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The spatial theory of elections: an analysis of voters' predictive dimensions and recovery of the underlying issue space

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The spatial theory of elections:

An analysis of voters' predictive dimensions

and recovery of the underlying issue space

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by

Thomas Cole Tanner

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Signatures have been redacted for privacy

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TABLE OF CONTENTS

AN INTRODUCTION TO SPATIAL ELECTION THEORY

A History of Spatial Voting Theory

The earliest roots of spatial voting theory can be found in Harold Hotelling's 1929 paper "Stability in Competition". The paper was primarily concerned with an analysis of the spatial equilibrium condition for two firms in competition. Hotelling's startling conclusion was that these two producers, choosing first their location and then their price, would choose to locate right next to each other. It was assumed that the consumers were uniformly distributed, and that they paid the cost of transportation so that each consumer would buy from the least-cost producer, taking account of both the base price and the transportation cost of the good. The equilibrium location for both firms under these conditions, he argued, must be located at the center of the consumer population; the location of the median consumer.

The conclusion Hotelling reached was disturbing, since it is clear that the optimal location for the two firms, the location where the firms will produce and distribute at the minimum cost, would be at the quartile points (that is, one-quarter of the interval length from each end of the interval). Hotelling's conclusion was that the equilibrium location for the two firms would be suboptimal.

In his concluding remarks, Hotelling claimed that this tendency for competitors to become identical might be more generally applicable. Of particular interest was his suggestion that this same centralizing tendency might be found in political programs. He concluded that political parties will tend to offer essentially identical platforms rather than offering clear and distinct alternatives. The latter, Hotelling thought, would be preferable.

Hotelling's argument as applied to the situation of competing firms was later shown to be fallacious (d'Aspremont, Gabszewicz, Thisse 1979). The flaw in his argument was that, when firms are choosing the price of their product, if the firms are sufficiently close to one another, the best strategy by one firm is to undercut the price charged by the other firm at that firm's location, and hence undercut the price for the entire market area beyond it. Regardless of the positions chosen by the two firms, there will be no pure strategy equilibrium in prices - there is no profit maximizing pricing strategy for either firm which remains unchanged regardless of the pricing strategy of the other firm. While this counterargument can be applied to all market situations where a pricing mechanism exists, it does not apply to the analogous equilibrium in the case of differentiated political parties, where no equivalent to the pricing mechanism exists.

Hotelling's paper spurred extensive research into the nature of spatial competition, although initially only Smithies (1941) examined the political implications of Hotelling's work. Smithies introduced the economic concept of elasticity into the analysis of voting behavior. The political interpretation of elasticity in a two-party campaign was the possibility that political extremists might abstain from voting as the preferred political party moved closer to the median voter in an attempt to capture moderate voters.

The breakthrough work on a spatial theory of voting was done by Black (1948 a, b). Black showed that, under the same assumption made by Hotelling and Smithies that the alternative political positions can be located on a single vector, and if preferences for each voter can be represented as a quasi-concave utility function, then the median most preferred point will have a majority against any other. Further, a pairwise majority vote among the alternatives will actually produce a complete order.

The early spatial models, with their heavy reliance on the strong assumptions of single-peaked utility curves and of one-dimensional voter space suggests that a general impossibility theorem would exist should either of these two assumptions be dropped. These problems were highlighted by Black and Newing (1951), who showed that if the political space were represented in two dimensions rather than one, even the quasiconcavity assumption is insufficient to guarantee the existence of a Condorcet majority, let alone an ordering.

Since these early explorations of spatial voting theory, there has been an explosion of research into spatial voting theory; so much research has been conducted in the field, addressing such a wide range of issues, that it can be divided into subfields. The most common distinction made is between spatial theory of committees and spatial theory of elections. The spatial theory model laid out by Black made no distinctions between the problems of elections and of committees, but subsequent research has raised separate and distinct issues for the two subfields. In the spatial theory of committees, the voters, each of whom are mapped as a point in voter space, are the key actors to determining the policy or policies which will be enacted. In the spatial theory of elections, the candidates and their location in voter space are the key actors, with the voters paying a more fixed role. There are strong similarities between the two subfields, but translation of the results of committee theory to election theory or vice-versa is not always possible or desirable.

Black viewed what would become the spatial theory of elections as nothing but a special case of the spatial theory of committees, where elected officials were simply modeled as a bundle of policy positions, which could be represented as a point in voter space. Voters were assumed to then vote strictly according to their preferences over the policy alternatives offered by the candidates; the result of Black's model of elections is essentially identical to the results he obtained for a committee voting on a set of policy alternatives.

The first to lay out a spatial theory to be applied specifically to elections was Downs (1957) with a thorough mathematical foundation for election theory laid out by Davis and Hinich (1966). The election theory initiated in this work focused on the election scenario of a large electorate with no incentive to vote strategically[1]. Election theory through the 1960's and 1970's focused on generalizing the assumptions of the model, but generally retained the characteristics set forth by

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[1] Strategic voting involves a voter not revealing his/her true preference on the issue, in order to or change the behavior voting outcome.

Downs, Davis, and Hinich of a nonstrategic electorate and strategic candidates.

Fahrquarson (1969) laid out much of the groundwork for modern committee theory based on the concept of sophisticated voting, and relied on an extensive use of game theory to provide a means of explaining the true strategic behavior inherent with the small number of voters usually examined in committee theory.

The most complete analysis of the state of spatial election theory from this period is from Riker and Ordeshook (1973), who list a wide range of assumptions regarding the behavior of both candidates and the electorate, and examine which of the various combinations of assumptions will result in a pure strategy equilibrium for the candidates. Riker and Ordeshook allowed voters to have differently shaped utility curves, and may abstain from voting through either alienation or indifference. The candidates basic goal of winning election is examined in several different variants, including maximization of expected plurality, maximization of expected number of votes, maximization of the probability of winning, and others.

One major problem encountered in basic election theory is that, once the assumption of a symmetric distribution of ideal points[2] is dropped, with simple preference-based voting and two or more issues, a pure strategy equilibrium will seldom exist for the candidates. The

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[2]A voter's ideal point is the point in the underlying issue space that the voter finds as good or better than all other possible points in the issue space

question of what conditions are necessary and/or sufficient for the existence of stability and a dominant strategy in a multidimensional spatial model was first examined by Plott (1967), and has since become the subject of a great deal of research (Davis, DeGroot and Hinich 1972; Kramer 1973). With few exceptions, under these more realistic assumptions, a candidate can potentially be defeated no matter what policy positions he/she adopts. McKelvey (1979) further found that when the above assumptions failed to produce a pure strategy equilibrium, it allowed for a candidate to potentially win regardless of his/her positions on the issues. By the late 1970's and early 1980's, several theorists had abandoned any hope of ever using the spatial theory of elections to predict candidate behavior (Riker 1980).

The future of election theory lay with the understanding that elections are a contest not simply between policy alternatives but between individuals. Modeling voter behavior in elections requires taking into account the existence of some degree of randomness in any spatial model of elections. While the behavior of each individual voter is wholely rational and non-random, any model which attempts to agregate the behavior of a large number of voters will inevitably result in a great deal of unexplained variation. This randomness is induced by several features inherent in elections, including abstention from either alienation of indifference, nonpolicy characteristics of the candidates, omitted policy vectors in the model, measurement error, and other factors. Modeling, which recognized these factors and included a probabilistic theory of voter behavior, began as early as 1972 with Hinich, Ledyard, and Ordeshook, but received little attention until the late 1970's and early 1980's (Hinich 1977; Coughlin and Nitzan 1981). Such probabilistic models seem a much more reasonable means of modeling the low information environment of the electorate, and the sufficient conditions for pure strategy equilibrium in a two-candidate, multidimensional model are much less restrictive for probabilistic than for non-probabilistic models (Enelow and Hinich 1989).

The early 1980's also saw the birth of an alternate approach to modeling elections which was designed not to determine the existence or non-existence of a pure strategy equilibrium for candidates, but to add additional realism to the model and determine the behavior of voters in the absence of extensive information on the positions of the candidates. McKelvey and Ordeshook(1985) introduced a rational expectations model of voter behavior. In their model, the uninformed voters determine which candidate to vote for based exclusively on the information provided in public opinion polls. McKelvey and Ordeshook found that, under a very few weak assumptions, these 'uninformed' voters will extract sufficient information from the public opinion polls to vote as they would be expected to if fully informed of the candidates positions.

Enelow and Hinich (1984) developed a model of voter behavior in which the voter estimates the candidates position in voter space based on the set of shorthand labels applied to the candidate, such as the Democrat/Republican, liberal/conservative, etc. While the model does offer appeal through its resemblance to observed electorate behavior, the justification for the model is more empirical. By reducing a large, multidimensional issue space to a relatively small 'political label' space in which both voters and candidates can be located The work of both McKelvey and Ordeshook and Enelow and Hinich is based on the critical question for election theory of how the electorate uses shorthand devices such as polls and party affiliation to cut down on the information costs that would be incurred to become truly informed on the candidates.

Other means of finding equilibria in election theory have included mixed minimax strategy solutions (Mc Kelvey and Ordeshook 1976; Kramer 1978), stochastic equilibrium (Ferejohn, Fiorina and Packel 1978) and dynamic stability (Kramer 1977). Questions about the worth of these models, however, has caused them to fall into disuse (Enelow and Hinich 1990).

While the primary focus of spatial election theory has been in finding the equilibrium, a body of literature has focused on other aspects of elections. Brams (1980), Palfry (1984) and Cox (1990), have used spatial election models to examine the results of electoral competition between three or more candidates, with or without entry. Sugden (1984) and Cox (1987) have researched the results of proportional representation systems on the results of spatial election theory.

Another area of interest to election theorists has been examined by Greenberg (1979), Schofield (1986), and Caplin and Nalebuff (1988).

All have examined the implications for elections of increasing the size of the winning vote from a simple majority to a larger majority. Not surprisingly, they have found that as the size of a majority increases, potential equilibrium points become more and more plentiful.

Riker (1986) has examined a different variant on the voter space model in which the candidates in an election have the ability to increase the dimensionality of voter space. Riker introduced what he calls Herestetics to the theory of elections by suggesting that candidates will attempt to win an election by the strategic introduction of new issues, and hence new dimensions, into the voter space which will act to increase the candidates' chances of election.

The Basic Spatial Election Model

The most basic spatial election model, on which all more advanced models are based, involves an election based on a single dimension. consider a population involved in an election, in which each individual's most preferred political policy could be mapped as a single point on a single dimension. The most frequently used dimension in a one dimensional model is that of left-right political ideology; thus, a very liberal individual might be mapped as a point on the far left end of the single predictive dimension, and a right-winger might be mapped as a point on the right end of the predictive dimension. Every voter can be mapped onto the predictive dimension in this manner, and in a campaign, the candidates can also be mapped as a point on the predictive dimension, in accordance with the policy positions they adopt for the campaign.

The other primary assumption of the simple spatial model is that every voter will most prefer the candidate whose position on the predictive dimension is closest to the location of that voter's most preferred point on the predictive dimension. This is the simple Euclidean distance rule, which means that a voter i, whose position on the predictive dimension is represented by v_i will prefer (and so vote for) a candidate A (located at a point A on the predictive dimension) to a candidate B (located at a point B on the predictive dimension) only if

$$|A - v_i| < |B - v_i|$$

and will vote for B if

$$|B - v_i| < |A - v_i|$$

and if

$$|A - v_i| = |B - v_i|$$

then the voter i will be indifferent between the two candidates.

In this and any spatial elections model, a special significance can be attached to the position on the predictive dimension of the median voter (the median voter is the voter whose position on the predictive dimension is such that half of the voters' ideal points lie on either side of the median voter's ideal point). The significance of the median voter is that, so long as their are an odd number of voter, with two candidates competing for a simple majority of the votes, the candidate who wins the vote of the median voter cannot lose the election.

For sake of argument, let $A < B$. All voters whose most preferred points lie to the right of B will vote for B, since they are clearly closer to B then to A. Likewise, all voters to the left of A will vote for candidate A. All voters whose ideal points are equal to B will vote for B and those whose ideal points are equal to A will vote for A. B will also capture all of the voters between A and B who are closer to B then to A, and A will capture all the votes between A and B closer to A. So A will capture all of the voters' whose ideal points lie to the left of the point $(A + B) / 2$ and B will capture all of the votes to the right of that point. If the median voter's most preferred point, v_{med}, lies to the right of $(A + B) / 2$ (as in figure 1), then the median voter, and every voter to the right of the median voter, will vote for B, and (by the definition of the median voter) B will win the election. On the other hand, if v_{med} lies to the left of $(A + B) / 2$, then the median voter and every voter to the left of the median voter will vote for A, and candidate A will win the election.

