

Lost in Space

POLITICAL GEOGRAPHY AND THE DEFENSE-GROWTH TRADE-OFF

MICHAEL SHIN

Department of Geography and Regional Studies

University of Miami

MICHAEL D. WARD

Department of Political Science

University of Washington

This study examines the political geography of the linkage between military spending and economic growth for the period from 1985 to 1995. Exploratory spatial data analyses are used to determine how the spatial arrangement of countries influences the defense-growth trade-off. The authors discover a strong spatial component to the linkage between guns and growth.

As we approach the end of the century—the most violent and militarized century in history—military expenditures have been reduced on a global level. What has been the link between military spending and economic growth during this period of very rapid change? Has the reduction of military spending over the past decade in some way been associated with the current economic boom? The disparities between the military capabilities of the United States and its European allies were brought to light during the war in Kosovo. Will the probable increase in defense spending by NATO member-states be coupled with a leveling off of the current economic expansion? In this article, we focus on one specific aspect of these questions: namely, how the local and regional context of arms spending and economic productivity can affect the link between guns and growth in each nation. Furthermore, we try to determine whether regional patterns and proclivities play an important role in our understanding of the link between guns and growth.

LOST IN SPACE

To what extent does geography affect the relationship between military spending and economic growth? This question remains unanswered because most studies of the

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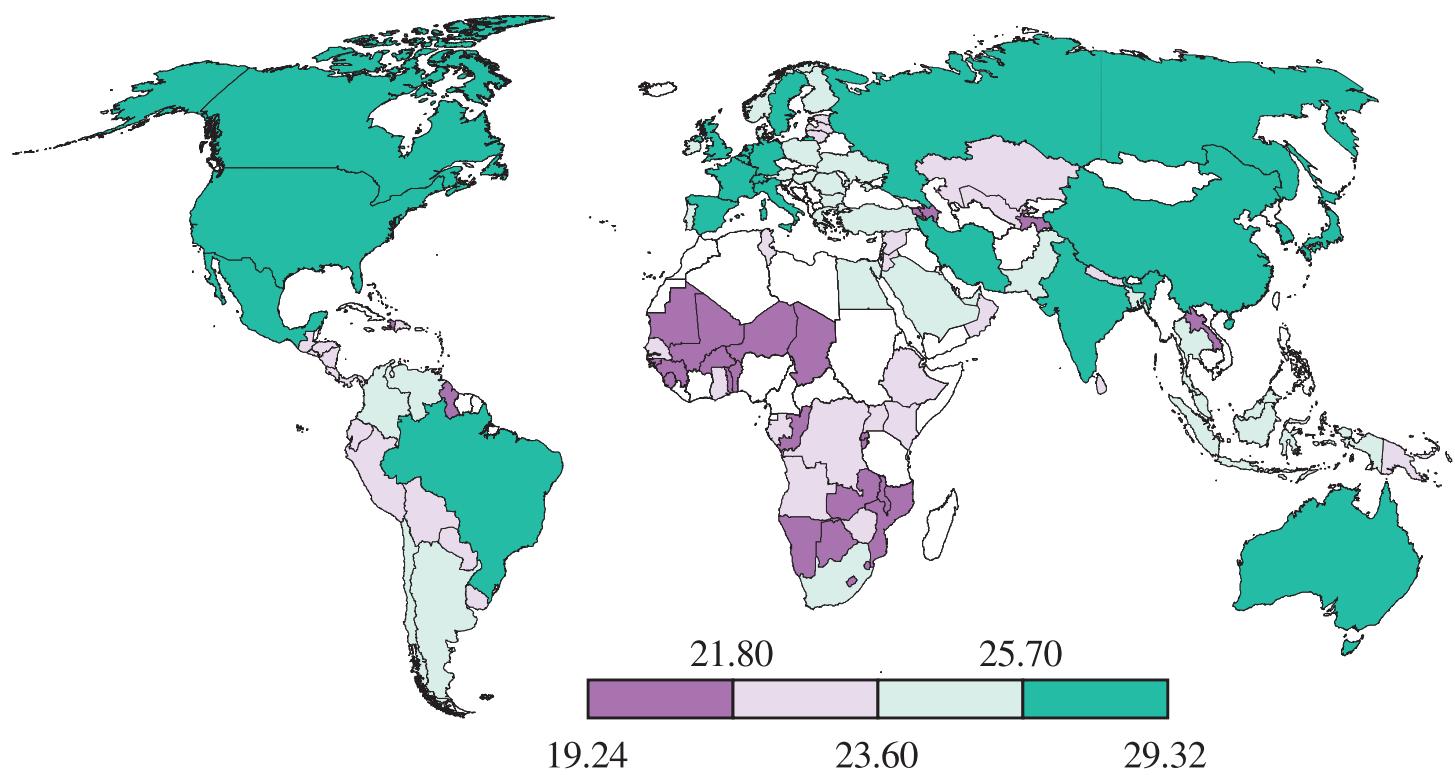
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defense-growth trade-off examine this relationship in individual countries (e.g., Ward, Davis, and Lofdahl 1995) or for a collection of states such as less developed countries (e.g., Atesoglu and Mueller 1991). Although some cross-national studies focus on the trade-off between military expenditures and economic growth in geographic regions such as Europe (e.g., Avramides 1997), the Middle East (e.g., Ward and Cohen 1996), Asia, Latin America (e.g., Murdock, Pi, and Sandler 1997), and Africa (e.g., Mohammed and Thisen 1996), the importance of the spatial arrangement of countries—in particular, their regional context—is overshadowed by the comparison of regional averages of defense spending and economic performance to global levels. We contend that a geographic perspective that acknowledges the importance of regional contexts can inform analyses of the defense-growth trade-off.

Interest in the relationship between military expenditure and economic productivity stems from Benoit's (1973) original work, which indicated that defense spending stimulates economic growth in less developed countries. Recent studies, however, have concentrated on the possibility of socioeconomic benefits associated with decreases in military expenditures in some states, as well as in certain regions of the world (see Gleditsch et al. 1996). The large body of empirical evidence compiled over the past 25 years contains support for both sides of the argument; defense spending is a burden on the economy in some cases (e.g., Deger and Smith 1983) and a benefit to it in others (e.g., Ward, Davis, and Lofdahl 1995). What is apparent from the literature is that this trade-off varies over time and across space. Although longitudinal analyses take into consideration the temporal domain, aside from arms race research, few if any systematic studies have examined the significance of interactions across the spatial dimension.

