ommitted variables will be attributed to those included in the

equation. With cross-section results one has to ask whether it is reasonable to believe, for instance, that the UK would invest and grow like Japan if it had Japanese levels of military expenditure. For policy purposes we are interested in changes over time in one country, cross section estimates answer that question only indirectly.

A common interpretation of the relationship between cross-section and time-series estimates is that time-series measure the short run, transitory, effects and cross sections the long run, permanent, effects. In Smith (1980), which uses both sorts of data, the average time series estimate, across countries, corresponds to the cross section estimate, which gives some support to this interpretation. Pooling time-series and cross-section data has a number of advantages, and enables a much wider range of hypotheses to be tested.

The final type of information which is used to analyse the effect of military expenditure is input-output data. This tabulates the flows between industries and final demands and has been the most effective framework for examining disarmament scenarios. Classic studies using this approach are Leontief et al (1965) for the US and Leontief and Duchin (1982) for the world. Aben and Smith (1985) review the available British and French studies. Input-output tables are often integrated into large dynamic econometric models to allow for a wider variety of feedbacks.

Input-output tables require a large amount of work, and often some very strong assumptions, to construct and are usually out of date, though the effect of this may be mitigated by varying coefficients. As with all quantitative models the results have to be interpreted with care. Although the predictions may be presented in precise numerical form, the uncertainties mean that they can only be treated as indications of orders of magnitudes. In addition, the estimated effects depend on the linkages included in the model. This raises more general questions about the type of model used.

c) Models.

The models which have been used to examine the economic impact of military expenditure can be divided into three main types: single-equations, small systems, large systems. Single-equations and small systems can be estimated on time-series or cross-section data. Large systems are almost invariably estimated on time-series data and may contain an input-output sub-system. The models may be static, just including current values of the variables or dynamic, including lagged values of the regressors and dependent variables.

Single equations are the easiest to work with, only involving regressing the variable of interest on military expenditure and other possible influences. They are easier to understand and analyse and require less specific prior theory to construct. In addition, they can be used in an exploratory mode to investigate the correlations without any particular theoretical structure. In a number of cases single equations have been used to investigate the dynamic feedbacks in an attempt to identify any "Granger causality" in the process by which military expenditure influences other economic variables, Georgiou and Smith (1983) and Chan, Hsiao and Keng (1982) (4).

There are, however, statistical and theoretical difficulties with single equation estimates. The statistical difficulty arises because the regressors on the right hand side of the equation are likely to be endogenous, jointly determined with the dependent variable. In this case, the least squares estimates of the parameters will be biased and inconsistent (5).

The theoretical problem arises because military expenditure may affect the dependent variable, not only directly, but indirectly through its impact on the other regressors in the equation. A full system is required to take account of these feedbacks. This is done most completely in the large systems, such as the INSEE Propage model in France, or the Cambridge Growth Project Model in the UK. Aben and Smith (1985) discuss the use of these models to estimate the employment impacts of military expenditure. These large systems may run into hundreds or thousands of equations, in fact they are

so big that it is impossible to apply consistent estimation methods to them. In addition, their size makes it difficult to interpret the results they provide or explain why they give the answers they do, since these depend on the complicated interaction of hundreds of parameters. The models can become a large and delphic "black-box", which even those who constructed it find difficult to understand, Smith (1984). This has led some to construct "maquettes", small models of the big model in order to understand what is happening, Deleau et al (1984).

Small systems (say between three and thirty equations) are designed to be sufficiently small to allow consistent-estimation and theoretical analysis, yet large enough to allow for simultaneous feedbacks. The models used in Fontanel, Smith and Martin (1985) for Britain and France are of this sort. Whether small systems represent an effective compromise between the advantages of single equations and large systems or merely manage to obtain the worst of both worlds is open to argument. The whole question of the optimum size for a model is a subject of dispute in econometrics.

4. Conclusion

This brief review has emphasized the difficulties and problems involved in the use of econometric models to analyse military expenditure. Econometric analysis needs to be conducted with care and interpreted with caution. But having said that, it is nonetheless and essential method of investigation. In the military area, many simple-minded theories are advanced, econometric analysis provides a way to evaluate them. Unless a theory can be shown to be in accord with the available data, it should be treated with scepticism. In addition, the econometric analysis often reveals further complications and factors that need to be taken into account, thus leading to more sophisticated explanations able to cover a wider variety of instances.

(*) We are grateful for financial support under an ESRC-CNRS award for the study of the Defence Efforts in France and Britain.

NOTES

(1) "Countries may be able to make the levels of arms perceived b the other country appear higher or lower than the true level, an thus influence the dynamics of the response".

(2) In order to apply statistical methods one must make some assumption about the distribution of this residual; or equivalently make some assumption about the distribution of the dependent variable conditional on the regressors. It is usual to assume that the residual is normally distributed independently of the regressors, with mean zero, constant variance, and no serial correlation; but there are alternative assumptions, and a variety of tests for the failure of these stochastic assumptions.

(3) These include familiar tests like the Durbin-Watson statistic, which tests for first order serial-correlation in the residuals, and other more recent tests for normality, non-constant variance, structural stability, or higher order serial correlation. To the extend that the model passes these tests, one's confidence in the specification increases.

(4) Granger Causality involves treating x as causing y, if knowledge of x helps predict future values of y.

(5) A large variety of consistent estimators, which use instrumental variable or maximum likelihood procedures are available, such as Two Stage and Three Stage Least Squares, Limited Information and Full Information Maximum Likelihood. The relative advantages of these estimators over each other and Ordinary Least Squares in realistic circumstances is hotly debated.

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