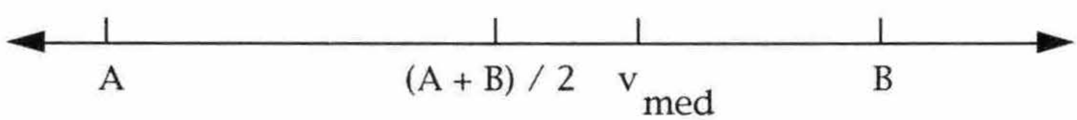

Figure 1: An election in one dimension, in which B will capture the median voter and win the election.

Because any two-way campaign will be won by the candidate who captures the vote of the median voter, another conclusion can be reached: if a candidate's location on the predictive dimension is the same as the position of the median voter, then the candidate cannot be beaten by any a candidate located anyplace else on the predictive dimension in a pairwise election with majority rule. If a candidate A is located at the same point as the median voter, and their opponent is more conservative (to the right of the median on the predictive dimension), then A is guaranteed to capture the median voter and every voter to the left of the median voter, and so will win the election. If the "median candidate's" opponent is more liberal (to the left on the predictive dimension) then the "median candidate" will capture the median voter and all who are more conservative than the median voter, and so is guaranteed a majority. Thus, the position of a median voter is a Condorcet winner[3].

Worth noting is the special cases where either the two candidates lie at the same point on the predictive dimension, or where the median voter lies exactly halfway between the two candidates (that is, on the point (A + B) / 2). In these cases, the results of the election are indeterminate. The election in this case will be determined by the indeterminate behavior of indifferent voters. These cases, however, do not pose a major problem, since the likelihood of these cases occurring are essentially nil.

The other candidate location which might be cause of some concern to theorists is the case of both candidates locating themselves on the median voter. This special case might appear quite problematic; it has been shown that the candidate located at the same point as the

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[3]A Condorcet winner is any candidate (or issue) that defeats all others in a pairwise majority rule comparison.

median voter cannot be beaten, so naturally both candidates might be expected to locate themselves at the ideal point of the median voter. The end result, then, would seem to be that both candidates would locate themselves at the median voter, and the model can tell us very little about the outcome of the election. However, the candidates in the election cannot be expected to have perfect information on the location of the median voter, and the median voter's ideal point will not necessarily remain static. The result on these uncertainties regarding the location of the median voter is that, while both candidates can be expected to attempt to locate themselves at the median, the likelihood of either, let alone both, candidates successfully locating at the median is so slight as to be of little concern. Both candidates would likely locate very near the median, but spatial voting theory will be unable to predict a winner if both candidates locate themselves at precisely the location of the median voter

The Enelow-Hinich Spatial Election Model

Perhaps the most comprehensive model of the spatial theory of elections, and the one examined in more detail here, is that originated by Enelow and Hinich (1984).

The most basic models, like the one described briefly above, assume that the voters are in full understanding of the policy options, and all have the same perception of the status quo policy and all the alternatives. Such models work well as an abstract representation of direct democracies, but a slightly different variation on the spatial voting model is needed for an analysis of indirect democracies, where there are a large number of voters voting not for a set of policies but for a candidate for political office. The spatial theory of elections, in many variations, has been used to explain the behavior of both candidates and voters in indirect democracies.

In a representative democracy, the candidates take on the role played by policy options in a direct democracy. But the choice between two candidates is more than just a choice between two policies or two sets of policies. Each candidate will, to some extent, stake out a position on the issues of the campaign, and the voters, also to some extent, will base their vote on the policy positions that the various candidates choose. But the range of policies and issues embodied in a single vote in an election is far more diverse and complex than the relatively limited set of policy options embodied in a vote in a direct democracy. Any large issue, such as the national debt, is likely to be discussed only in the broadest of terms, leaving voters with only a general idea of what the candidate's exact policy position is. Unlike issues examined in direct democracies (and modeled in the spatial theory of committees), the policy options as embodied by candidates in indirect democracies are likely to be much less clearly delineated.

Exacerbating the problem of a lack of specificity in the discussion of policy issues by candidates is the problem of information costs. The vast majority of voters in elections lack incentive to invest much time, energy, or money into acquiring information about the policy positions of the candidates. When the vote of any single individual is "watered down" by the votes of millions of others, it is unreasonable to assume that the voter would devote as many resources in examining the candidates as they would if their decision was decisive in determining the outcome of the election. Because the individual voter's choice of whom to vote for will ultimately have very little impact on the outcome of the election, and thus very little impact on the utility experienced by that voter, they will have little incentive to seek out information about the candidates.

It is also noteworthy that policy issues are not the only issues that will be raised during a campaign, and not the only issues on which voters will base their votes. While candidates take positions on such issues as the debt, foreign policy, energy policy, entitlements, and so on, the characteristics of the candidates themselves are also issues. The age of a candidate, the experience of a candidate, the intelligence of a candidate or the morality of a candidate have all been issues in election campaigns. The position of a candidate on these nonpolicy issues is both important to voter perception of the candidate, and clearly beyond the control of the candidate.

Typically, voters receive information on the candidates through indirect means, such as newspapers and television. These sources generally present a simplified analysis of the candidates, with information on policy issues being particularly scant. Candidates are generally described with shorthand labels such as "New Deal democrat" of "fiscal conservative." While these shorthand descriptions are brief, they do convey a great deal of information on policy positions to the voters. A New Deal democrat might be expected to advocate an increase in social welfare spending, cuts in defense spending, a more progressive tax structure, increased regulation of private enterprise, as well as a number of other implied policy positions. The shorthand labels attached to candidates have the effect of greatly simplifying discourse on candidate positions by avoiding the alternative of presenting an enormous list of the candidates' positions on each individual issue. Given the lack of incentive on the part of voters to gather information on the candidates, political labels seem an ideal means of communicating candidates' positions to voters.

The labeling of political candidates is key to many models of spatial election theory, most notably that advanced by Enelow and Hinich (1984). In this model it is assumed that the political labels may be arranged into one or more predictive dimensions that represent the underlying space in which the electoral competition takes place. assume for the time being that there is a single predictive dimension (see figure 2). The dimension most often used is the classic left-right ideological dimension proposed by Downs (1957). What is assumed in this model is that each candidate may be given a label along

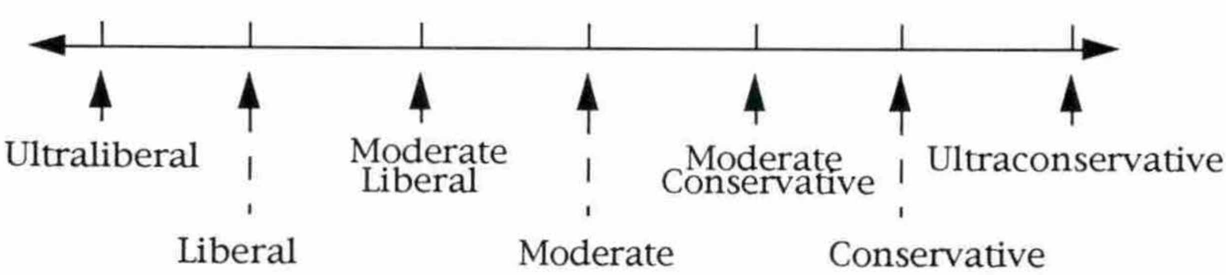

Figure 2: A classic left-right predictive dimension.

this predictive dimension, ranging from ultraliberal to liberal, moderate liberal, moderate, moderate conservative, conservative and ultraconservative. More points of the single predictive dimension could be identified by attaching more adjectives, the essential requirement being that the labels may be viewed in a natural linear ordering, like numbers on a number line. It is further assumed that a the label a candidate has cannot be changed in the space of a single election. While many politicians manage, to some extent, to change their perceived political ideology over the course of a decades long political career, it is difficult to conceive of a candidate convincingly changing political ideologies over the course of a single campaign.

Also key to this model of elections is the assumption that while all voters share a common perception of the set of political labels assigned to each candidate, each label may suggest a different set of policy implications to different voters. The result of these two assumptions is that political debates are framed in terms of the ideological labels, but the labels assigned to the candidates are subjectively interpreted into a set of policy positions by each individual voter.

Critical to the analysis of voter behavior, then, is the question of how voters translate the predictive dimension as defined by the predictive label into a set of policy positions in the mind of each individual voter. If we are given two candidates, A and B whose location on predictive dimension Π shall be denoted π_a and π_b respectively. All voters, as discussed before, will know these labels, which are fixed for the duration of the campaign, but they will not necessarily agree on the policy positions implied by the predictive labels.

Suppose that A_{ij} is the estimate of candidate A's position on issue j by voter i. The question is how does i arrive at that estimate of A's position on j? The simplest model is based on the assumption that A's policy position on j is a linear function of his position on the predictive dimension Π, as shown in figure 3. Let $w_{ij}(\pi)$ denote voter i's estimate of a candidates position on issue j as a function of the predictive label π attached to that candidate. The simplest functional form which might be used would be

$$w_{ij}(\pi) = m_{ij} + \pi v_{ij}$$

where m_{ij} and v_{ij} are the intercept and slope coefficients, respectively, of the linear function. With this linear prediction rule, where policy positions are a function of the candidate's predictive label alone, then it follows that voter i's estimate of candidate A's position on policy issue j would be

$$A_{ij} = m_{ij} + \pi_a v_{ij}$$

and his estimate of the position of candidate B on issue j would be

$$B_{ij} = m_{ij} + \pi_b v_{ij}$$

with B_{ij} being voter i's estimate of candidate B's position on issue j.

Worth noting is that no point on the predictive dimension Π can be considered an absolute origin. Any point on Π can be designated as the origin, and the absolute difference between any two points may be used as a unit of measurement. Accordingly, for consistency, one may set

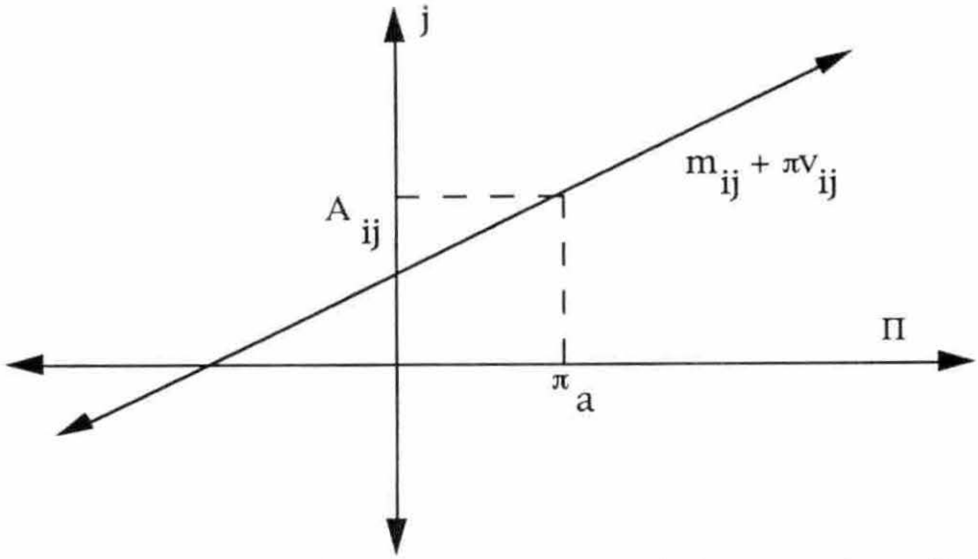

Figure 3: A simple linear function by which voter i predicts candidate A's position on issue j.

the origin of Π equal to the position of candidate A on the predictive dimension. Likewise, in the case of two candidates with different locations on the predictive dimension, the absolute difference between the positions of candidates A and B shall be used as a unit of measurement. With the introduction of these standards, $\pi_a = 0$ and $A_{ij} = m_{ij}$, so m_{ij} is voter i's perception of A's position on issue j. By using $|\pi_a + \pi_b|$ as the unit of measurement along Π, one must set $\pi_b = 1$ or $\pi_b = -1$. Which one to choose is entirely arbitrary, but since liberal-conservative ideology is generally arrayed with labels to the left as more liberal and to the right as more conservative, it would be reasonable to assign $\pi_b = 1$ if B is more conservative than A, and $\pi_b = -1$ if B is more liberal than A.

Suppose, then, that B is to the right of A on the predictive dimension (B more conservative than A). Then A's position on issue j as perceived by i is $m_{ij} + v_{ij}$. The expected sign of v_{ij}, which represents the perceived difference between the two candidates, might be positive, negative, or zero, depending on the nature of issue j and its perceived relationship to the predictive dimension. If, for example, j is defense spending, then v_{ij} is likely to be positive, with the more conservative candidate, B, advocating a larger defense expenditure than A. If j were welfare expenditure, then v_{ij} might be negative - the more conservative the candidate the less welfare spending they will advocate. On the other hand, if j were a subject such as NATO policy, which is relatively nonpartisan, then v_{ij} might well be zero.