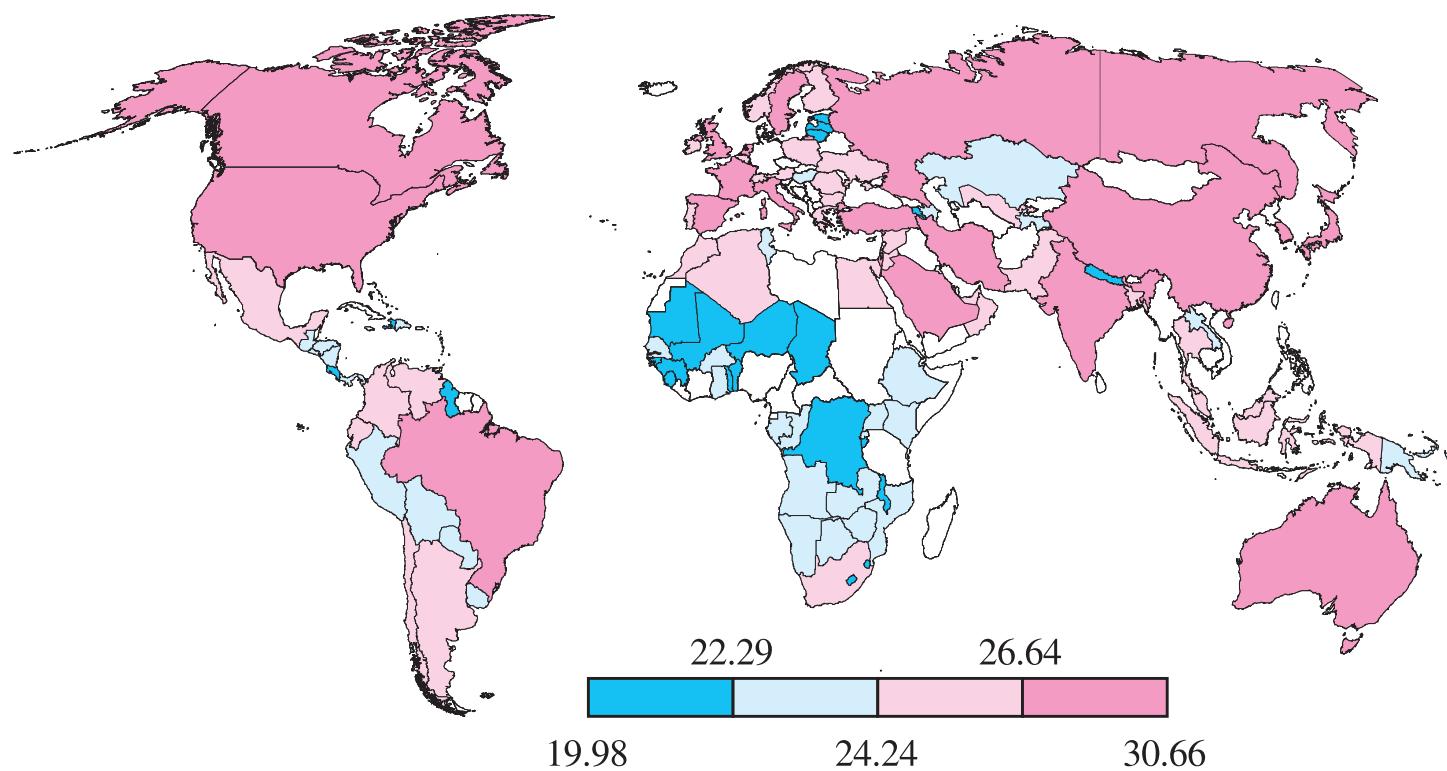
It seems trivial to argue that a country's military spending and economic productivity are, in part, a function of its interactions with other states. Yet, few econometric models in the defense-growth trade-off literature attempt to evaluate or control for these effects (i.e., geography). By default, this omission leaves one to assume incorrectly that either (1) countries are spatially independent from one another or (2) interactions between states are homogeneous and isotropic. Taking exception to this omission, we argue that geographically proximate countries tend to interact more frequently with each other than with countries that are more distant. National security and economic prosperity are very much shaped by regional circumstances. Maps of the distribution of logged 1995 gross national product (GNP) and 1995 military expenditures in billions of 1987 U.S. dollars for 117 countries provide preliminary support for this argument.

As seen in Map 1 and Map 2, similar levels of GNP and defense spending appear to be concentrated in certain areas of the world (e.g., Western Europe, Central Europe, Sub-Saharan Africa), although there are notable differences between such regions. If, in fact, countries were independent and isolated from each other, or if there were no variation in interstate interaction, the patterns of GNP and military spending would be distributed randomly across the world. This is not the case in these maps.



Map 1: Geographic Distribution of Gross National Product, 1995 (in thousands of 1987 U.S. dollars, logged)

796



Map 2: Geographic Distribution of Military Spending, 1995 (in thousands of 1987 U.S. dollars, logged)

The notion that propinquity is important to shaping and understanding international politics is not new. From Mackinder's (1904) heartland theory to contemporary research on the diffusion of war, it has long been argued that geography matters (e.g., Russett [1967] 1975; Spykman 1944; Vasquez 1995). Throughout the diffusion of war literature, it has been illustrated that proximity, measured as the number of neighbors a state has, can increase the likelihood of a country's involvement in a violent conflict (e.g., Starr and Most 1976). Geographic proximity in itself, however, is not a sufficient condition for the outbreak of war, but it is considered to be a contributing factor because "the more borders a nation has, the greater the number of risks and opportunities confronting the nation" (Siverson and Starr 1991, 162). If the risk of war should increase for a country, regional levels of military spending may reflect this insecurity. This may stimulate the affected economies, or it may have adverse effects on economic growth. It is also plausible that a decrease in the likelihood of war involvement for a country may contribute to regional stability and free resources previously allocated to defense, which in turn could facilitate economic productivity.

The arguments surrounding the effects of proximity on economic growth are similar to those concerning military expenditures. We contend that a nation's economic well-being is linked to that of its neighbors, most likely through international trade. This is not to say that proximity necessarily leads to trade between neighboring countries; rather, proximity facilitates economic exchanges between countries. Although the debate continues about the extent of positive and negative effects that trade has on a nation's economy, the theory of comparative advantage tells us that the gains of trade outweigh remaining autarkic. Throughout history, distance has been a critical factor with respect to international trade. International trade involves costs in terms of transport and time, which are functions of distance. Therefore, trading with neighbors is usually more cost-efficient than trading with those who are farther away. Furthermore, the indirect costs of trade in terms of familiarity with market structures, cultures, and even language tend to increase with distance, which can also affect trade relations.

The literature on the formation of regional trading blocs provides many illustrative examples of how geography and economics are linked (e.g., Frankel 1997; Frankel and Romer 1999; Krugman 1991; Mansfield and Milner 1997). Generally, regional trading agreements attempt to coordinate policies that facilitate and increase the amount of trade between members. Although proximity is not a prerequisite for the formation of a trading bloc (Cohen 1997), it usually provides the impetus for such economic arrangements. It should also be noted that such regional trading agreements vary considerably in nature, extent, and efficacy. The European Union is an example of a highly developed regional trading bloc with an evolving agenda and a membership that is underpinned by several advanced industrial economies. The Economic Community of West African States, on the other hand, comprises developing countries that, to date, have been reluctant to implement agreements that would liberalize trade (Bhalla and Bhalla 1997). Patterns of economic productivity, therefore, may reflect the regional nature of economic interdependence. The logic underlying the role of proximity

within studies of regional trading bloc formation and war diffusion is relevant to this examination of the defense-growth trade-off and may help to determine whether geography can inform research on the defense burden and peace dividend.

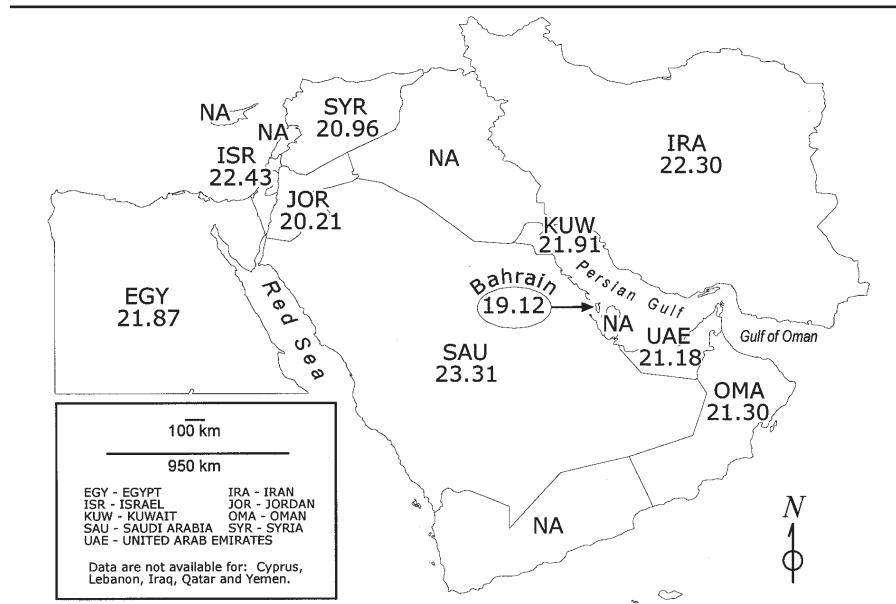
Proximity is considered to be a fundamental determinant of interactions between countries (for a discussion of this idea in the broad context of human behavior, see Zipf 1949). Defining proximity (i.e., which metric should be used to gauge or capture the interdependencies of interstate interaction), however, remains an arbitrary exercise in map reading. Some studies define proximity as the presence of a shared border or physical contiguity (O'Loughlin 1986), whereas others, such as the Correlates of War project, specify critical distances (Gochman 1991). Gleditsch (1999) reviews the use of various interstate metrics. In an effort to update and refine existing data, Gleditsch and Ward (2000a) constructed and compiled distance matrices based on “the shortest distance between the closest physical locations in every pair of independent polities between 1875 and 1996.” These were measured for all distances up to 950 kilometers. An interesting and very useful feature of these contiguity matrices is that the actual physical distance is reported if two countries are separated by less than 950 statute kilometers. Thus, proximity measured as a critical distance can be changed as necessary.

