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INTERDEPENDENT NATIONAL BUDGETS: A Model of U.S.-USSR Defense Expenditures

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INTRODUCTION

Public sector expenditures have been analyzed from several distinct perspectives. Samuelson (1954, 1969), Musgrave (1958), and others have dichotomized public-private goods and indicated welfare optimization conditions. Arrow (1953), Black (1958), and Buchanan and Tullock (1962) have attempted to derive positive theories of public choice by analyzing underlying political mechanisms. Brazer (1959), Henderson (1968), and many others,[1] using cross-section, regression analysis, have explained variations in expenditure behavior on the basis of economic and demographic variables.

Explicit analysis of budget behavior over time has been hampered by the paucity of data and the absence of a well-developed behavioral theory of budget choice; however, several authors, notably Wagner (1958), Peacock and Wiseman (1961), and Musgrave (1969a, b), have noted time trends in public sector expenditure behavior. In this paper I wish to go beyond trend analysis and analyze a portion of the U.S. national budget, national defense, from a behavioral vantage point. Defense is a peculiar budget item in the sense that it is probably the "purest" public good in the federal market

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basket. Another peculiar aspect of the defense budget is its relationship to adversary defense expenditures. Thus, while most federal expenditures are determined by internal political and economic forces, defense is unique in that its level in significant measure is externally determined. This expenditure competition[2] among nations, as it were, utilizes a significant portion of the world's resources and deserves more analytic and empirical attention than presently given by economists. Below I develop, estimate, and simulate a model of this interdependent budget process for the United States (U) and the Soviet Union (S).

A MODEL OF THE DEFENSE EXPENDITURE PROCESS

We draw from existing theory of duopoly and agricultural markets[3] to develop a model of interdependent defense expenditures. A typical stock adjustment model applied to two nations purchasing safety by means of deterrence seems a plausible specification. More specifically, we presume that a nation U_t, adjusts its expenditure toward a desired level ($\overset{*}{U}_t$). Negative deviations ($U_t > \overset{*}{U}_t$) from this level are undesirable since expenditures have opportunity costs in terms of domestic public programs and private resources in general. Similarly, positive deviations ($U_t < \overset{*}{U}_t$) are undesirable because such "underspending" may entail undue risk. In turn, such desired levels of expenditure may be conditioned by some minimum felt need for security and an adjustment to an adversary's defense posture. To add further realism to the model, we presume this second adjustment is conditioned by expected adversary expenditures; this refinement accounts for likely lead times to implement complex defense systems. Finally, we expect similar reasoning on the part of the adversary.

The model symbolically stated is:[4]

$$\overset{*}{U}_t = a + bS_t' \qquad (1)$$

$$\overset{*}{S}_t = c + dU_t' \qquad a,\ b,\ c,\ d > 0$$

where an asterisk denotes a desired value and a prime denotes an expected value. Adjustments to desired and anticipated values are hypothesized to be formed as indicated below:

$$U_t - U_{t-1} = \delta(\overset{*}{U}_t - U_{t-q}) \qquad (3)$$

$$S_t' - S_{t-1}' = \beta(S_t - S_{t-1}') \qquad (4)$$

$$S_t - S_{t-1} = \rho(\overset{*}{S}_t - S_{t-1}) \qquad (5)$$

$$U_t' - U_{t-1}' = \gamma(U_t - U_{t-1}') \qquad (6)$$

By a well-known series of transformations, through which equation (1) is combined with equations (3) and (4), and equation (2) is combined with equations (5) and (6), $\overset{*}{U}_t$ and $\hat{S}_t$ may be reduced to observables:[5]

$$U_t = a\beta\,\delta + b\beta\,\delta\,S_t + (2 - \beta - \delta)\,U_{t-1} - (1 - \beta)\,(1 - \delta)\,U_{t-2} \tag{7}$$

$$S_t = c\rho\,\gamma + d\,\rho\gamma\,U_t + (2 - \rho - \gamma)\,S_{t-1} - (1 - \rho)\,(1 - \gamma)\,S_{t-2} \tag{8}$$

Thus in terms of observables, U and S depend simultaneously on each other and on lagged values of themselves. Of particular interest are the sizes of the various parameters in the system and predictions of expenditures which equations (7) and (8) can generate over the next two decades. The following section discusses estimation techniques and data and the section after that presents regression and simulation results.