Suppose that there are two issues in a campaign, with one underlying predictive dimension. Continuing with the above assumptions, $\pi_a = 0$ and $\pi_b = 1$ represent the positions of the candidates on the predictive dimension. In the case of a two issue campaign, the most preferred policy options of each of the voters can be represented as a two-dimensional vector. For example, voter i's most preferred policy options on issues 1 and 2 may be represented by the vector $x_i = (i_1, i_2)$.

For example, let us suppose that the two issues in the campaign are spending on welfare programs (issue 1) and defense spending (issue 2), measured as a percentage increase or decrease from the status quo. The location of the most preferred points of three voters i, j, and k might be represented by the vectors $x_i = (.2, 0)$, $x_j = (-.2, .2)$, and $x_k = (0, .1)$. Thus, for example, voter i would most prefer to see a 20% increase in welfare spending and no change in defense expenditures.

For simplicity one assumes that all voter preferences are based on simple Euclidean distance; in other words, each voter weighs the two issues equally, and the preferences are independent across the two issues.

The next necessary information is the voters' estimation coefficients. For the purpose of simplifying the mathematics involved, let us assume that candidate A (the candidate who lies at the origin of P) is the incumbent in the race, and that all voters share a common perception of the current policies on both dimensions. Then, $A_{i1} = A_{i2} = A_{j1} = A_{j2} = A_{k1} = A_{k2} = 0$; also, $B_{i1} = v_{i1}$, $B_{i2} = v_{i2}$, $B_{j1} = v_{j1}$, $B_{j2} = v_{j2}$, $B_{k1} = v_{k1}$, and $B_{k1} = v_{k1}$. Suppose that voter i, understanding that the challenger, B, is more conservative than incumbent A, expects B to decrease welfare expenditures by 40% and increase defense spending by 20%. Then $v_{i1} = -.4$ and $v_{i2} = .2$. Voters j and k might have slightly different estimates of B's positions on the issues, such that $v_{j1} = -.3$ and $v_{j2} = .1$ $v_{k1} = -.1$ and $v_{k2} = .2$.

Remember that the voter will prefer the candidate whose estimated position in the policy space is closest to the voters ideal point. In two-dimensional Euclidean space (the space which corresponds with the assumed two issue election), the distance between two points, say voter i's ideal policy point and voter i's estimation of the location of candidate A, is given by the formula

$$\|A_i - x_i\| = [(A_{i1} - i_1)^2 + (A_{i2} - i_2)^2]^{1/2}$$

and the Euclidean distance between i's ideal policy bundle and i's estimate of the policies of candidate B is given by

$$||B_i - x_i|| = [(B_{i1} - i_1)^2 + (B_{i2} - i_2)^2]^{1/2}$$

substituting the numbers from the example set out above, we find that

$$||A_i - x_i|| = [(0 - .2)^2 + (0 - 0)^2]^{1/2} = .2$$

and

$$||B_i - x_i|| = [(-.4 - .2)^2 + (.2 - 0)^2]^{1/2} = .63$$

Since the voter prefers the candidate nearest to his most preferred bundle, because $||A_i - x_i|| < ||B_i - x_i||$, voter i would vote for candidate A.

One can also determine i's candidate preference solely in terms of the predictive dimension. Because

$$A_i = (A_{i1}, A_{i2}) = m_i + \pi_a v_i = (m_{i1} + \pi_a v_{i1}, m_{i2} + \pi_a v_{i2})$$

the Euclidean distance between A_i and x_i can be expressed as

$$[(m_{i1} + \pi_a v_{i1} - x_{i1})^2 + (m_{i2} + \pi_a v_{i2} - x_{i2})^2]^{1/2}$$

The Euclidean distance between B_i and x_i may be expressed similarly. With these two formulas, and the simple Euclidean distance preference rule, we know that voter i will prefer the challenger, B, to A if and only if

$$[(m_{i1} + \pi_a v_{i1} - x_{i1})^2 + (m_{i2} + \pi_a v_{i2} - x_{i2})^2]^{1/2} >$$
$$[(m_{i1} + \pi_b v_{i1} - x_{i1})^2 + (m_{i2} + \pi_b v_{i2} - x_{i2})^2]^{1/2}$$

Squaring both sides of the equation, multiplying through, and gathering like terms, we find that B is preferred only if

$$(\pi_b^2 - \pi_a^2)\ (v_{i1}^2 + v_{i2}^2) <$$
$$2(\pi_a - \pi_b)\ (m_{i1}v_{i1} + m_{i2}v_{i2} - v_{i1}x_{i1} - v_{i2}x_{12})$$

Factoring $(\pi_b - \pi_a)$ from both sides, gathering terms, and diving through leaves

$$[v_{i1}\ (x_{i1} - m_{i1}) + v_{i2}\ (x_{i2} - m_{i2})]\ /\ (v_{i1}^2 - v_{i2}^2) > (\pi_a + \pi_b)\ /\ 2$$

The left hand side of this equation (which shall henceforth be labeled z_i) represents the most preferred point for voter i on the predictive dimension - that is, the point on the predictive dimension which lies closest to the voter's most preferred policy bundle in the two - dimensional policy space. As demonstrated in figure 4, the set of all policy estimates by voter i based upon predictive dimension Π is defined by the line $m_i + \pi v_i$. The estimates (by voter i) of the location of candidates A and B in the issue space are given by $m_i + \pi_a v_i$ and

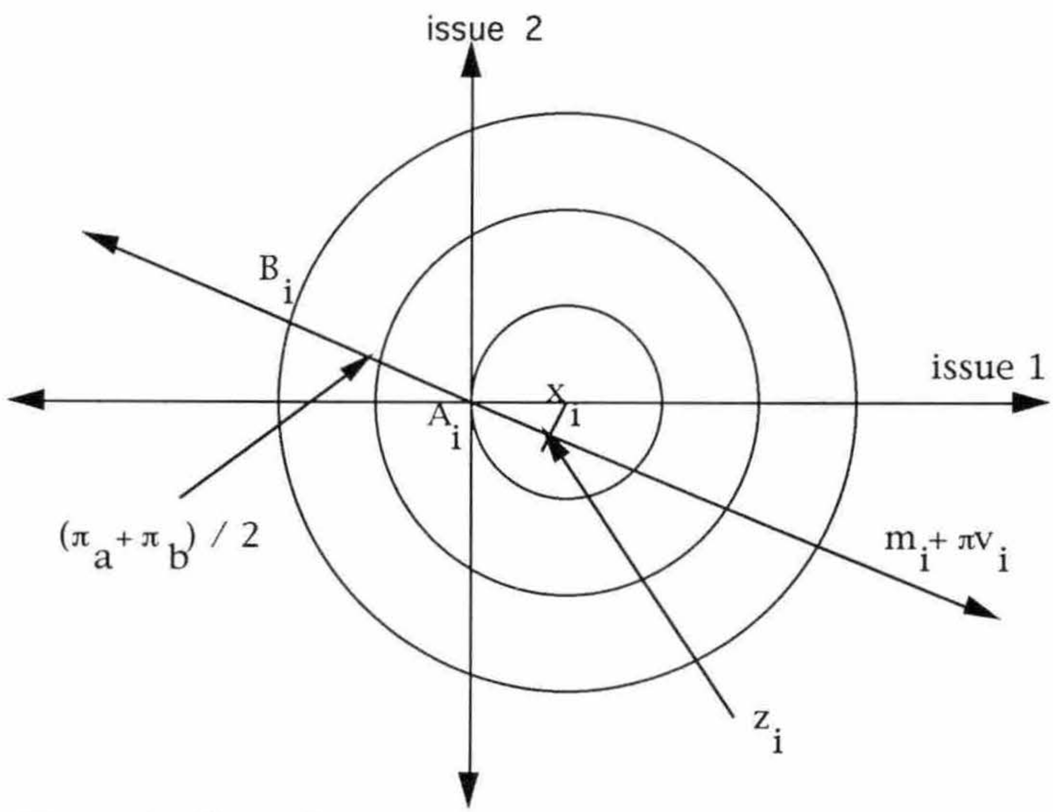

Figure 4: Voter i's prediction of the locations of candidates A and B on the two issues (welfare and defense). Note that the location of i's most preferred point on predictive dimension lies closer to A than to B, and so voter i will vote for candidate A.

$m_i + \pi_b v_i$ respectively. The question then becomes: for which candidate will i vote? All voters are assumed to follow the simple Euclidean distance preference rule, so i will view all points on the issue space that are the same distance from his/her ideal point as being equally preferred, and the farther away a point in issue space is from voter i's ideal point, the less preferred that policy option. In figure 4, all of the points on the each individual circle centered on x_i will be equally preferred (they are all the same Euclidean distance from x_i), and all points on the smallest circle about x_i are preferred to the set of points on the middle circle (all points on the middle circle being farther from x_i), and so on.

The point z_i, the most preferred point of voter i on the predictive dimension, is located at the intersection of the predictive dimension with the perpendicular that passes through the point x_i, that is, z_i is the point on the predictive dimension which lies closest to x_i. Because the point z_i is closer to A than to B, $z_i < (\pi_a + \pi_b) / 2$, voter i prefers A_i to B_i.

Note that the voter's ideal point in the issue space, x_i is not the same point as the voter's most preferred point on the predictive dimension, z_i. The issue positions associated with z_i are given by $m_{i1} + z_i v_{i1}$ and $m_{i2} + z_i v_{i2}$ for issues 1 and 2. These points are different from the ideal policy positions in the policy space x_{i1} and x_{i2}, except in the special case where the ideal policy bundle for i, x_i, lies on the predictive dimension Π.

The model is designed specifically to avoid any reference to the ideology of the voter. While the ideology of the candidates is used as a predictive device, the ideology of the voters plays no role in the model. While the voter's ideal policy position is critical, the method by which the voter finds his ideal policy position is external to the model, and unnecessary to predict election behavior. Again, looking at the figure, x_i does not correspond with any point on the predictive "ideology" dimension. Furthermore, over the course of a campaign, the actions of the candidates can change the z_i's of the voters, so that unlike the candidates' π's, the most preferred points of the voters can change over the course of the election.

It is also important to note that the linear estimation procedure induces a single peaked preference curve for each voter on the predictive dimension Π. The points on the predictive dimension are less preferred the more distant they are from the point $m_i + z_i v_i$. Thus, voter i will prefer A to B only if $|\pi_a - z_i| < |\pi_b - z_i|$.

The importance of this result is that, for the case of a singe predictive dimension, we can use a form of the median voter result to determine which candidate will tie or win the election. We can define a median for the set of most preferred points z on the underlying predictive dimension. In the case of the example set forth above,

$$z_i = [\ -.4(.2 - 0) + .2(0 - 0)]\ /\ (.16 + .04) = -.4$$

$$z_j = [\ -.3(\ -.2 - 0) + .1(.2 - 0)]\ /\ (.09 + .01) = .8$$

$$z_k = [\ -.1(0 - 0) + .2(.1 - 0)]\ /\ (.01 + .04) = .4$$

so $z_{med} = z_k = .4$. Consequently, since $.4 < (\pi_a + \pi_b) / 2 = .5$, z_{med} is closer to $\pi_a = 0$. Thus, A will win a majority of the votes (the votes of i and k).

With a single predictive dimension, the candidate whose position on the predictive dimension lies closest to z_{med} either ties or wins the election. However, because the π's attached to the candidates are fixed, the candidate competition consists of trying to move z_{med} closer to the candidate's position. This means the that candidates must attempt to alter the v_{ij}'s and m_{ij}'s; and thus the z_{ij}'s, of the individual voters. When candidates debate what each one's policy positions are, they are attempting to alter the coefficients of the translation function by which policy positions are mapped into positions on the predictive dimension.

We assume that changes in the b_{ij}'s and v_{ij}'s of individual voters are the result of a deliberate effort on the part of the candidates to alter the location of z_{med}. Whichever candidate is farther from z_{med} is attempting to alter the b_{ij}'s and v_{ij}'s of enough voters to move z_{med} closer to him than to his opponent. Likewise, his opponent is attempting to make certain that z_{med} stays closer to him than to his opponent.

The problem for the candidates then becomes how to alter voter perceptions in such a way as to move z_{med} in their favor. In our example, the original $z_{med} = .4$, which is closer to A than to B. Clearly, it becomes B's goal to move z_{med} closer to $\pi_b = 1$.

Suppose that B can exert some influence over the v_{ij}'s of the individual voters. Further, suppose that v_{ij} can be expressed as the sum of a constant effect under the control of the candidates, and a random effect beyond the candidates' control. If this constant effect is equal to the average v_{ij} across i and residual term is i's perceptual bias with respect to v_j, we can express v_{ij} as

$$v_{ij} = v_j + \varepsilon_{ij}$$

where v_j is the average v_{ij} and ε_{ij} is the residual term representing the perceptual bias of i on the issue. Then how would candidate B wish to alter v_j to move z_{med} closer to 1?