ON MEASURING SPATIAL CONTEXT AND ASSOCIATION

The two concepts behind the exploratory spatial analysis of the defense-growth trade-off are pattern recognition and pattern evaluation. First, we determine the degree to which defense spending and economic growth are concentrated across the world. Geographic concentration is referred to as spatial dependence. The spatial clustering of defense spending and GNP among proximate countries supports the notion that state behavior is a function of the regional context in which it is situated. Second, we compare and contrast world regional patterns of the defense-growth trade-off. Spatial dissimilarity is called spatial heterogeneity. Such variations support the argument that not all regional contexts are the same, perhaps due to differences in the nature and extent of interstate interactions. Thus, both concentration and heterogeneity are potentially complementary and should not be looked at as opposites. This suggests that regionally specific explanations of the defense-growth trade-off may be informative.

Connectivity matrices based on proximity are implemented in the spatial analyses as relative measures of interdependence in interstate interactions. Although there are several ways to represent the interactions between states, we selected connectivity matrices based on physical distances to evaluate the significance of the spatial dimension at different intervals in time.¹ Map 3 and Table 1 are used to illustrate these concepts.

1. Distance is but one of many useful metrics that might be employed in a similar fashion. Others in the field of international relations include trade “connectedness,” alliance membership, international organization membership, and cultural and ethnolinguistic characteristics.



Map 3: Defense Expenditures in the Middle East, 1995

Table 1 summarizes the connectivity based on distances of 1 kilometer or less, 100 kilometers or less, and 950 kilometers or less among countries in the Middle East. Note how the number of countries considered contiguous—or proximate—increases with distance. We have also included the concatenation of the first- and second-order contiguities for the 1-kilometer distance band.² Matrixes provide a more efficient way to present, archive, and use contiguity or connectivity data. In most spatial statistical analyses, two formats of spatial weights matrices are used: binary and row standardized. To continue using the Middle East example, we can define a binary weights matrix, W , in such a way that if two countries are separated by a distance of 100 kilometers or less, $w_{ij} = 1$; otherwise, $w_{ij} = 0$. For the Middle East example, the full binary spatial weights matrix is presented in Table 2.³

Row standardization involves dividing each row in the matrix by its row sum. For example, the row for Egypt would be divided by the row sum of three, which represents the number of countries with which Egypt is contiguous. The row-standardized matrix, W^S , is presented in Table 3.

Multiplying W^S and a vector of coincident observations, y , such as logged 1995 military spending, would return a vector that contains the average level of defense expenditures for countries falling within 100 kilometers of each any given observation, which is called the spatial lag, $W^S y$.

2. These are given for the closed system described above. Second-order (and higher order) connectivity for the entire world would expand into Europe, Asia, and Africa beyond the Middle East, as shown above.

3. The higher order contiguity matrices can be obtained by powering the first-order matrix.

TABLE 1
Military Expenditures and Various Contiguities in the Middle East, 1995

Country	1995 Military Expenditures ^a	<i>Contiguous Countries Using Cumulative Links by Virtue of Minimum Distances Less Than</i>			<i>First- and Second-Order Spatial Lags (neighbors of neighbors at 1 km)</i>
		1 km	100 km	950 km	
Bahrain	19.12	Saudi Arabia	Saudi Arabia	Iran, Iraq, Kuwait, Oman, Saudi Arabia, United Arab Emirates (UAE), Yemen	Egypt, Iraq, Jordan, Kuwait, Oman, Saudi Arabia, UAE, Yemen
Cyprus	NA	None	None	Egypt, Iran, Iraq, Israel, Jordan, Saudi Arabia, Syria	None
Egypt	21.87	Israel, Saudi Arabia	Israel, Jordan, Saudi Arabia	Cyprus, Iraq, Israel, Jordan, Saudi Arabia, Syria	Bahrain, Egypt, Iraq, Israel, Jordan, Kuwait, Oman, Saudi Arabia, Syria, UAE, Yemen
Iran	22.30	Iraq	Iraq, Kuwait, UAE	Bahrain, Cyprus, Iraq, Jordan, Kuwait, Oman, Saudi Arabia, Syria, UAE	Iraq, Jordan, Kuwait, Saudi Arabia, Syria
Iraq	NA	Iran, Jordan, Kuwait, Saudi Arabia, Syria	Iran, Jordan, Kuwait, Saudi Arabia, Syria	Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Kuwait, Oman, Saudi Arabia, Syria, UAE	Bahrain, Egypt, Iran, Israel, Jordan, Kuwait, Oman, Saudi Arabia, Syria, UAE, Yemen
Israel	22.43	Egypt, Jordan, Syria	Egypt, Jordan, Saudi Arabia, Syria	Cyprus, Egypt, Iraq, Jordan, Saudi Arabia, Syria	Egypt, Iraq, Jordan, Syria, Saudi Arabia
Jordan	20.21	Iraq, Israel, Saudi Arabia, Syria	Egypt, Iraq, Israel, Saudi Arabia, Syria	Cyprus, Egypt, Iran, Iraq, Israel, Kuwait, Saudi Arabia, Syria	Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Oman, Saudi Arabia, Syria, UAE, Yemen
Kuwait	21.91	Iraq, Saudi Arabia	Iran, Iraq, Saudi Arabia	Bahrain, Iran, Iraq, Jordan, Oman, Saudi Arabia, Syria, UAE	Bahrain, Egypt, Iran, Iraq, Jordan, Oman, Saudi Arabia, Syria, UAE, Yemen

Oman	21.30	Saudi Arabia, UAE, Yemen	Saudi Arabia, UAE, Yemen	Bahrain, Iran, Iraq, Kuwait, Saudi Arabia, UAE, Yemen	Bahrain, Egypt, Iraq, Jordan, Kuwait, Oman, Saudi Arabia, UAE, Yemen
Saudi Arabia	23.31	Bahrain, Egypt, Iraq, wait,	Bahrain, Egypt, Iraq, Jordan, Kuwait, Oman, UAE, Yemen	Bahrain, Cyprus, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Oman, Syria, UAE, Yemen	Bahrain, Egypt, Iraq, Iran, Israel, Jordan, Ku- wait, Syria, UAE, Yemen
Syria	20.96	Iraq, Israel, Jordan	Iraq, Israel, Jordan	Cyprus, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Saudi Arabia	Egypt, Iraq, Iran, Israel, Jordan, Kuwait, Saudi Arabia
United Arab Emirates (UAE)	21.18	Oman, Saudi Arabia	Iran, Oman, Saudi Arabia	Bahrain, Iran, Iraq, Kuwait, Oman, Saudi Arabia, Yemen	Bahrain, Egypt, Iraq, Jordan, Kuwait, Oman, Saudi Arabia, Yemen
Yemen	NA	Oman, Saudi Arabia	Oman, Saudi Arabia	Bahrain, Oman, Saudi Arabia, UAE	Bahrain, Egypt, Iraq, Jordan, Kuwait, Oman, Saudi Arabia, UAE

NOTE: NA = not available.

a. In logged thousands of 1987 U.S. dollars.