ESTIMATION TECHNIQUE AND DATA

Least squares estimation of equations (7) and (8) is complicated by actual U_t and S_t being simultaneously or jointly determined and the likely intercorrelation of error terms between equations. That is, estimation by ordinary least squares of:

$$U_t = \theta_1 + \theta_2 S_t + \theta_3 U_{t-1} + \theta_4 U_{t-2} + e_t \tag{9}$$

$$S_t = \pi_1 + \pi_2 U_t + \pi_3 S_{t-1} + \pi_4 S_{t-2} + s_t \tag{10}$$

will lead to biased estimates since $E(e_t,\ S_t)$, $E(s_t,\ U_t)$, and $E(e_t,\ s_t)$ are likely to be non-zero. We shall estimate equations (11) and (12) using three-stage least squares to correct for these likely intercorrelations.[6] Assuming θ and π are unbiased, we may relate them to theoretic parameters:

$$\hat{\theta}_1 = (\hat{a}\beta\,\delta) \tag{11a}$$

$$\hat{\theta}_2 = (b\hat{\beta}\,\delta) \tag{11b}$$

$$\hat{\theta}_3 = (2 - \hat{\beta} - \delta) \tag{11c}$$

$$\hat{\theta}_4 = [(1 - \hat{\beta})\,(1 - \delta) \tag{11d}$$

Adding $\hat{\theta}_3$ to $\hat{\theta}_4$, we have

$$\hat{\theta}_3 + \hat{\theta}_4 = 1 - \beta\,\delta$$

i.e. =

$$\beta\,\delta = 1 - \hat{\theta}_3 - \hat{\theta}_4 \tag{12}$$

Substituting equation (12) into equation (11a) and (11b), we find for a and b, respectively,

$$\hat{a} = \frac{\hat{\theta}_1}{1 - \hat{\theta}_3 - \hat{\theta}_4} \tag{13a}$$

$$\hat{b} = \frac{\theta_2}{1 - \hat{\theta}_3 - \hat{\theta}_4} \tag{13b}$$

Analogously,

$$\hat{c} = \frac{\hat{\pi}_2}{1 - \hat{\pi}_3 - \hat{\pi}_4} \tag{14a}$$

$$\hat{d} = \frac{\hat{\pi}_2}{1 - \hat{\pi}_3 - \hat{\pi}_4} \tag{14b}$$

Since β and δ enter the model symmetrically, we cannot solve equation (11a) through equation (11d) to obtain unique values of each.[7] However, we can derive a quadratic statement for each by adding and rearranging equations (11c) and (11d):

$$\beta = \frac{(2 - \hat{\pi}_3) \pm (\hat{\pi}_3{}^2 + 4\hat{\pi}_4)^{1/2}}{2} \tag{15a}$$

$$\delta = \frac{(2 - \hat{\pi}_3) \pm (\hat{\pi}_3 + 4\pi_4)^{1/2}}{2} \tag{15b}$$

Similar results of course obtain for ρ and γ.

Data for U.S. and Soviet defense expenditures are from the Stockholm International Peace Research Institute [SIPRI (1970)] and are in billions of 1960 U.S. dollars (Table 1). Reliability of Soviet expenditure data is an intractable problem. It is believed that the Soviets understate defense expenditures. Also, since market valuation of Soviet outlays does not occur, budgetary outlays may not reflect comparable opportunity costs in a Western economy. The Stockholm estimates, which are independently generated and attempt to account for inflation and comparable purchasing power, must be viewed as a preliminary, independent set of figures. Comparison of the latter part of the aggregate Stockholm series with the United States Arms Control and Disarmament Agency figures (which are similar to U.S. Central Intelligence Agency estimates) indicate that the percentage changes (1964 to 1967) are approximately the same (SIPRI (1970)]. The data are the most readily available for the period of interest and are used with their limitations well in mind.

TABLE 1. United States and Soviet Union Defense Expenditures in Billions of 1960 U.S. Dollars[a]

Year	United States (U)	Soviet Union (S)
1951	37.781	22.948
1952	52.992	25.952
1953	54.409	25.666
1954	46.915	23.881
1955	44.428	25.476
1956	45.307	23.167
1957	46.843	23.029
1958	46.432	22.286
1959	47.085	22.310
1960	45.380	22.143
1961	47.335	27.619
1962	51.203	30.238
1963	50.527	33.095
1964	48.821	31.667
1965	48.618	30.476
1966	57.951	31.905
1967	66.889	34.450
1968	68.213	39.780
1969	67.770*	42.143*

[a]Using Benoit-Lubell Exchange Rates: 1951 to 1969. (*) = Tentative. (Source: Stockholm International Peace Research Institute Yearbook.)

ESTIMATION AND SIMULATION RESULTS

Three-stage least squares estimates of equations (9) and (10) were computed[8] to be (t ratios in parentheses with H_o: $\hat{\theta}i = 0$)

$$\begin{aligned} \hat{U}_t &= 14.91 + .6507S_t + .7680U_{t-1} - .4223U_{t-2} \\ &\quad (24.515)\ (3.923)\quad (5.750)\qquad (-4.358) \end{aligned} \tag{16}$$

$$R^2 = 0.8963 \qquad \sigma = 2.963$$

$$\begin{aligned} \hat{S}_t &= .6647 + .0469U_t + 1.261S_{t-1} - .3450S_{t-2} \\ &\quad (0.1858)\ (0.3816)\quad (4.463)\qquad (-1.445) \end{aligned} \tag{17}$$

$$R^2 = 0.8803 \qquad \sigma = 2.279$$

The model seems to fit observed U.S. expenditure behavior rather well. All regression coefficients are significant at better than the 95 percent level. The model does less well for observed Soviet behavior. While the "t" statistics are disappointing, the R^2 and standard error of forecast are more reassuring. Examination of correlations of the variables on the right side of equation (15) indicate intercorrelations (see Appendix D, page 268) among determining variables, which in turn suggests collinearity. Using the calculated regression coefficients, we find the parameters of the model to be (in billions of 1960 U.S. dollars):