Given the data in the example,

$$v_1 = (-.1 - .3 - .4) / 3 = -.267$$

$$v_2 = (.2 + .2 + .1) / 3 = .167$$

so that $\varepsilon_{i1} = -.4 + .267 = -.133$, $\varepsilon_{j1} = -.3 + .267 = -.033$, and $\varepsilon_{k1} = -.1 + .267 = .167$; likewise, $\varepsilon_{i2} = .2 - .167 = .033$, $\varepsilon_{j2} = .1 -.167 = -.67$, and $\varepsilon_{k1} = .2 - .167 = .033$.

If B possessed this information, then the question becomes what it would be best to change v_1 and v_2 to. Because in this example x_i, x_j, and x_k all happen to lie in a line in the issue space, $x_{med} = x_k$ is a unique dominant point. It would therefore be best for B to attempt to alter v_1 and v_2 so as to move the perception of his policy positions as close as possible to $x_k = (0, .1)$. Because $B_i = (v_{i1}, v_{i2}) = (v_1 + \varepsilon_{i1}, v_2 + \varepsilon_{i2})$, $B_j = (v_{j1}, v_{j2}) = (v_1 + \varepsilon_{j1}, v_2 + \varepsilon_{j2})$, and $B_k = (v_{k1}, v_{k2}) = (v_1 + \varepsilon_{k1}, v_2 + \varepsilon_{k2})$, setting $(v_1, v_2) = (-.167, .067)$ will change B_i from (-.4, .2) to (-.3, .1), B_j from (-.3, .1) to (-.2, 0), and B_k from (-.1, .2) to (0, .1). Such a change will move z_i to -.6 and both z_j and z_k to 1. So if candidate B can convince the voters that the changes he would enact on the two issues are less than the voters initially assumed, he can win the votes of both and k.

Candidate A, on the other hand, would be benefited by an opposite change in v_1 and v_2. Suppose for example that v_2 remains unchanged, but v_1 is changed to -.3. Further suppose that all voter bias on issue 1 is eliminated, so $v_{i1} = v_{j1} = v_{k1} = -.3$. Then each voter will believe that candidate B will enact a 30% decrease in welfare spending. The result of such a change in perceptions would be to move the most preferred points of the voters to $z_i = -.6$, $z_j = .67$, and $z_k = .1$. The incumbent now would receive the votes of i and k and would win the election. What has happened in this last example is that candidate A has successfully changed voter perceptions of the way in which the predictive label maps into the issue space. Specifically, the result has been to convince voters that B's more conservative label translates into much larger cuts in welfare expenditures than the voters originally believed. in this instance, such a suggestion is particularly alarming to k, who advocates the status quo on the issue.

The discussion to this point has been limited to the simplest case, an election involving a single predictive dimension and two issues. The model can be expanded to include any number of issues and/or predictive dimensions. Consider, for example, the case of a campaign involving two issues and two predictive dimensions.

A model with two predictive dimensions might include a economic liberal - conservative axis, and a social liberal conservative axis, to represent the fundamental separability of economic and social policy. The economic axis might be used as a shorthand label for the degree to which the candidate advocates government intervention in business, with conservatives at the right end of the axis advocating less intervention and liberals at the left end of the axis advocating greater intervention. The social liberal-conservative axis is, perhaps, less well defined, but the label would reflect the candidate's positions on social issues. The liberal (left) end of the axis might advocate greater government intervention in issues like integration, affirmative action, and bilingual education, and less government intervention in issues such as free speech, drug use, and public morality. The conservative (right) end of the axis might favor heavy government intervention on issues such as homosexuality, abortion, and pornography, and relatively little intervention on matters such as integration, affirmative action and prayer in schools.

Consider once again candidates A and B, With voters having a common understanding of the location of incumbent candidate A in both the issue space and the policy space, and a common understanding of the location of challenger B. Thus A's positions on predictive dimensions 1 and 2 are $\pi_a = (\pi_{a1}, \pi_{a2}) = (0, 0)$ and B's positions on the predictive dimensions are $\pi_b = (\pi_{b1}, \pi_{b2}) = (1, 1)$. B in this example is considered more conservative on both predictive dimensions (both π_{b1} and π_{b2} are positive).

Let us consider predictive dimension 1 to be the economic predictive dimension and predictive dimension 2 to be the social predictive dimension. Likewise, consider issue 1 to be an economic issue and issue 2 to be a social issue. Then voter i's perception of voter B's policy position would be

$$B_i = (B_{i1}, B_{i2}) =$$

$$(m_{i1} + v_{i11}\,\pi_{b1} + v_{i21}\,\pi_{b2},\ m_{i2} + v_{i12}\,\pi_{b1} + v_{i22}\,\pi_{b2})$$

where m_{ik} is i's perception of the incumbents policy on issue k (k = 1, 2) and v_{ijk} is i's perception of the change in position on issue k associated with a one unit change in the jth predictive dimension. For example, v_{i11} is the marginal change in B_{i1} given a unit change in π_{b1} and v_{i21} is the marginal change in B_{i1} given a unit change in π_{b2}.

For purposes of simplification, assume that the predicted location of the candidates on the economic issue is a function only of the economic predictive dimension, and that the predicted location of the candidates on the social issue is solely a function of the social predictive dimension. Then $v_{i12} = v_{i21} = 0$, and

$$B_i = (B_{i1}, B_{i2}) = (m_{i1} + v_{i11},\ m_{i2} + v_{i22})$$

and

$$A_i = (A_{i1}, A_{i2}) = (m_{i1}, m_{i2})$$

Once again using the weighted Euclidean distance preference rule (assuming that the two issues are weighted equally by the voter and are completely separable), and squaring both sides, voter i prefers challenger B to A only if

$$(v_{i11} - x_{i1} + m_{i1})^2 + (v_{i22} - x_{i2} + m_{i2})^2 <$$

$$(- x_{i1} + m_{i1})^2 + (- x_{i2} + m_{i2})^2$$

which would reduce to

$$v_{i11}^2 - 2v_{i11}^2 z_{i1} + v_{i22}^2 - 2v_{i22}^2 z_{i2} < 0$$

where $z_{i1} = (x_{i1} - m_{i1}) / v_{i11}$ and $z_{i2} = (x_{i2} - m_{i2}) / v_{i22}$ are points on predictive dimensions 1 and 2, respectively. The above equation may be rewritten

$$[v_{i11} (x_{i1} - m_{i1}) + v_{i22} (x_{i2} - m_{i2})] / (v_{i11}^2 + v_{i22}^2 > 1/2$$

or

$$(v_{i11}^2 z_{i1} + v_{i22}^2 z_{i2}) / (v_{i11}^2 + v_{i22}^2) > 1/2$$

so that voter i will prefer candidate B to candidate A only if the above inequality holds.

Note that this model is merely a two-dimensional generalization of the single predictive dimension model examined earlier. Regardless of the number of dimensions in the issue space and the number of predictive dimensions, the determination of a voter's preference between two candidates is, in fact, found in the same manner. The voter's estimation of the candidates' locations on the underlying issue space, based on the candidates' locations in the predictive space, is calculated. Then, the location of the voter's most preferred point in the predictive space is calculated. Finally (assuming one keeps the simple Euclidean distance preference rule), the distance between the voter's most preferred point in the predictive space and each of the candidate's locations in the predictive space is measured, and the candidate who is located closer to the voter will be the preferred candidate, regardless of the number of dimensions in the predictive or the issue space.

The case of a voter basing his candidate preference on more than one predictive dimension is different in one critical way from the single predictive dimension model. In the single predictive dimension model, the median voter is critical to the outcome of the election; the candidate that captures the vote of the median voter will win the election, and the candidate who holds the same location on the predictive dimension as the median voter's most preferred point cannot be beaten in pairwise competition. But with more than one predictive dimension, a dominant strategy cannot be guaranteed. In order for a dominant strategy to exist with multiple predictive dimensions, it is necessary that there exist a median in all directions. In two-dimensional predictive space, a median in all directions exists at a voter most preferred point x if any line passing through x places at least one half of all voter most preferred points on each side of the line (counting all most preferred points on the line, including x, as being on both sides). Consider figure 5, with lines one and two passing through x, the median voter in the eleven voter, two-dimensional predictive space. Line one divides the space into eight voters on the left side of the space and seven voters on the right (counting the four voters on the line on both sides). Line two divides the space into six voters on each side. Every line drawn through x will have the characteristic of maintaining a majority on either side of the line, so x is a median in all directions.

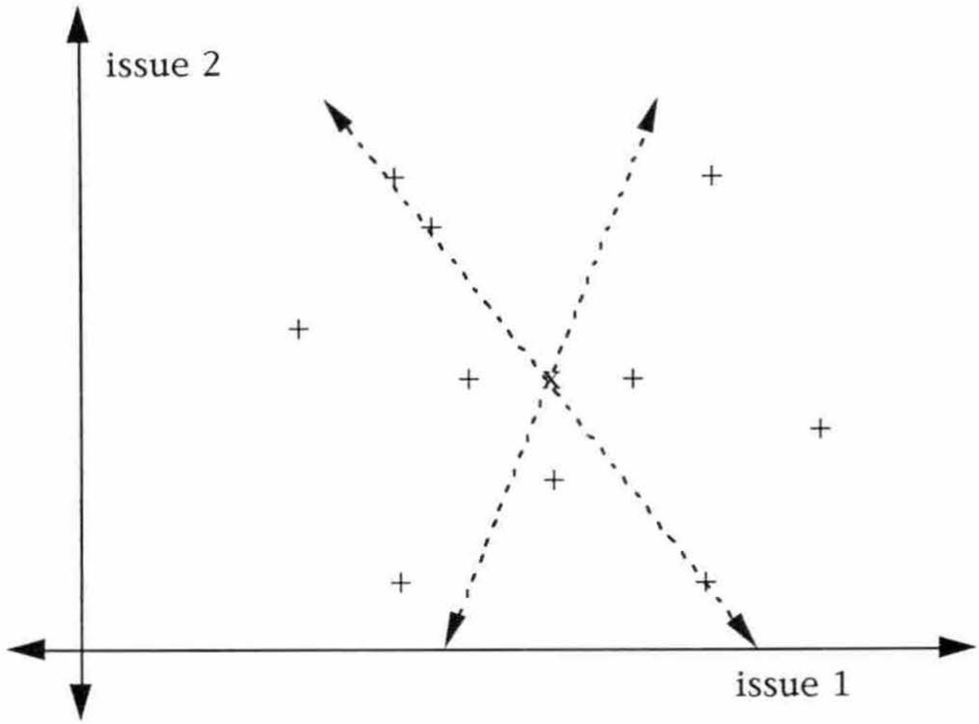

Figure 5: The point x is a median in all directions.

Likewise, in three-dimensional predictive space, a median in all directions exists at voter most preferred point x if for any plane passing through x at least one half of all voter most preferred points lie on either side of the plane (counting all most preferred points on the plane, including x, on both sides).

The requirement that there exist a median in all directions for a dominant strategy to exist is quite stringent. However, the absence of a dominant strategy does not mean that the model cannot accurately predict election outcomes and candidate behavior. With or without a dominant point, the model does explain how candidates will attempt to alter the m_{ij}'s and v_{ijk}'s of the voters in order to preserve or gain a winning position. Thus, one can gain insight into actual electorate and candidate behavior without a dominant strategy existing (Enelow and Hinich 1984).

The spatial theory of elections, as demonstrated even in the relatively simple form presented here, can potentially become enormously complex. Despite this complexity, the model is, at its heart, quite elegant. The only fundamental assumption of the spatial voting model is that voters and candidates will act in their rational self interest, where rational self interest is defined only in the loosest of terms: a voter's or candidate's policy positions might be based on economic well being, religious or moral principles, or on nothing at all. The only requirement is that the individuals act rationally to realize the policy positions that they most prefer. This fundamental assumption is tremendously intuitively appealing, and from that simple assumption, the spatial theory of elections, and its vast potential for unraveling the complexities of election behavior, can be naturally derived.

AN ANALYSIS OF THE PREDICTIVE DIMENSIONS

An Introduction to the Question

The spatial model of elections, as set forth by Enelow and Hinich, has in recent years become the basis for a good deal of research into election behavior. the model has proven to be quite useful in explaining voter behavior in several elections, including the 1976 and 1980 U.S. presidential elections examined by Enelow and Hinich (1984).