TABLE 2
Binary Contiguities for Middle East Countries

	Bahrain	Cyprus	Egypt	Iran	Iraq	Israel	Jordan	Kuwait	Oman	Saudi Arabia	Syria	United Arab Emirates	Yemen
Bahrain	0	0	0	0	0	0	0	0	0	1	0	0	0
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0	0
Egypt	0	0	0	0	0	1	1	0	0	1	0	0	0
Iran	0	0	0	0	1	0	0	1	0	0	0	1	0
Iraq	0	0	0	1	0	0	1	1	0	1	1	0	0
Israel	0	0	1	0	0	0	1	0	0	1	1	0	0
Jordan	0	0	1	0	1	1	0	0	0	1	1	0	0
Kuwait	0	0	0	1	1	0	0	0	0	1	0	0	0
Oman	0	0	0	0	0	0	0	0	0	1	0	1	1
Saudi Arabia	1	0	1	0	1	1	1	1	1	0	0	1	1
Syria	0	0	0	0	1	1	1	0	0	0	0	0	0
United Arab Emirates	0	0	0	1	0	0	0	0	1	1	0	0	0
Yemen	0	0	0	0	0	0	0	0	1	1	0	0	0

NOTE: Distance band = 100 kilometers.

TABLE 3
Row Standardized Contiguity Matrix for Middle East Countries

	Bahrain	Cyprus	Egypt	Iran	Iraq	Israel	Jordan	Kuwait	Oman	Saudi Arabia	Syria	<i>United Arab Emirates</i>	Yemen
Bahrain	0	0	0	0	0	0	0	0	0	1/1	0	0	0
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0	0
Egypt	0	0	0	0	0	1/3	1/3	0	0	1/3	0	0	0
Iran	0	0	0	0	1/3	0	0	1/3	0	0	0	1/3	0
Iraq	0	0	0	1/5	0	0	1/5	1/5	0	1/5	1/5	0	0
Israel	0	0	1/4	0	0	0	1/4	0	0	1/4	1/4	0	0
Jordan	0	0	1/5	0	1/5	1/5	0	0	0	1/5	1/5	0	0
Kuwait	0	0	0	1/3	1/3	0	0	0	0	1/3	0	0	0
Oman	0	0	0	0	0	0	0	0	0	1/3	0	1/3	1/3
Saudi Arabia	1/9	0	1/9	0	1/9	1/9	1/9	1/9	1/9	0	0	1/9	1/9
Syria	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	0
United Arab Emirates	0	0	0	1/3	0	0	0	0	1/3	1/3	0	0	0
Yemen	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0

NOTE: Distance band = 100 kilometers.

TABLE 4
Moran's *I* Using the 950-Kilometer Distance Band
for GNP in Thousands of 1987 U.S. Dollars, Logged

	1985	1990	1995
Moran's <i>I</i>	.443	.477	.456
<i>z</i> -score	9.5	10.3	11.4
Probability	.000	.000	.000

NOTE: GNP = gross national product. Comparison to normalization; randomization results are virtually identical.

The spatial lag of a specified variable is used to calculate Moran's *I*, a measure of and test for spatial correlation. In this analysis, Moran's *I* is used to determine the degree to which defense spending and GNP are spatially clustered across the world. The statistic is calculated using contiguity matrices based on a critical distance of 950 kilometers. Moran's *I* is formally expressed,

$$I = \frac{n}{\sum_i \sum_j w_{ij}} \sum_i \sum_j w_{ij} \frac{(y_i - \bar{y})(y_j - \bar{y})}{\sum_j (y_j - \bar{y})^2},$$

where w_{ij} is an element of a row-standardized spatial weights matrix, W^S , which indicates whether i and j are contiguous. A significant, positive *I* value indicates the presence of spatial clustering, and a significant, negative *I* value indicates a pattern of dissimilarity among proximate units of analysis. Table 4 and Table 5 report Moran's *I* statistic for both logged GNP and logged military spending in thousands of 1987 U.S. Dollars.⁴ Both logged GNP and logged military spending are significantly clustered across the world in all years at all distance bands. Significance tests based on the assumptions of normality (reported above) and randomness (omitted) return the same value of Moran's *I*, although the significance levels between tests differ slightly (for details, see Anselin 1995). These results support the argument that a country's GNP and defense spending may be a function of regional circumstances.

Moran's *I* is referred to as a global indicator of spatial association because it returns a single value that summarizes the nature of spatial dependence across the entire data set. Local indicators of spatial association complement global indicators, such as Moran's *I*, by providing information about the degree to which each observation resembles those that surround it or are proximate. Figure 1 shows the scatter plots of 1985 and 1995 logged military spending and GNP against their respective 1-kilometer spatial lags. As can be seen, the relationship is neither linear nor random. The scatter plots illustrate the overall global association while portraying significant localized differences. Although Moran's *I* assumes the relationship between a variable and its spatial lag is linear, the summary plots show that this is not the case for military spending and GNP. The best-fitting additive line is not linear (a loess smoother is shown along

4. These data are from the World Bank (1998).

TABLE 5
Moran's I Using the 950-Kilometer Distance Band
for Military Expenditures in 1987 U.S. Dollars, Logged

	1985	1990	1995
Moran's I	.492	.467	.442
z -score	10.5	10.1	11.1
Probability	.000	.000	.000

NOTE: Comparison to normalization; randomization results are virtually identical.

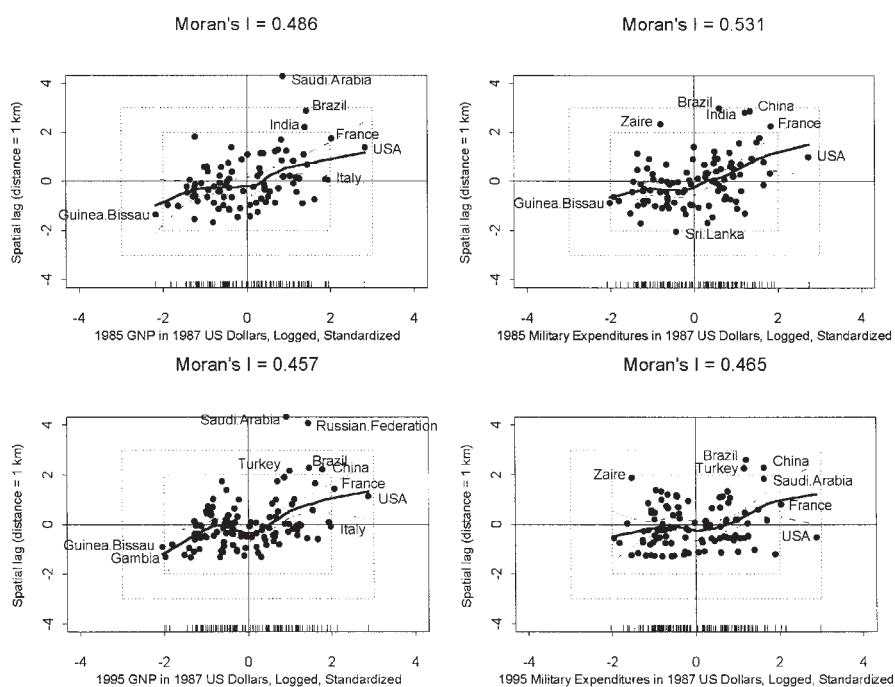


Figure 1: Scatter Plots of Gross National Product and Military Spending against Their Spatial Lags

with a 1 standard error band). Observations falling in the upper right-hand quadrant are those that have high values on the variable and its spatial lag; those countries that have values greater than $|2\sigma|$ are those that are significantly different from their neighbors.