$\hat{a} = 22.7877 \qquad \hat{c} = 7.9131$

$\hat{b} = 0.9945 \qquad \hat{d} = 0.5583$

Our model then becomes

$$\overset{*}{U}_t = 22.7877 + .9945S_t'$$
$$\overset{*}{S}_t = 7.9131 + .5583U_t'$$

Apparently the United States is willing to spend 99¢ to the dollar of expected Soviet defense expenditures, while the latter is willing to spend only 56¢ to expected U.S. expenditures. We also note that the United States desires nearly three times the Soviet minimum level of expenditure ($22.79 versus $7.91 billion).

Of particular interest are forecasts of U.S. and USSR expenditures for the next two decades. To generate such forecasts, the reduced form of equations (14) and (15) was found and initial forecasts generated by using actual 1968 and 1969 data. For 1971, actual 1969 and forecast 1970 data were used. Post-1971 forecasts used entirely model-generated results. To add realism, the model was adjusted each time period by drawing a random number from a uniform distribution with zero mean and variance of 1, multiplying the shock times the standard error of forecast, σ, and then adding this adjustment to the forecast. Table 2 shows the simulation results. The stability of the budgetary interdependence is quite apparent, as is the cyclical nature of real defense expenditures through time. U.S. expenditures are then predicted to rise slightly in real terms through 1972 and then decline through 1975. On the other hand, USSR expenditures are predicted to decline slowly from 1970 to 1974. Over the entire forecast period, U.S. expenditures attain a high of $67.531 billion in 1983 and a low of $58.973 billion in 1975. Corresponding figures for the Soviet Union are $43.597 billion in 1982 and $36.774 billion in 1977. Of course, the model and forecasts must be viewed cautiously since the quality of utilized USSR data is unknown.

TABLE 2. Predicted U.S. and USSR Expenditures in Billions of 1960 U.S. Dollars

Year	Predicted U	Predicted S
1970	66.564	43 534
1971	66 784	43.062
1972	66.815	41.946
1973	66.442	39.640
1974	64.441	37.023
1975	58.973	37.405
1976	59.866	37.918
1977	58.041	36.774
1978	60.923	38.776
1979	60.453	40.162
1980	64.722	39.941
1981	64.410	41.823
1982	66.687	43.597
1983	67.631	42.252
1984	65.630	40.604
1985	62.770	42.463
1986	61.985	42.891
1987	63.983	42.618
1988	64.983	41.456
1989	66.747	40.068
1990	64.612	42.135

CONCLUSIONS

A sizeable item in the U.S. Federal budget has been analyzed from a behavioral vantage point. The interdependent model of defense expenditures suggests that the United States would like to spend 99¢ to the dollar of expected USSR defense expenditures while the Soviet Union would like to spend 56¢ to the dollar of expected U.S. expenditures. Also, it was found that the United States desires \$22.8 billion for security purposes independent of what the Soviet Union spends, while the latter desires only \$7.9 billion. Stochastic simulation of this model of interdependent defense budgets suggests that the system is stable over a two-decade forecast period and that an erratic cyclical tendency is projected. Of course, this first foray into the study of international influences on internal public expenditures has ignored internal influences and pressures. A fruitful avenue for further research may be to build into the model the multiplier-accelerator effects of increased defense spending which a nation may view as a countercyclical tool. What is clear from this study is that USSR defense expenditures do have a significant influence on U.S. defense expenditures.

NOTES

1. For a systematic review of the "determinants literature" see Bahl (1968).
2. Useful discussions of the analogous intergovernmental transfer, tax competition problem can be found in Plummer (1966, 1967), and Goetz (1967).
3. The basic stock adjustment model used is due to Nerlove (1958).
4. The model as stated in the text is deterministic. An initial stochastic specification leads to complicated autoregressive structures which the error terms will follow only under unusual circumstances. Two avenues appear open: assume U and S are initially evaluated at their means or assume a deterministic structure at the outset. The latter is more appealing to the author.
5. See for example Johnston (1963), p. 220.
6. Ibid., pp. 226-268.
7. This identification problem is in principle solvable; by adding an exogenous variable to equation (1) (say R_t with unknown parameter e) and solving as before, one obtains a statement for U_t in terms of S_t, U_{t-1}, U_{t-2}, R_{t-1}, and R_{t-2} which, using constrained regression techniques, allows one to obtain estimates of all parameters in the system. No candidate variable suggests itself for equations (1) and (2), however. For a discussion of the identification problem, see Waud (1968).
8. Computations were performed at the University of North Carolina-Research Triangle Computation Center on an IBM Model 360/75 using a double precision version of the Zellner-Stroud "Leastsquares" program (Madison, Wisconsin, 1967).

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