However, the model has opened up several paths of inquiry that are as yet unexplored. Of particular interest are the obvious questions surrounding the voter choice of predictive dimensions and the mapping of those predictive dimensions into the issue space. While the number of predictive dimensions the voter uses in predicting a candidate's policy positions is critical, it is clear from the model and subsequent research that little is known about how many predictive dimensions the voter actually uses. Also left unexplored is the question of how accurately the voter can, in fact, predict the location of the candidate on the underlying issue space. Clearly, both of these question are important to any model that purports to accurately describe voter behavior - a model that has voters using one or two predictive dimensions is clearly inadequate to describe real-life voters who are using five or six predictive dimensions. Further, the accuracy with which voters can predict the location of candidates in the issue space (and thus the accuracy with which the voter can determine his/her preferences) is clearly critical to understanding the accuracy of the underlying model.

The research presented here is designed to provide some insight, then, into these two fundamental questions regarding the nature of the predictive space of the voters:

1) How many dimension are there to the voters' predictive space? and
2) How accurately does the predictive space of the voter describe the nature of the underlying issue space?

The Dataset and Assumptions of the Model

Answering these two questions requires, first and foremost, some information regarding the nature of the underlying policy space. The most comprehensive information regarding the nature of the issue space of the United States Congress, for example, might be found in the congressional record, with every vote on every bill brought before congress characterized as a single dimension on the issue space, and the congressman's location on that dimension determined by his or her vote on the particular issue. The end result would be a issue space with thousands of dimensions, with every senator mapped as a point on every dimension. At first examination, a policy space which includes every congressperson's vote on every issue, being the most comprehensive data available of the congresspersons' views, might also appear to be the most desirable for a model of the issue space.

However, such a dataset suffers from certain shortcomings. First, it would include as dimensions votes on "issues" that many or all voters would not consider relevant to there voting decision ("National Artichoke Week", for example), and many more dimensions would be issues which, while important to a small minority of voters, would most likely play little role in the average voter's voting decision (the honey subsidy). The dataset is also problematic in that it plots candidates at different points in the issue space which might be, to a voter aware of the issue space, identical. By way of example, consider two congresspersons who have identical voting records, but one has voted against federally funded abortion and against parental notification of abortion. The other congressperson voted the opposite way on these two issue (that is, for federal abortion funding and for parental notification). As a result, the two congresspeople would reside at different points in the issue space - but the voter might well consider the positions of the two as identical, in that both are equally pro- or anti-abortion. In a sense, then, a breakdown of issue space into one dimension per vote creates an issue space that is too disagregated, as well as extremely ungainly.

A much more desirable model of the issue space is provided by the Center for National Independence in Politics. This organization collects "performance evaluations" on all senators and representatives. These performance evaluations consist of a single percentage score (0-100) for each congressperson, provided to the center by 21 different special interest groups. Each special interest group scores each congressperson by first selecting any number of bills which have gone before congress which the interest group feels was relevant to their organization's interests. Then, for each senator and representative, the organization calculates the percentage of votes the congressperson cast in the special interests favor; for example, a score of 80% for a representative would mean that that representative voted as the special interest would have on 80% of the bills relevant to that organization's interests. The end result of the data collected by the Center for National Independence in Politics is that each senator and representative has been given a single score by 21 different special interest groups, each score representing the degree to which that senator or representative conforms to the ideals of the special interest assigning the score.

Using a few safe assumptions, the data provided by the Center for National Independence in Politics provides a comprehensive view of the issue space (or that portion which is relevant to the U.S. congress), while being much less clumsy than the issue space provided by information on every individual vote. First, it is safe to assume that every vote which is relevant to any significant number of voters is represented in the scores provided by at least one of the interest groups. The scores provided by the center are, in fact, chosen from the scores produced by over 70 special interest groups around the country. The process of gleaning out the 21 most relevant scores is done by the center simply by examining which scores are most frequently requested by the reporters, researchers, and interested voters who contact the center for such information. The vast majority of voters and reporters who contact the center are interested in the scores provided by these 21 organizations, suggesting that the scores of the other 49 interest groups cover issues of interest to only a very small number of individuals.

One can also safely assume that no irrelevant issues will enter the policy space described by the center's 21 scores. The scores are provided by 21 significant special interest groups, which are, presumably, significant primarily because there interests are also the interests of a large number of voters. It is reasonable to assume further that no score from any interest group would include an "irrelevant" vote in calculating congresspersons' scores, since doing so can only serve to "water down" the meaning of the score and undermine the credibility of the interest group.

Finally, one must, and can safely, assume that any two congresspeople with the same score from the same interest group are equally preferred with regards to the issues of interest to that interest group. Because there is no limit to the number of votes which can be the basis of any individual organization's score, the organizations will choose a body of votes sufficient to distinguish between all congresspeople who are, to the point of view of the interest group, distinguishable. Conversely, because no "irrelevant" votes will be included in any of the scores, any differences in the scores of various congresspeople must reflect actual, relevant differences in their locations in the issue space.

With these assumptions - that every relevant issue is covered, that every identical score reflects an identical location in the issue space, and that every different score reflects a different location in the issue space, it is clear that the 21 scores provided by these 21 interest groups must, in fact, provide sufficient information to locate the candidate in issue space. The issue space examined in this paper, then, will be the 21 dimension issue space described by the data provided by the Center for National Independence in Politics for the United States Congress for 1992. Each congressperson's score on each of the 21 dimensions is defined be the score provided by each of 21 different special interest groups. Only the 400 congresspeople with scores from all 21 special interests will be included in the analysis.

The 21 special interest groups, as well as what interest they represent, are as follows:

1) U.S. Chamber of Commerce: Business
2) AFL-CIO: Labor
3) American Conservative Union: Conservative
4) Americans for Democratic Action: Liberal
5) American Security Council: Conservative Defense/Foreign Policy
6) Council for a Livable World: Liberal Defense/Foreign Policy

7) National Right to Life Committee: Anti-Abortion

8) National Abortion Rights Action League: Abortion Rights

9) National Federation of Independent Business: Business

10) Consumer Federation of America: Consumers

11) American Civil Liberties Union: Civil Liberties

12) Christian Voice: Moral/Family Issues

13) League of Conservation Voters: Environment

14) National Taxpayer's Union: Taxes

15) American Association of University Women: Women's Issues

16) American Farm Bureau Federation: Farm Issues

17) National Council of Senior Citizens: Seniors' issues

18) NAACP: Civil Rights

19) National Education Association: Education

20) Liberty Lobby: Populist

21) Citizens Against Government Waste: Taxes

One will quickly note that heavy correlation is quite likely among several (if not all) of the above scores. For example, one expects a strong (negative) correlation between the scores provided by the National Right to Life Committee and NARAL, since the organizations are working at cross purposes (though the correlation, notably, is not 100%). Though this may seem to be a problem, it is in fact the very feature that voters will exploit in using predictive dimensions to predict a congressperson's location in the 21 dimension issue space - with heavy correlation among the various dimensions in the issue space, a single predictive dimension can potentially predict quite accurately the location of a congressperson in the issue space.

Before exploring the power of predictive dimensions to map the space, some minor adjustments were made to the data set both to ease interpretation of the dimensions and to allow for application of meaningful predictive dimensions. The first step is that each score is converted from the raw 0-100 scale to standard deviation form. That is, each candidates score on each dimension is subtracted from the mean of the 400 scores and the difference is divided by the standard deviation on the 400 scores - the result is that each score is transformed to a standard form which reflects the number of standard deviations that candidate is from the mean score for that dimension. This transformation of scores is performed to guarantee that, to the extent that the various scores are measuring the same phenomenon, they are measuring that phenomenon on the same scale and from the same origin - a necessary characteristic for subsequent analysis.

The second transformation, once again needed for subsequent analysis - was to adjust the scores so that all were positively correlated with some base score, arbitrarily chosen. In this instance, the dimension described by the American Conservative Union (number 3) was selected. The scores of each dimension negatively correlated with the scores given by the American Conservative Union was multiplied by -1, so that after adjustment every score, to the extent that it was correlated with the score provided by the ACU, was positively correlated[4]. The decision to use the ACU score as the base was based on two factors. First, the single dimension most often used in spatial voting theory, and generally viewed as the most basic, is the left-right political dimension, so choosing a issue dimension that purports to measure that dimension seems reasonable. Secondly, when a single left-right predictive dimension is used, it is customary to arrange the dimension as per a number line, with the political right at the right (and thus positive) end of the number line and the political left at the left (and thus negative) end of the number line. Thus, to the extent that each dimension reflects some political left/right split, the more positive the score the more conservative the congressperson, and the more liberal congresspeople will tend to have large negative scores. A fortunate characteristic of the issue space, with these alterations, is that the scores of every dimension are positively correlated with every other dimension.

With the issue space for the United States Congress for 1992 set forth, and the location of the congresspeople in the issue space defined, the goal is to determine the nature of the predictive dimensions used by the voter to predict the location of these congresspeople in the issue space. Calculating how a voter will

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[4]The scores which were negatively correlated with the scores given be the American Conservative Union, and which were consequently multiplied by -1, were (referring to the list provided), dimensions number 2, 4, 6, 8, 10, 11, 13, 15, 17, 18, and 19. The others were left in their standard deviation form.

chose predictive dimensions, and how those predictive dimensions will be mapped into the issue space requires assuming only that the voter gather use his/her available information as efficiently as possible. With such an assumption it becomes apparent that voters will chose as a first predictive dimension that dimension which best explains the location of the congressperson, will chose as a second dimension that dimension which best explains the difference between the prediction given by the first dimension and the congresspersons actual location in issue space, will chose as a third dimension the dimension which best explains that not explained by the first two dimensions, and so on. Further, assuming efficient voters, each predictive dimension will be mapped as accurately as possible into the underlying issue space. The statistical analysis required to model the nature of the predictive dimensions is somewhat complex; for expository purposes, a full description of the modeling technique, with a sample, can be found in the appendix.

The First Predictive Dimension

One obvious characteristic of the best single predictive dimension is that it be correlated with at least one of the 21 dimensions of issue space. The correlation might be positive or negative, and for sake of convention, we shall define the dimension to be positive (the negatively correlated predictive dimension which best describes the data would simply be the negative of the positively correlated dimension). Because the dimensions of the issue space are all positively correlated with each other, this first predictive dimension will therefore be positively correlated with all of the underlying issue dimensions - so it is unnecessary to worry about which of the issue dimensions the predictive dimension is positively correlated with. The single value which best approximates a set of values (by ordinary least squares) is the simple mean of those values. The goal of the first predictive dimension is simply to provide a single score for each congressperson which best estimates scores of that candidate on the 21 underlying issue dimension. The predictive dimension which most accurately describes the issue space, then, will be given by the mean of the 21 dimensions for each of the 400 congresspeople. The question then becomes: how accurately will the first predictive dimension, given by the means, model the issue space. Recalling that voters will use each dimension in the predictive space to explain as accurately as possible the predictive space, a least squares estimation procedure which regresses each of the 21 issue dimensions on the single predictive dimension will provide an estimation of the extent to which the predictive dimension explains the issue dimension. The R^2 value provided by such a regression will provide an estimate of the percent of the issue dimension explained. A measure of the overall degree to which the predictive dimension explains the entire issue space is given by the average of the R^2 of the regressions (table 1).

Table 1: The R^2 values resulting from the regression of the first predictive dimension on each of the 21 predictive dimensions, with the overall goodness-of-fit given by the mean R^2.

Dimension	Interest Group	R^2
1	U.S. Chamber of Commerce	76.4%
2	AFL-CIO	38.1%
3	American Conservative Union	96.4%
4	Americans for Democratic Action	94.9%
5	American Security Council	67.2%
6	Council for a Livable World	77.5%
7	National Right to Life Committee	60.0%
8	National Abortion Rights Action League	68.4%
9	National Federation of Independent Business	86.6%
10	Consumer Federation of America	88.6%
11	American Civil Liberties Union	95.0%
12	Christian Voice	92.1%
13	League of Conservation Voters	73.0%
14	National Taxpayers Union	63.1%
15	American Association of University Women	80.7%
16	American Farm Bureau Federation	85.3%
17	National Council of Senior Citizens	86.9%
18	NAACP	88.8%
19	National Education Association	90.8%
20	Liberty Lobby	19.1%
21	Citizens Against Government Waste	63.5%
	MEAN	68.5%

What is extraordinary about the first predictive dimension is the high degree to which it is capable of explaining the location of the underlying issue space. With a single predictive dimension, properly chosen and properly fitted to the issue space, the location of a congressperson can be calculated with 68.5% accuracy. This predictive dimension goes a very long way in describing issue dimension 3 and 4, those of the American Conservative Union and Americans for Democratic Action, and issue dimensions 11 and 12, the American Civil Liberties Union and Christian Voice. Because all of these organizations are generally considered to be have a liberal or conservative position (the ACU and ADA are by design conservative and liberal, respectively, while the ACLU and CV have a definite strong liberal and strong conservative viewpoint respectively), the hypothetical predictive dimension which describes these dimensions so thoroughly can be considered the political left-right predictive dimension often sighted in spatial election research. Thus, the single predictive dimension hypothesized by spatial election theorists to be the most important and useful, the left-right predictive dimension, is in fact the single most efficient predictive dimension when it comes to covering the issue space, and will, based on our assumptions regarding voter behavior, therefore be the first predictive dimension chosen by the voter to predict the nature of the issue space.