The G_i family of statistics developed by Getis and Ord (1992), and later refined (Ord and Getis 1995), provides measures of the statistical significance of local patterns of spatial dependence.⁵ The G_i statistics also use a row-standardized spatial weights

5. The G stands for geography; Fischer said something remarkably similar about F .

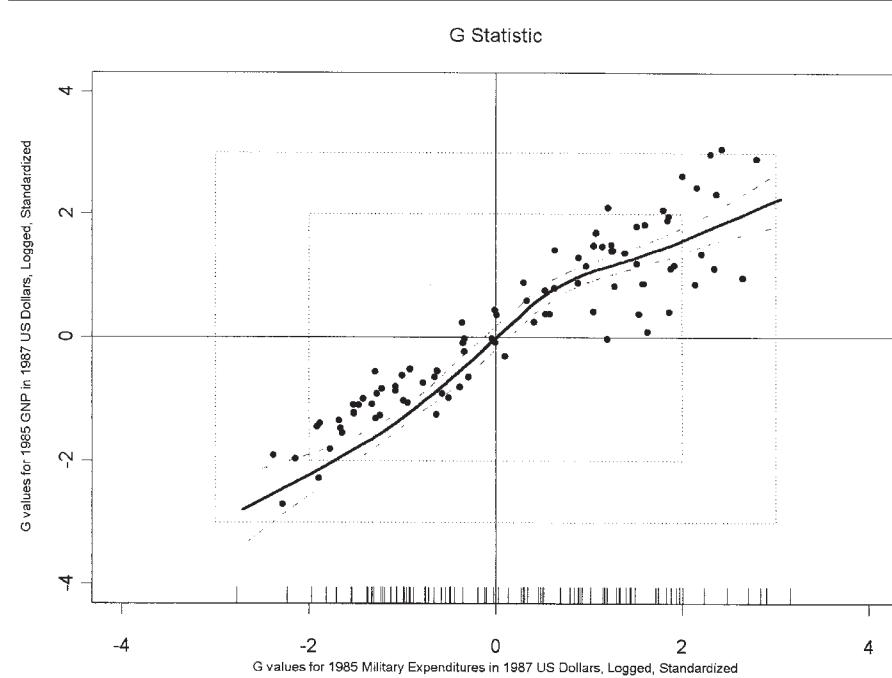


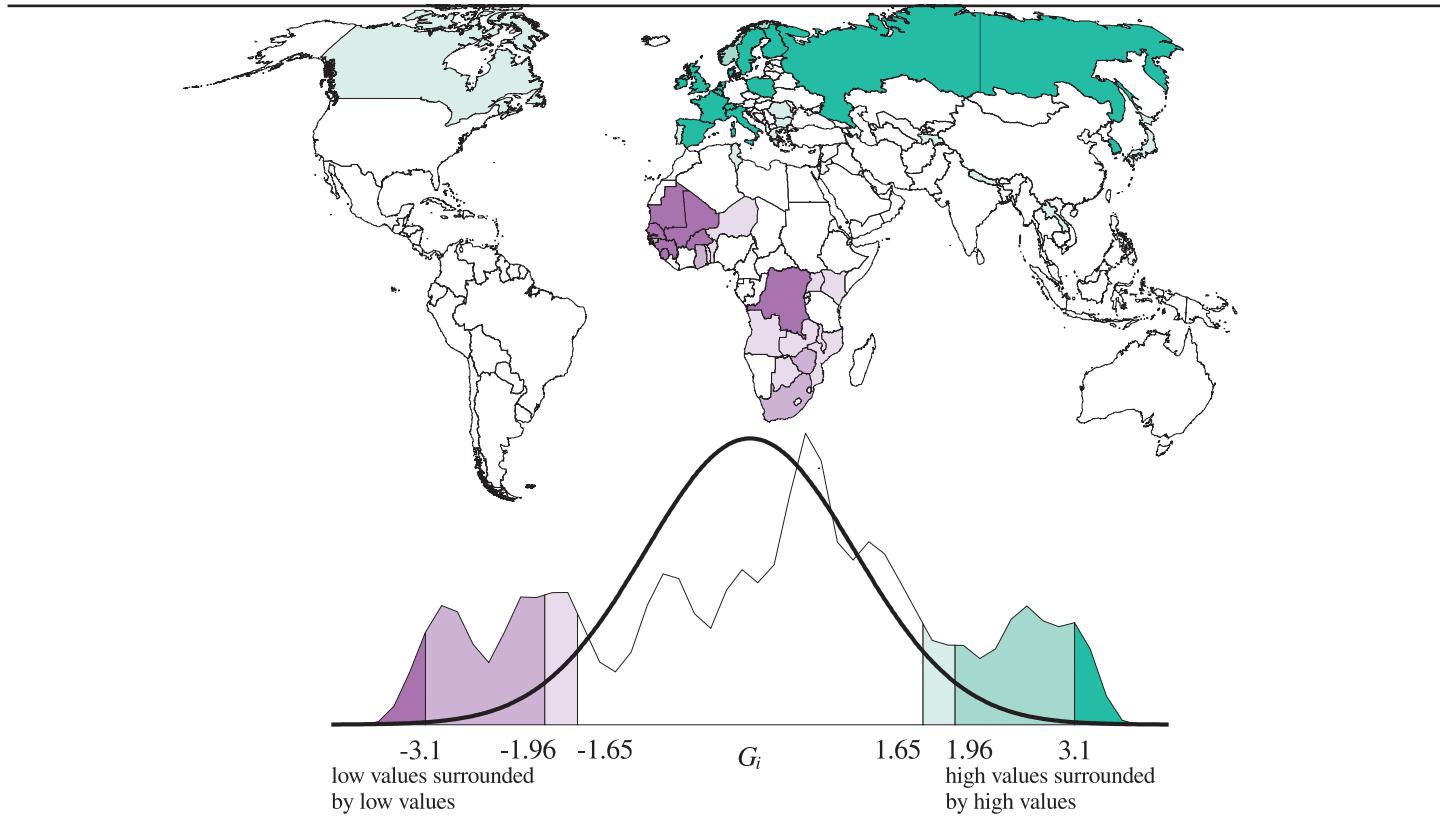
Figure 2: The Relationship between the Spatial Clustering of Gross National Product (y-axis) and Military Spending (x-axis)

matrix, but unlike Moran's I , the G_i statistics return values for each individual location. A statistically significant, positive G_i value indicates the clustering of similarly high values around an observation, where a significant, negative G_i value indicates the clustering of low values around an observation. The G_i statistic is formally expressed,