The Second Predictive Dimension

The method for finding the best second predictive dimension is similar, though slightly more complex, than the method used for calculating the first predictive dimension. The best second predictive dimension will be that one which, naturally, best predicts that portion of the issue space not explained by the fist predictive dimension - the second dimension, then, must explain as much as possible the residual (error) terms resulting from the regressions of each of the issue space dimensions on the first predictive dimension. From the regressions run to test the performance of the first predictive dimension on the issue space, the residuals are saved, yielding 400 individual residuals for each of the 21 issue dimensions. As with the original scores, the residuals are adjusted to standard deviation form by subtracting each residual value from the mean of the standard deviation scores for the issue dimension and dividing by the standard deviation of the residual values. As with the original values, the adjusted residuals all share an origin (the mean score) and have a common scale (number of standard deviations from the mean). These adjustments guarantee that, to the extent that the various issue space dimensions are correlated, they are measuring the same phenomena on the same scale and with the same origin.

The greatest problem encountered in calculating the second predictive dimension (and all subsequent dimensions) is that the correlation coefficients of all of the 21 sets of residuals cannot (through multiplication of the appropriate dimensions by -1) be simultaneously made positive. Much as the various residuals are placed in deviation form to guarantee that they are measuring on the same scale and from the same origin, positive correlation among all of the 21 dimensions to insure that, to the extent that they are measuring the same phenomenon, they are measuring the phenomenon in the same direction. In absence of a set of residuals which are all simultaneously positively correlated with one another, the requirement that the best predictive dimension for the residuals must be positively correlated with at least one of the residual dimensions must be invoked. The appropriate residual dimensions are multiplied by -1 to induce positive correlation between the residuals of the first issue dimension and the residuals of the remaining 20 issue dimensions, to guarantee that to the extent that each of the 21 sets of residuals are measuring the same phenomenon as that measured by the residuals of the first issue dimension, they are measuring the phenomenon in the same direction. Once positive correlation with respect to residuals of dimension 1 has been induced, the mean of the 21 residuals is calculated separately for each of the 400 congresspeople - this mean becomes one of the candidates for the best second predictive dimension. This procedure is repeated for each of the 20 remaining residuals; the 21 dimensions are adjusted (through multiplication of the appropriate residuals by -1) to in turn be positively correlated with the residuals of the second through 21st issue dimensions. For positive correlation with each of the remaining 20 dimensions, the mean of the 21 scores of each of the 400 congresspeople is calculated. After these steps have been taken, 21 different sets of means have been calculated, one of which must be the best second predictive dimension.

Determining which of these 21 sets of means represents the best second dimension requires that the original scores (the scores which represent the location of each congressperson on the underlying issue space) be regressed on the first predictive dimension (the means of the original scores), and on, in turn, each of the 21 candidates for the best second predictive dimension (the 21 sets of means of the adjusted residuals). As with the regressions on the first dimension alone, each set of regressions will yield 21 R^2 values. That dimension of the 21 candidates for best second dimension is second best which yields the highest average R^2. As can be seen in table 2, the best second dimension is found by inducing positive correlation with the residuals of the 20th dimension of the issue space (the dimension associated with the Liberty Lobby).

As with the single predictive dimension, the average R^2 resulting from regressions on the first and second predictive dimension provides an estimate of the percentage of the issue space which may be recovered by efficiently using two predictive dimensions.

Table 2: The results of the regressions performed to determine the best second dimension. note that the average R^2 resulting from inducing positive correlation with the 20th issue dimension is the largest.

Regression Dim.:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	*20*	21
1	84.9	76.4	84.9	85.0	83.6	85.5	82.4	81.6	79.9	81.8	79.9	79.1	78.9	77.5	82.0	85.5	80.5	83.4	78.5	*84.9*	78.5
2	38.3	52.2	38.3	38.5	39.5	38.2	43.3	44.2	45.4	44.2	45.1	45.9	42.0	48.6	44.4	38.2	45.2	40.8	47.2	*40.5*	45.1
3	97.4	96.4	97.4	97.5	97.4	97.2	97.3	97.4	97.3	97.0	92.1	96.4	96.5	96.5	97.4	97.4	97.2	97.1	96.9	*97.6*	97.0
4	96.0	96.4	96.0	96.3	96.0	96.2	95.7	95.7	95.5	95.9	95.6	95.3	94.9	95.3	95.7	96.2	95.7	96.1	95.2	*96.0*	94.9
5	72.8	69.6	72.8	72.7	81.1	74.9	70.1	69.6	69.3	67.4	67.3	67.5	71.0	71.4	70.7	74.8	67.3	72.6	68.2	*73.6*	67.2
6	82.6	79.2	82.6	83.2	85.5	84.6	80.4	79.6	79.4	80.4	78.5	79.1	80.0	80.8	79.9	84.0	78.7	83.8	77.6	*82.1*	78.9
7	83.7	70.6	83.7	81.4	68.6	78.6	88.0	85.8	80.6	84.4	80.2	80.9	60.0	63.6	84.4	79.6	83.5	80.0	74.3	*85.0*	72.7
8	83.8	79.5	83.8	83.0	71.7	79.0	88.6	89.7	87.8	84.9	88.0	82.7	71.7	74.6	89.1	80.3	88.7	77.5	82.4	*85.0*	81.9
9	89.1	90.4	89.1	89.0	86.8	88.1	89.6	90.2	91.3	88.7	90.6	88.4	88.9	89.7	90.2	87.1	90.0	86.7	90.1	*88.8*	90.6
10	90.3	89.6	90.3	90.4	88.6	90.7	90.3	89.9	89.9	91.2	90.2	91.3	88.8	89.1	90.0	90.4	90.2	90.2	89.9	*89.9*	88.6
11	95.3	95.8	95.3	95.2	95.3	95.1	95.6	95.7	96.0	95.5	96.1	95.7	95.8	96.0	95.7	95.2	95.8	95.0	95.9	*95.3*	96.0
12	92.8	94.1	92.8	92.8	92.4	92.6	93.4	93.2	93.1	94.0	93.4	95.5	92.1	93.8	92.9	92.5	93.4	92.8	93.5	*92.3*	92.2
13	73.1	77.5	73.1	73.0	75.0	74.3	73.1	75.3	76.8	73.0	76.3	73.4	85.7	77.7	75.2	73.7	75.7	75.1	79.0	*73.0*	80.4
14	64.3	77.0	64.3	64.9	75.4	68.0	63.2	63.9	65.3	63.1	66.6	63.6	80.9	81.5	63.6	66.2	65.3	70.0	69.0	*64.8*	72.1
15	88.8	85.3	88.8	87.3	83.7	87.3	91.1	90.7	90.7	88.3	89.5	87.3	81.9	83.6	91.6	87.9	89.4	85.2	84.4	*89.7*	87.1
16	88.8	85.3	88.3	87.9	87.8	88.5	87.6	87.1	85.4	87.4	86.6	86.6	86.6	85.8	87.2	89.2	86.8	88.2	85.3	*88.0*	86.3
17	88.3	90.0	90.5	90.7	87.0	89.6	90.8	90.9	90.5	91.3	91.3	90.8	87.6	88.6	90.4	89.3	91.3	89.3	91.2	*89.9*	89.9
18	90.5	89.1	90.5	90.7	90.7	90.4	90.2	89.9	88.9	90.7	88.9	90.1	89.8	89.3	89.7	90.5	90.0	91.8	89.8	*90.6*	88.8
19	91.2	92.2	91.2	91.3	91.1	90.8	91.4	91.4	91.3	91.8	91.5	91.8	91.2	91.5	90.8	90.8	91.7	91.2	92.5	*91.1*	91.5
20	52.8	19.5	52.8	51.4	44.1	48.2	48.4	45.6	36.7	42.9	36.9	23.5	23.5	25.3	43.9	50.8	40.3	50.6	31.3	*57.4*	26.6
21	64.8	75.1	64.8	63.8	64.3	63.6	67.4	70.5	72.6	63.9	72.8	63.5	78.8	74.0	70.9	63.9	71.1	64.9	72.6	*65.2*	82.2
MEAN	81.4	81.4	76.4	80.3	80.3	81.0	81.8	81.8	81.1	80.8	81.1	79.4	76.5	79.7	81.7	81.1	81.3	81.1	80.2	*82.0*	80.4

The Third through Thirteenth Predictive Dimensions

The procedure for calculating the third and higher predictive dimensions was identical to the technique used to calculate the second predictive dimension. First, the residuals from the regressions on all existing predictive dimensions are preserved, and placed in deviation form. Then, the residuals for the appropriate issue dimensions are multiplied by minus one in order to induce positive correlation with the residuals of the first issue dimension, and the average for each congressperson of the 21 residuals is calculated. Then a regression is run on each of the 21 issue dimensions as a function of all previously calculated predictive dimensions and the newly calculated means, and the R^2 values for each of the 21 regressions is preserved, and the average R^2 value is calculated. The entire process is repeated with positive correlation induced with respect to residuals of the second issue dimension, then the third, and so on for all 21 issue dimensions. The result will be 21 "average R^2" values, one associated with the residuals of each issue dimension. The average R^2 values are then compared, and the mean of residuals which provided the highest average R^2 value will be preserved as the best third dimension. The entire process will be repeated using the residuals from regressions on the first three dimensions to calculate the best fourth dimension, the residuals from regressions of the best four dimensions to calculate the best fifth dimension, and so on. The results for the first thirteen dimensions are summarized in table 3.

Table 3: The R^2 values for each of the issue dimensions based upon the 1-13 predictive dimension. the numbers in italics are the issue dimensions with which the residuals were positively correlated from that predictive dimension.

# of Predictive Dimensions:	1	2	3	4	5	6	7	8	9	10	11	12	13
Issue Dim.:1	76.4	84.9	86.0	86.2	87.2	87.4	88.2	88.7	89.4	90.5	*97.1*	98.2	98.4
2	38.1	40.8	*59.3*	*85.4*	87.0	88.1	88.4	*94.8*	96.5	96.8	97.2	97.3	98.2
3	*96.4*	97.6	97.6	97.8	97.9	97.9	98.4	98.4	98.5	98.6	98.6	98.7	98.8
4	94.9	96.0	96.5	96.7	96.9	97.4	97.8	98.0	98.0	98.6	98.6	98.6	98.6
5	67.2	73.6	74.8	75.5	75.5	*87.6*	89.3	90.3	91.3	91.7	92.7	94.9	95.9
6	77.5	82.1	84.1	84.2	88.1	88.6	89.6	90.7	90.9	*97.7*	97.8	98.0	98.2
7	60.0	85.0	89.4	89.4	90.8	91.1	92.3	93.2	93.2	94.1	95.4	95.5	96.4
8	68.4	85.0	91.6	92.4	93.1	94.0	94.8	95.2	95.2	95.3	95.4	96.6	96.6
9	86.6	88.8	89.7	91.1	91.5	91.5	91.8	92.5	92.9	93.0	93.7	94.0	*97.8*
10	88.6	89.9	89.9	90.0	91.0	91.9	93.4	93.8	94.6	94.6	95.0	95.0	95.7
11	95.0	95.3	96.3	96.3	96.8	96.9	96.9	97.1	97.7	98.2	98.6	98.7	99.0
12	92.1	92.3	93.1	93.5	93.7	94.4	95.6	96.2	96.5	97.1	97.3	97.7	98.2
13	73.0	73.0	77.0	79.7	83.0	84.8	*93.7*	94.2	94.4	94.4	94.7	94.7	95.8
14	63.1	64.8	80.7	84.9	85.4	91.3	92.2	93.9	95.9	96.0	96.5	96.5	97.5
15	80.7	89.7	94.4	94.8	95.8	96.7	97.0	97.4	97.6	97.7	97.8	98.0	98.0
16	85.3	88.0	88.3	88.4	88.9	88.9	90.2	90.7	91.2	91.4	91.5	*97.3*	97.7
17	86.9	89.9	89.9	90.3	90.6	91.2	91.9	93.4	93.5	94.0	95.0	95.1	95.1
18	88.8	90.6	91.0	92.3	93.0	94.1	94.2	94.2	94.3	96.2	96.5	96.5	96.6
19	90.8	91.1	91.1	91.1	91.3	92.1	92.5	93.3	93.4	93.8	94.8	94.9	95.2
20	19.1	*57.4*	68.5	70.4	*86.5*	87.6	87.6	90.2	*98.6*	98.6	98.6	98.7	99.4
21	63.5	65.2	79.0	82.1	85.7	87.2	89.2	92.8	93.0	94.4	95.0	95.5	95.5
mean	68.5	82.0	86.1	88.2	90.0	91.5	92.6	93.8	94.6	95.4	96.1	96.7	97.3
gain	68.5	13.5	4.1	2.1	1.8	1.5	1.1	1.2	0.8	0.8	0.7	0.6	0.6