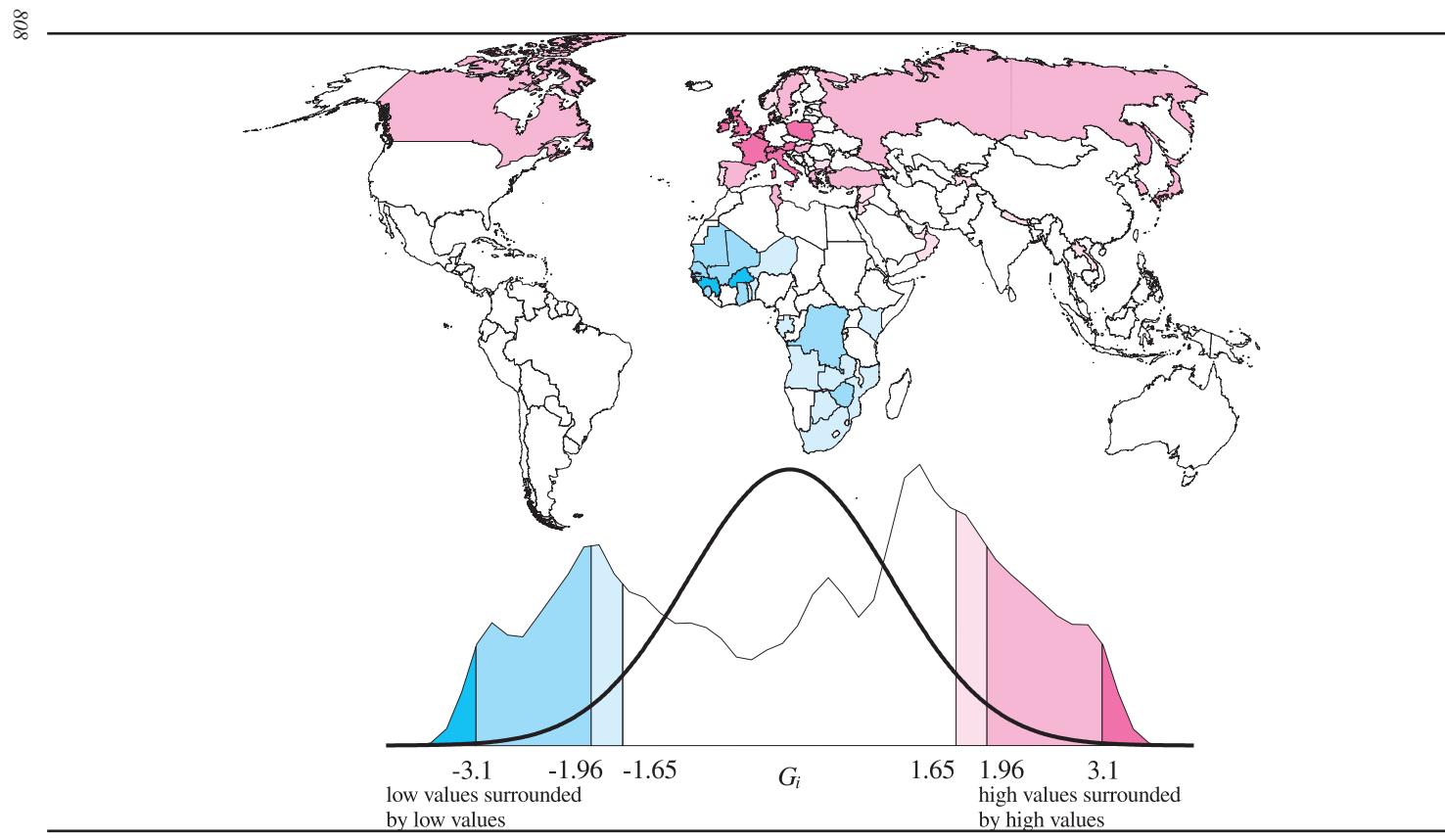
$$G_i = \frac{\sum_j w_{ij} y_j - \sum_j (w_{ij} + w_{ji}) \bar{y}}{\hat{\sigma}_y \sqrt{n \sum_j w_{ij}^2 - w_{ij}^2 / (n-1)}}, j \neq i.$$

If the diagonal elements of the spatial weights matrix are set to 1, each observation i is included in the calculation of the statistic. An asterisk is used to differentiate between matrices with diagonals set to 1 (i.e., G_i^*) and diagonals set at 0 (i.e., G_i). As can easily be seen in Figure 2, there is a strong correlation between these statistics for GNP and military spending, indicating a convolution of local effects.

The individual values of the G_i statistic are mapped (see Maps 4 and 5) to show the extent and location of significant clusters of high and low levels of logged GNP and logged military expenditures around the world. Progressive shades of green in Map 4 and red in Map 5 denote the increasing significance (i.e., at $p < .05$, $.01$, and $.001$, respectively) of positive G_i values, or the local clustering of high levels of GNP or military spending. Progressive shades of purple in Map 4 and blue in Map 5 indicate



Map 4: Spatial Clustering of Gross National Product, 1995



Map 5: Spatial Clustering of Military Expenditures, 1995

tary spending. Progressive shades of purple in Map 4 and blue in Map 5 indicate increases in the significance of negative G_i values, or the local clustering of low values of logged GNP or military expenditures, respectively. The legends below each map plot the density functions and significance limits for the G_i statistics against a normal distribution for visual comparison.

When looking at global patterns, the similarity of high and low clusters of logged GNP and logged defense spending within each year are most striking. It is logical to assume that a country's military spending is a function of GNP, but the significant spatial clustering of both high and low GNP and defense spending suggests that the region in which a country is situated may also affect levels of military spending and GNP. Relatively high levels of logged GNP and logged defense spending are clustered throughout Europe in all years, and the countries in west and south-central Africa exhibit significant, negative clustering of logged GNP and logged military expenditures. The new regional geographies created after the collapse of the Soviet Union (i.e., the introduction of new states to the international system that subsequently modified the contiguity matrices) also probably affected the 1995 results to a certain degree.

SPATIAL CONTEXT AND THE LINK BETWEEN MILITARY SPENDING AND ECONOMIC GROWTH

The exploratory spatial data analyses indicate that the geographic context in which states exist and, arguably, interact is important. Before turning to empirical estimation, we present the development of two widely employed models for representing continuous spatial processes: the spatial autoregression model and the spatial error model. In the former, we assume that there is a spatial process of some substantive importance to be examined; in the latter, we assume that there is simply a coincident problem with the errors. Turning to the spatial autoregression model, we assume a process described by $y = \rho W y + \mathbf{X}\beta + \varepsilon$, where y is the dependent variable and $W y$ its spatial lag, with \mathbf{X} representing a matrix of k independent variables and β a vector of k coefficients. ε contains the random error, distributed normally, $\varepsilon \sim N(0, \sigma^2)$. The coefficient ρ portrays the relationship between the spatial lag and the dependent variable.⁶

6. If we assume that y is a random variable that is distributed normally, it will have a probability density function that is given by

$$f(y|\mu, \Sigma) = 2\pi^{-N/2} |\Sigma|^{-1/2} e^{[-1/2(y-\mu)' \Sigma^{-1}(y-\mu)]},$$

where μ describes the mean(s) of the multivariate normal distribution and Σ its covariance matrix. Note that by assumption, Σ is equal to $I\sigma^2$. The distribution of the error process is also given similarly:

$$f(\varepsilon|0, \sigma^2) = 2\pi^{-N/2} \sigma^{2-N/2} e^{\left[\frac{-\varepsilon'\varepsilon}{2\sigma^2}\right]},$$

with terms defined as above. The Jacobian matrix is given as the partial derivatives of the errors with respect to the dependent variables:

The spatial error model rests on a different underlying notion, namely, that the spatial association is a characteristic of the error process, not the substantive process: $y = \mathbf{X}\beta + \lambda\mathbf{W}\varepsilon + \nu$, with terms as above, $\nu \sim N(0, \sigma^2)$, and λ portraying the spatial error contamination.⁷ We now turn to an evaluation of the spatial autoregressive and error models in the context of military spending and economic output for the period from 1990 to 1995.

There are two major approaches to studying the trade-off between guns and growth. One approach employs time series analysis, typically cast as a cointegration or granger causality issue. Examples of this include Kinsella (1990, 1991) and Avramides (1997). The chief liabilities of these studies are the short time series available for studying these questions and the demands of the techniques for long time series. A second approach avoids these known problems by focusing on the comparative statics as applied to cross-sections of sets of nations. Developed first by Ram (1986) as a modification of a trade model (Feder 1982), it has been applied and extended many times to study the trade-off question (e.g., Murdock, Pi, and Sandler 1997). The basic insight is that government spending can be decomposed into military and nonmilitary components, and the elasticity of these aspects of economic change can be mapped onto changes in gross output (i.e., GNP). By successive decomposition and differentiation, a coherent model is developed that illustrates that GNP growth is a function of changes in investment, consumption, and public spending—divided into military and nonmilitary components. The basic result of most of the cross-sectional studies is that growth

$$J = \frac{\partial \varepsilon}{\partial y} = \mathbf{I} - \rho \mathbf{W}.$$

This allows a restatement of the density function for y :

$$f(y|\mu, \Sigma) = |\mathbf{I} - \rho \mathbf{W}| 2\pi^{-N/2} \sigma^2^{-N/2} e^{\left[\frac{-(y - \rho \mathbf{W}y - \mathbf{X}\beta)^T (y - \rho \mathbf{W}y - \mathbf{X}\beta)}{2\sigma^2} \right]},$$

or $f(y|\mu, \Sigma) = |J| f(\varepsilon)$. When logged, this yields the likelihood function:

$$L = \ln |\mathbf{I} - \rho \mathbf{W}| - N/2 \ln 2\pi - N/2 \ln \sigma^2 - (y - \rho \mathbf{W}y - \mathbf{X}\beta)^T (y - \rho \mathbf{W}y - \mathbf{X}\beta) / 2\sigma^2.$$

Unlike ordinary least squares, this has no analytical solution and must be solved through numerical techniques. Ord (1975) demonstrated $|\mathbf{I} - \rho \mathbf{W}| = \prod_i (1 - \rho \omega_i)$, where the ω_i s are the eigenvalues of \mathbf{W} , the spatial weights matrix. By separating the eigenvalues, the interdependencies are reduced, allowing the likelihood function for the spatial autoregressive model to be solved numerically through minimization of the following to yield unbiased, consistent estimates of the unknown parameters, ρ , β , and σ :

$$\underset{SAR}{L} = \sum \{ \ln(1 - \rho \mathbf{W}) - 1/2 \ln 2\pi - 1/2 \ln \sigma^2 - (y - \rho \mathbf{W}y - \mathbf{X}\beta)^T (y - \rho \mathbf{W}y - \mathbf{X}\beta) / 2\sigma^2 \}.$$

Because of advances in computer software since the mid-1970s, for moderately sized problems, these tricks are not necessary, and the Jacobians can be included in the likelihood function without compromising the solution.

7. Following the same logic as presented in footnote 6 leads to an estimable likelihood function for the spatial error model:

$$\underset{SER}{L} = \sum \{ \ln(1 - \lambda \mathbf{W}) - 1/2 \ln 2\pi - 1/2 \ln \sigma^2 - (y - \lambda \mathbf{W}y - \mathbf{X}\beta + \lambda \mathbf{W}\mathbf{X}\beta)^T (y - \lambda \mathbf{W}y - \mathbf{X}\beta + \lambda \mathbf{W}\mathbf{X}\beta) / 2\sigma^2 \}.$$

can be affected positively or negatively (or not at all) by military spending in different local contexts. Some countries will exhibit a positive link, others a negative link.

Given the strong spatial clustering of both military spending and economic output uncovered and documented above, it seems entirely plausible that our understanding of the linkage between military spending and economic output can be enhanced by a specification that takes into account spatial, or regional, contextual information. In this study, we concentrate on that link while ignoring the confounding effects of investment and labor. Under this assumption, the Feder-Ram approach can be characterized by a simple equation (which can be cast either in difference or differential form): $dy/dt \sim \beta dm/dt + \varphi dn/dt + \phi dx/dt + \varepsilon$, where y is economic output, m is military spending, n is nonmilitary public spending, x is other factors such as investment and labor, and ε is Gaussian error. The coefficients β , φ , and ϕ are unknown and portray the impact of changes in the individual components of y on changes in y itself. Our investigation concentrates solely on the military and nonmilitary aspects of public spending as they relate to economic growth. We formulated this as a difference equation given in logs for which $\varphi = \phi = 0$. In this context, we examined a spatial lag (autoregressive) model specified as

$$\ln\left(\frac{y_{1995}}{y_{1990}}\right) \sim \rho \mathbf{W} \ln\left(\frac{y_{1995}}{y_{1990}}\right) + \beta \ln\left(\frac{m_{1995}}{m_{1990}}\right) + \varepsilon$$

where y portrays the GNP in 1987 U.S. dollars, m is military spending, and \mathbf{W} represents the weights matrix developed above for a distance band of 950 kilometers.⁸ This model portrays a spatial lag effect whereby localized economic processes may spill-in from neighbors and thereby affect the trajectory of growth in individual countries at the same time as the economy is affected domestically by growth in military spending. We also estimated⁹ the following model of the spatial error process that poses the question of whether the error terms are spatially correlated, but there is no substantive, economic spill-in:

$$\ln\left(\frac{y_{1995}}{y_{1990}}\right) \sim \beta \ln\left(\frac{m_{1995}}{m_{1990}}\right) + \lambda \mathbf{W}\varepsilon + \nu.$$

Table 6 portrays the results of the estimation of the spatial lag model of defense-growth trade-offs, and Table 7 presents the results for the spatial error model. The parameter estimates from the spatial lag model obtained via bootstrap estimation are provided in Table 8.

The spatial lag model is shown to be strongly preferred to an ordinary least squares (OLS) model without a spatial lag (the likelihood ratio is very unlikely to occur by chance, and the lag term is estimated with a narrow standard error). Economic growth is strongly affected by growth in surrounding societies (the coefficient is ~.08) as cap-

8. It may not be obvious, but the spatial term in this equation effectively represents multilateral and simultaneous interaction between all members of the system. As such, it presents a possible way to solve the n-adic arms race literature in the context of empirical models that are not devoid of degrees of freedom.

9. These models were estimated with version 1.9 of SPACESTAT, available at www.spacestat.com. They were replicated in S-PLUS® 4.5, running under Windows®98.

TABLE 6
Maximum Likelihood Estimates of Spatial Lag Model
of Military Spending on Economic Growth, 1990-1995

<i>Coefficient</i>	<i>Estimate</i>	<i>Standard Error</i>	<i>Probability</i>
Spatial lag, ρ	.081	.002	.000
Growth effect, β	.153	.040	.000
Log likelihood = 13.54 N = 95			

TABLE 7
Maximum Likelihood Estimates of Spatial Error Model
of Military Spending on Economic Growth, 1990-1995

<i>Coefficient</i>	<i>Estimate</i>	<i>Standard Error</i>	<i>Probability</i>
Spatial error, λ	.080	.003	.000
Growth effect, β	.147	.040	.000
Log likelihood = 14.25 N = 95			

TABLE 8
Bootstrap Estimation of the Spatial Lag Model (10,000 permutations)
of Military Spending on Economic Growth, 1990-1995

<i>Coefficient</i>	<i>Estimate</i>	<i>Standard Error</i>	<i>Probability</i>
Spatial lag, ρ	.134	.012	.000
Growth effect, β	.161	.038	.000
Log likelihood = 13.54 N = 95			

tured by the spatial lag variable. It is also evident that changes in military spending are positively linked with changes in economic output. In short, there is no apparent evidence of a strong trade-off between growth and military spending. Many societies are able to maintain growth in both aspects, although there are some notable exceptions to this rule. However, the direct translation of growth in military spending toward a subsequent increase in economic output appears to be fairly weak or small in magnitude in this example. These results show that the link between military spending and economic growth is complemented by a strong economic spill-in from neighboring states. This has been ignored in the vast empirical literature on this subject. These have separate impacts on economic growth. Table 7 investigates the question of whether the residuals from a standard regression model are themselves independent and shows convincingly that the error terms are significantly clustered across space. In other words, by ignoring the spatial component of economic growth, our understanding of

the link between economic growth and military spending is potentially biased and clearly less precise in two senses. In the first instance, we completely ignore the spill-in effects of regional economic processes (i.e., we have an important, omitted variable, which biases our results); in the second instance, our estimates give us less confidence in the precise nature of the linkages (i.e., the standard errors are inflated).