In the interest of finding some reasonable terminus to this exercise, the iterative process of calculating the best third, fourth, fifth, etc. dimension was terminated at the best thirteenth dimension (the results are summarized in figure 6), as the thirteenth dimension marks the point at which every one of the 21 issue dimensions are explained with R^2 values of 95% or better. In fact, no research using the Enelow and Hinich model has posited anything on the order of thirteen predictive dimensions, and the concept of the average voter using more than thirteen predictive

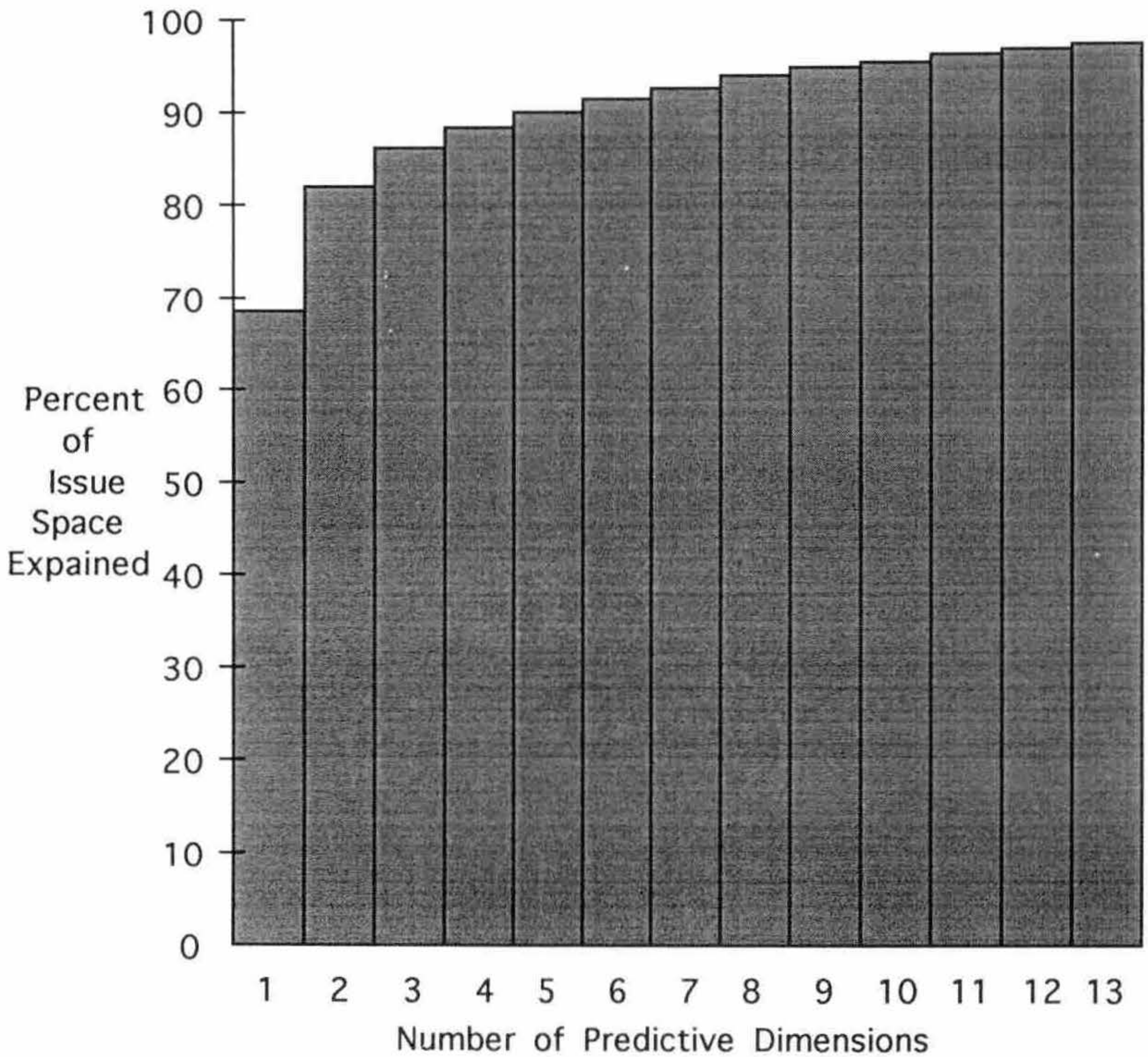

Figure 6: The percentage of the issue space explained by various numbers of predictive dimensions.

dimensions is sufficiently beyond the pale that one may safely assume that all predictive dimensions that might actually be used by the voter have been accounted for. The R^2 values for each of the 21 issue dimensions for the first thirteen best predictive dimensions, as well as the average R^2 for those predictive dimensions, is provided in table 3. Of particular interest, as shown in the table, is the high degree to which the first few predictive dimensions explain the issue space, as well as how quickly the "payoff" (in terms of increase in accuracy in modeling the issue space) of adding a predictive dimension drops off. The first dimension describes a congresspersons location in issue space with almost 70% accuracy, and the first two dimensions explain the issue space with over 80% accuracy, yet the next 11 predictive dimensions add less than 15% to the total accuracy in describing the issue space.

CONCLUDING REMARKS

Ideally, one could readily produce a theoretically sound and intuitively convincing formula for the voter's utility curve in the issue space, as well as a function which reflects the cost of accumulating predictive dimensions. Armed with these formulas, and using the data concerning the recovery of the issue space which is the bulk of this paper, one could calculate precisely how many issue dimensions the voters use in making their voting decision. Unfortunately, utility and cost functions are not readily available, and the series of assumptions which would be needed to derive any such functions would most likely be neither compelling nor convincing.

Although no convincing quantitative method can be used to calculate the number of issue dimensions that a voter will use in the voting decision, the data on recovery of the issue space does suggest some interesting possibilities. The utility that any individual voter derives from the voting process is going to be absolutely minimal, both because the candidates from which the voter has to choose are generally very close to each other in the issue space (Black 1948 a, b, Enelow and Hinich 1984, et al) and because the likelihood of the individual voter changing the outcome of the election is negligible. Because the voters will perceive very little chance of increasing their well being through voting, they will not be willing to go to very much effort to determine the candidates location in the issue space. But the first predictive dimension allows the voter to determine the candidates' positions on the issue with 68.5% accuracy, which seems likely to be as much information as most voters would be inclined to need or want (given the minimal utility gained by voting). It might well be, then, that elections are best modeled by the use of a single predictive dimension, since few if any voters would bother to pick up any additional information.

If this is the case, the bulk of election theory since Black's early work of the 1940's has been unnecessarily complicated, and that the many unsatisfying results associated with multiple-dimension models of elections are not a matter of great concern. As Enelow and Hinich (1984) mention, in the case of elections with multiple issue dimensions but with only a single predictive dimension, the model collapses to a single-dimension model essentially identical to that proposed by Black (1948 a, b). If a single predictive dimension is sufficient to describe voter behavior (as the data suggests is possible), and if the voters have quasi-concave utility function as Black hypothesized (a very reasonable assumption), then the desirable characteristics of the black model would naturally follow. That is, the median most preferred point will have a majority against any other, and a pairwise majority vote among the alternatives will actually produce a complete order.

Of course, the claim that only a single predictive dimension is used by the voters, while suggested by the data presented here, is by no means proven. To make the assumption of a single predictive dimension would be a very strong assumption indeed. Nonetheless, it remains an intriguing possibility.

Enelow and Hinich (1984) hypothesize and give some empirical evidence based on voter surveys, about the nature of the first two predictive dimensions. Enelow and Hinich use a model with two issue dimensions, which they felt described voter behavior sufficiently. The two dimensions that they use are a liberal-conservative axis, and an axis which they characterize as a "libertarian" axis. They site data to support their choice of these two axis, but ultimately rely more on intuitive appeal than anything else to make their case.

The data collected here regarding both the best first predictive dimension and the best second predictive dimension suggests that the dimensions identified and used by Enelow and Hinich in their two predictive dimension model are, in fact, precisely the two predictive dimensions that voters would use, assuming that voters used exactly two dimensions (an assumption, as discussed above, which might not be correct).

First, consider the best first predictive dimension, as uncovered in this paper. It goes a very long way in describing the issue dimensions provided by Americans for Democratic Action and the American Civil Liberties Union, both of which would generally be described as liberal organizations, and in describing the dimensions provided by the American Conservative Union and Christian Voice, both of which would be described as basically conservative organizations. Because the first predictive dimension describes these liberal and conservative issue dimensions so well, it strongly suggests that the first predictive dimension is the liberal-conservative predictive dimension sited by Enelow and Hinich, as well as many other researchers.

The best second predictive dimension found in this study was positively correlated with the issue dimension of the Liberty Lobby, and best describes the Liberty Lobby's dimension. Because this best second predictive dimension so clearly reflects the issue dimension defined by a Libertarian Lobby, it seems clear that the second dimension measures the degree of libertarian tendency of congresspeople. The correlation of the best two issue dimensions deduced in this paper with the two issue dimensions hypothesized by Enelow and Hinich provides some evidence that both are correct.

BIBLIOGRAPHY

Aranson, P., M. Hinich and P. Ordeshook. 1974. "Election Goals and Strategies: Equivalent and Nonequivalent Candidate Objectives." *American Political Science Review* 68:135-52.

Arrow, K .J. 1963. *Social Choice and Individual Values.* 2nd. ed. New Haven: Yale University Press.

Bergstrom, T. C. and R. P. Goodman. 1973. "Private Demands for Public Goods." *American Economic Review* 63: 280-96.

Black, D. 1948a. "On the Rationale of Group Decision-Making." *Journal of Political Economy* 56: 23-34.

Black, D. 1948b. "The Decisions of a Committee using a Special Majority." *Econometrica* 16: 262-70.

Black, D. and A. S. Newing. 1951. *Committee Decisions with Complementary Valuation.* London: W. Hodge.

Black, D. 1958. *Theory of Committees and Elections.* Cambridge: Cambridge University Press.

Borcherding, T. E. and R. T. Deacon. 1972. "The Demand for the Services of Non-Federal Governments." *American Economic Review* 62:891-901.

Bowen, H. R. 1943. "The Interpretation of Voting in the Allocation of Resources." *Quarterly Journal of Economics* 58: 27-48.

Brams, S. 1978. *The Presidential Election Game.* New Haven: Yale University Press.

Brams, S. 1980. "Approved Voting in Multi-Candidate Elections." *Policy Studies Journal* 9: 102-108.

Caplin, A., and B. Nalebuff. 1988. "On 64% Majority Rule." *Econometrica* 56: 787-814.

Coughlin, P. 1982. "Pareto Optimality of Policy Proposals with Probabilistic Voting." *Public Choice* 39:427-33.

Coughlin, P. and S. Nitzan. 1981. "Electoral Outcomes with Probabilistic Voting and Nash Social Welfare Maxima." *Journal of Public Economics* 15:113-22.

Cox, G. W. 1987. "Electoral Equilibrium Under Alternative Voting Institutions." *American Journal of Political Science* 31: 408-22.

Cox, G. W. 1990. "Multicandidate Spatial Competition." in *Advances in the Spatial Theory of Voting,* J. Enelow and M. Hinich, Cambridge: Cambridge University Press, pp. 179-98.

Davis, O. A. and M. J. Hinich. 1966. "A Mathematical Model of Policy Formation in a Democratic Society." In *Mathematical Applications in Political Science II,* edited by Joseph Bernd, pp. 175-208. Dallas: Southern Methodist University Press.

Davis, O. A. and M. J. Hinich. 1968. "On the Power and Importance of the Mean Preference in a Mathematical Model of Democratic Choice." *Public Choice* 5:59-72.

Davis, O. A., M. DeGroot, and M. Hinich. 1972. "Social Preference Orderings and Majority Rule." *Econometrica* 40: 147-57.

Denzau, A. and R. Parks. 1975. "The Continuity of Majority Rule Equilibrium." *Econometrica* 43:853-66.

Downs, A. 1957. *An Economic Theory of Democracy*. New York: Harper & Row.

d'Aspermont, C., J. J. Gabszewicz and J. Thisse. 1979. "On Hotelling's 'Stability in Competition.'" *Econometrica* 47: 1145-58.

Enelow, J. M. and M. J. Hinich. 1982. "Nonspatial Candidate Characteristics and Electoral Competition." *Journal of Politics* 44:115-130.

Enelow, J. M. and M. J. Hinich. 1982. "Ideology, Issues, and the Spatial Theory of Elections." *American Political Science Review* 76:493-501.