Diagnostics for both the spatial lag and spatial error models indicate that spatial dependence within the error term remains problematic. Bootstrap estimation was employed to obtain nonparametric, alternative estimates and significance levels for the spatial lag model. This technique employs Monte Carlo simulation to generate an empirical estimate of the sampling distribution for the desired statistic, such as an estimated regression coefficient (Mooney and Duval 1993, 9). Obtaining a bootstrapped regression coefficient begins with resampling (with replacement) the error term, adding this vector of resampled errors to the vector of predicted values, and, finally, estimating new coefficients with the bootstrapped dependent variable and the set of fixed, exogenous variables. This procedure was repeated 10,000 times in our analysis and used spatial lags as instruments to generate the error term (for details, see Anselin 1988, 1992; Mooney and Duval 1993).

The estimates for the spatial lag model obtained via bootstrap estimation are provided in Table 8. Using the bootstrap estimator, both the coefficient and standard error for the change in military spending are remarkably similar to the estimates obtained via maximum likelihood estimation reported in Table 6. The estimate for ρ , however, is more than 50% greater than those reported in Table 6 and Table 7, and it remains remarkably significant (i.e., z value > 10). This shows that the actual amount of bias is relatively small, but that the impact on the estimated variance-covariance matrix is substantial.

The spatial lag effect is approximately as strong (.134/.161 = .83%) as the impact of military spending, which remains roughly the same as when spatial effects are excluded. This shows clearly that the spatial lag effect of regional economic processes has an independent and important role to play in our understanding of the linkage between economic growth and military spending in the contemporary world.

Whether one chooses to view the spatial process as driven by a substantive linkage between growth and military spending (the spatial lag approach) or some unspecified force affecting the error process (the spatial error approach), it is clear that ignoring the spatial process will produce statistical descriptions that are inferior. The OLS model (not presented) not only presents biased estimates with incorrect standard errors but portrays the linkage between growth and spending in an inadequate and inferior fashion. In short, the link between military spending and economic growth is dependent on the spatial linkages represented (herein) by contiguity. This means that the process that links the economic growth of these countries and their military spending is *conditional* upon the linkages represented by the spatial weights matrix. Without taking these links into account, neither the effects (the coefficients) nor their confidence intervals (the variance covariance matrix) can be adequately determined to permit confident inferences. Both the spatial lag and spatial error models are strongly preferred to the OLS

specification. In short, economic growth is not only constrained by the endogenous macro-economy, but it is also tightly connected to the surrounding political economic milieu.

If everything else is held constant, and there are no countervailing or compensating adjustments, there is a synergy rather than a trade-off between guns and growth. That much seems obvious. However, it is also now apparent that there is a spatial pattern to these synergies. Not only are GNP and military spending highly clustered, each in its own right, but their relationship is also in part determined by localized, spatial processes, which differ across the globe. The economic output of contemporary polities is strongly affected by their military spending patterns. Even setting aside the questions of openness and economic exchange, it is also affected by the economic productivity and output of neighboring states. States could experience falling GNP as a consequence of the collapse of a sector within the economy, as would be represented by drastic cuts in military spending. But they also could experience similar consequences from their linkages to regional neighbors. Obviously, countries are not mobile. Although our results suggest that attention to the regional political economy is only about one-half as important as attention to the guns-growth linkage, the impact is substantial. Our results demonstrate that the trade-off between guns and growth must be examined in the context of regional patterns, since the regional influences are especially salient both for military spending and economic growth.

CONCLUSION

We end by reiterating that the local spatial context is an essential part of understanding the evolution and dynamics of arms expenditures and economic growth. We have shown that levels of defense spending are tightly clustered in space. Standard models of the arms process have for the most part ignored this. As a result, it is quite likely that many prior models will require reexamination. Moreover, we have shown that economic output is also highly clustered in space, something that is widely known, perhaps, but totally ignored in most empirical and theoretical work. As a result, it seems absolutely clear that our knowledge about the linkages between the economy and defense spending remains lost in space. Finally, we have illustrated that the changes in economic output and military spending are tightly coupled. There is a strong synergy between them, one that is illuminated more clearly if spatial models are applied. Not only do borders create (or reflect) interaction opportunities that may increase the risk of (or result from) war (Gleditsch 1999; Gleditsch and Ward 2000b; Starr 1978; Starr and Most 1976, 1978, 1985), but a nation's GNP growth is also affected positively by its neighbors: good neighbors make good neighbors, as well.¹⁰

Do these results have broader implications for scholarship? Much quantitative research in the areas of international politics and economics, encompassing security studies as well as empirical investigations of comparative political economy, use cross-sectional designs for which the units have a connection to one another. An

10. We recognize the shortcomings of our assumption that investment and labor as well as nonmilitary government spending can be ignored for the purposes of concentrating on the guns/growth trade-off. We hope to address this more fully in subsequent research.

assumption that these units are independent belies our fundamental interest in their interrelationship. Many analyses tend implicitly to assert that the economies of Sweden and Finland are independent, for example. At the same time, it is unknowingly posited that the military spending patterns of North and South Korea are also independent. There is strong evidence from regional- and country-level studies and the spatial statistics presented above that these kinds of assumptions are not warranted. More important, this tells us that the image of the world that we constructed in our scholarship is necessarily truncated if our methods continue to ignore the very linkages we seek to understand.

Many social science studies will be enhanced by the adoption of a spatial framework. Setting aside the statistical aspects, there are two compelling reasons. First, the distribution of empirical (qualitative and quantitative) studies is bimodal. Many studies concentrate on a single case or alternatively on a large collection of single cases: small N or large N . Dyadic studies tend to examine very large numbers of bilateral interactions. Yet, many of us believe that the world we study has a political and economic life that is neither solitary nor exclusively bilateral. By using the spatial approach to incorporate a matrix of social relations and networks, we may be able to address the multilateral aspects of international and comparative economics and politics.

Second, there is a wide gap between those in our disciplines who assert that context counts and those who believe that it does not. Whether context is the substance of economics and politics or simply a statistical nuisance is not an especially interesting question. We have shown how regional “context” is important in investigating the link between guns and growth. Yet, this does not imply that context is everywhere the same. In fact, the second compelling reason that promotes the use of these approaches is that it embraces the notion that context can be important, but that it is not necessarily the same everywhere, yet it does so in a systematic, testable manner. These tools permit us to evaluate more clearly the arguments about how context affects politics and economics in a fashion similar to the standard sets of evaluative framework that are widely employed in empirical social science.

As a *systematic* way of embracing multilateral and contextual information about our complicated world, these spatial, political geographic approaches hold considerable promise. It would be hard to choose (just) two variables that are more broadly representative of comparative and international scholarship on politics and economics than GNP and military spending.¹¹ It would be apparent to most scholars that these variables will be correlated over time. Few longitudinal studies will be believed that do not in some way come to grips with this fact. It should now be evident that these two variables have a strong spatial association as well. In the same way that we must come to grips with the temporal dynamics that undergird social and political change, it is important to confront, if not embrace, the spatial dynamics as we move toward a deeper understanding of the world. It will enhance our understanding and embellish our conceptual models and should allow us to have greater confidence in what we know.

11. For the record, war, militarized disputes, and trade are also highly clustered in space.

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