Enelow, J. M. and M. J. Hinich. 1984. *The Spatial Theory of Voting: An Introduction.* Cambridge: Cambridge University Press.

Enelow, J. M. and M. J. Hinich. 1989. "A General Probabilistic Spatial Theory of Elections." *Public Choice* 61:101-113.

Enelow, J. M. and M. J. Hinich. 1990. *Advances in the Spatial Theory of Voting.* Cambridge: Cambridge University Press.

Farquharson, R. 1969, *Theory of Voting.* New Haven: Yale University Press.

Ferejohn, J., M. Fiorina and E. Packel. 1980. "Nonequilibrium Solutions for Legislative Systems." *Behavioral Science* 25: 140-8.

Fiorina, M. P. and K. A. Shepsle. 1982. "Equilibrium, Disequilibrium, and the General Possibility of a Science of Politics." In *Political Equilibrium*, edited by P. C. Ordeshook and K. A. Shepsle, pp. 49-64. Boston: Kluwer Nijhoff.

Greenberg, J. 1979. "Consistent Majority Rules Over Compact Sets of Alternatives." *Econometrica* 47: 627-36.

Hinich, M. J. 1977. "Equilibrium in Spatial Voting: The Median Voter Result is an Artifact." *Journal of Economic Theory* 16:208-19.

Hinich, M. J., J. O. Ledyard and P. C. Ordeshook. 1972. "Nonvoting and the Existence of Equilibrium under Majority Rule." *Journal of Economic Theory* 4:144-53.

Hinich, M. J. and W. Pollard. 1981. "A New Approach to the Spatial Theory of Electoral Competition." *American Journal of Political Science* 25:323-41.

Hotelling, H. 1929. "Stability in Competition." *Economic Journal* 39: 41-57.

Kessel, John. 1980. *Presidential Campaign Politics.* Homewood, Ill. Dorsey Press.

Kramer, G. 1973. "On a Class of Equilibrium Conditions for Majority Rule." *Econometrica* 41: 285-97.

Kramer, G. 1977. "A Dynamical Model of Political Equilibrium." *Journal of Economic Theory* 16:310-334.

Kramer, G. 1978. "Existence of Electoral Equilibrium." In *Game Theory and Political Science*, P. Ordeshook, New York: New York University Press, pp. 371-89.

Ledyard, J. O. 1984. "The Pure Theory of Large Two-Candidate Elections." *Public Choice* 44:7-41.

Levitin, T., and W. Miller. 1979. "Ideological Interpretations of Presidential Elections." *American Political Science Review* 73:751-71.

McKelvy, R. D. 1979. "General Conditions for Global Intransitives in Formal Voting Models." *Econometrica* 47:1085-111.

McKelvy, R. D. and P. C. Ordeshook. 1976. "Symmetric Spatial Games Without Majority Rule Equilibria." *American Political Science Review* 70: 1172-84.

McKelvy, R. D. and P. C. Ordeshook. 1985. "Elections with Limited Information: A Fulfilled Expectations Model Using Contemporaneous Poll and Endorsement Data as Information Sources." *Journal of Economic Theory* 36:55-85.

Murdoch, J. C., T. Sandler and L. Hansen. 1991. "An Econometric Technique for Comparing Median Voter and Oligarchy Choice Models of Collective Action: The Case of the NATO Alliance." *The Review of Economics and Statistics* 73:624-631.

Palfrey, T. R. 1984. "Spatial Equilibrium With Entry." *Review of Economic Studies* 51: 139-56.

Plott, C. R. 1967. "A Notion of Equilibrium and Its Possibility Under Majority Rule." *American Economic Review* 57:787-806.

Rabinowitz, G. 1973. *Spatial Theory of Electoral Choice: An Empirical Analysis*. Chapel Hill: Institute for Research in Social Science.

Riker, W. 1980. "Implications From the Disequilibrium of Majority Rule for the Study of Institutions." *American Political Science Review* 74:432-46.

Riker, W. 1986. *The Art of Political Manipulation.* New Haven: Yale University Press.

Riker, W., and P. Ordeshook. 1973. *An Introduction to Positive Political Theory.* Englewood Cliffs: Prentice-Hall.

Rusk, J., and H. Weisberg. 1972. "Perceptions of Presidential Candidates." *Midwest Journal of Political Science* 16:388-410.

Shepsle, K. 1979. "Institutional Arrangements and Equilibrium in Multidimensional Voting Models." *American Journal of Political Science* 23:27-59.

Schofield, N. 1986. "Existence of a 'Structurally Stable' Equilibrium for a Non-Collegial Voting Rule." *Public Choice* 51: 267-84.

Sloss, J. 1973. "Stable Outcomes in Majority Rule Voting Games." *Public Choice* 15:19-48.

Smithies, A. 1941. "Optimal Location in Spatial Competition." *Journal of Political Economy* 99: 423-39.

Sugden, R. 1984. "Free Association and the Theory of Proportional Representation." *American Political Science Review* 78: 31-43.

Tullock, G. 1981. "Why So Much Stability?" *Public Choice* 37:189-202.

APPENDIX

To more fully explore the steps involved in this analysis, consider a more condensed set of data, with ten congresspeople, each having scores (between 0 and 100) for five dimensions in the underlying issue space. the score for congresspeople A-J on the issue dimensions V-Z are:

	V	W	X	Y	Z
A	20	65	50	33	30
B	0	50	36	17	30
C	20	75	29	75	30
D	0	10	36	58	40
E	10	40	29	92	60
F	0	40	17	92	30
G	20	65	8	67	70
H	60	90	71	67	50
I	0	40	0	93	50
J	74	80	100	20	40

Step 1: Alter each score to deviation form by expressing each in terms of standard deviations from the mean of the relevant issue dimension. For example, the adjusted score for candidate A on issue V (designated V_{Aa}) is given by V_{Aa} = (V_A - mean V) / StDev V. This step guarantees

that the various dimensions vary from the same mean (0), and to the same scale (standard deviations from the mean).

	V	W	X	Y	Z
A	-0.01522	0.39627	0.41512	-0.97587	-1.03712
B	-0.77634	-0.22942	-0.05356	-1.52566	-1.03712
C	-0.01522	0.81340	-0.28791	0.46732	-0.29632
D	-0.77634	-1.89794	-0.05356	-0.11683	-0.29632
E	-0.39578	-0.64655	-0.28791	1.05147	1.18528
F	-0.77634	-0.64655	-0.68964	1.05147	-1.03712
G	-0.01522	0.39627	-0.99093	0.19243	1.92607
H	1.50701	1.43910	1.11815	0.19243	0.44448
I	-0.77634	0.64655	-1.25875	1.08583	0.44448
J	2.03979	1.02197	2.08899	-1.42258	-0.29632

The objective of finding the first best predictive dimension - the single score for each congressperson which best describes the issue dimensions, will utilize two characteristics that must be present in the predictive dimension that best describes the data. First, it must be the case that the best predictive dimension be positively correlated with at least one issue dimension. Second, the predictive dimension will necessarily be an average of the scores of the candidates on the issue dimensions, since by ordinary least squares the mean of a set of numbers is the best single number estimate of that set. The goal now becomes checking all scores which fit these criterion.

Step 2: Check the correlation coefficients of the issue dimensions.

	V	W	X	Y
W	0.793			
X	0.852	0.538		
Y	-0.379	-0.289	-0.644	
Z	0.120	0.096	-0.277	0.445

Step 3: Multiply the scores of issue dimensions which are negatively correlated with the first issue dimension by -1, so that the adjusted scores will all be positively correlated with the first issue dimension. In this case, multiply the scores on issue dimension Y by -1, so that all dimensions are positively correlated with issue dimension V. This is done to guarantee that, to the extent that the various dimensions vary with issue dimension V, they vary in the same direction as dimension V.

	V	W	X	Y	Z
A	-0.01522	0.39627	0.41512	0.97587	-1.03712
B	-0.77634	-0.22942	-0.05356	1.52566	-1.03712
C	-0.01522	0.81340	-0.28791	-0.46732	-0.29632
D	-0.77634	-1.89794	-0.05356	0.11683	-0.29632
E	-0.39578	-0.64655	-0.28791	-1.05147	1.18528
F	-0.77634	-0.64655	-0.68964	-1.05147	-1.03712
G	-0.01522	0.39627	-0.99093	-0.19243	1.92607
H	1.50701	1.43910	1.11815	-0.19243	0.44448
I	-0.77634	0.64655	-1.25875	-1.08583	0.44448
J	2.03979	1.02197	2.08899	1.42258	-0.29632

	V	W	X	Y
W	0.793			
X	0.852	0.538		
Y	0.379	0.289	0.644	
Z	0.120	0.096	-0.277	-0.445

Step 4: For each of the ten congresspeople, calculate the average of the five adjusted issue dimensions. These numbers will be positively correlated with issue dimension V, and so are a candidate for the best first predictive dimension.

A	0.14699	F	-0.84022
B	-0.11416	G	0.22475
C	-0.05067	H	0.86326
D	-0.58147	I	-0.66460
E	-0.23929	J	1.25540

Step 5: Regress each of the adjusted issue dimensions X-Z on the means calculated above, preserving the R^2 values and the residuals for each of the five regressions involved. To compare the various potential predictive dimensions, the regression of each potential predictive dimension on the issue dimensions will be used to determine how much of the variation in the various issue dimensions is captured by the variation in the potential predictive dimension.

V	90.1	W	67.2	X	69.2	Y	31.7	Z	2.2

Step 6: Calculate the average of the R^2 values of the first set of regressions. in this example, the average for the R^2 values is 52.08. This score tells us what percentage of the variation of the candidates' positions in the issue space is captured by the potential predictive dimension.

Step 7-11: Repeat steps 2-5 for the second the issue dimension. In this case, when all of the scores are positively correlated with V, all are also positively correlated with issue dimension W, so the results shown in step 6 are the same as will result in step 11.

Step 12: Repeat Step 2.

	V	W	X	Y
W	0.793			
X	0.852	0.538		
Y	0.379	0.289	0.644	
Z	0.120	0.096	-0.277	-0.445

Step 13: Multiply the scores of issue dimensions which are negatively correlated with the third issue dimension by -1, so that the adjusted scores will all be positively correlated with the third issue dimension. In this case, multiply the scores on issue dimension Z by -1, so that all dimensions are positively correlated with issue dimension X.

	V	W	X	Y	Z	A
-0.01522	0.39627	0.41512	0.97587	1.03712		
B	-0.77634	-0.22942	-0.05356	1.52566	1.03712	
C	-0.01522	0.81340	-0.28791	-0.46732	0.29632	
D	-0.77634	-1.89794	-0.05356	0.11683	0.29632	
E	-0.39578	-0.64655	-0.28791	-1.05147	-1.18528	
F	-0.77634	-0.64655	-0.68964	-1.05147	1.03712	
G	-0.01522	0.39627	-0.99093	-0.19243	-1.92607	
H	1.50701	1.43910	1.11815	-0.19243	-0.44448	
I	-0.77634	0.64655	-1.25875	-1.08583	-0.44448	
J	2.03979	1.02197	2.08899	1.42258	0.29632	

	V	W	X	Y
W	0.793			
X	0.852	0.538		
Y	0.379	0.289	0.644	
Z	-0.120	-0.096	0.277	0.445

Step 14: For each of the ten congresspeople, calculate the average of the five adjusted issue dimensions.

A	0.56183	F	-0.42538
B	0.30069	G	-0.54568
C	0.06785	H	0.68547
D	-0.46294	I	-0.84239
E	-0.71340	J	1.37393

Step 15: Regress each of the issue dimensions X-Z on the means calculated above, preserving the R^2 values and the residuals for each of the five regressions involved.

V 64.9 W 49.0 X 84.3 Y 58.4 Z 17.4

Step 16: Calculate the average of the R^2 values of the set of regressions. in this example, the average for the R^2 values is 54.8.

Step 17-21: Repeat steps 12-16 for the fourth issue dimension. In this case, when all of the scores are positively correlated with X, all are also positively correlated with issue dimension Y, so the results shown in step 16 are the same as will result in step 21.

Step 22: Repeat Step 2.

	V	W	X	Y
W	0.793			
X	0.852	0.538		
Y	0.379	0.289	0.644	
Z	-0.120	-0.096	0.277	0.445

Step 23: Multiply the scores of issue dimensions which are negatively correlated with the fifth issue dimension by -1, so that the adjusted scores will all be positively correlated with the fifth issue dimension. In this case, multiply the scores on issue dimensions V and W by -1, so that all dimensions are positively correlated with issue dimension Z.

	V	W	X	Y	Z
A	0.01522	-0.39627	0.41512	0.97587	1.03712
B	0.77634	0.22942	-0.05356	1.52566	1.03712
C	0.01522	-0.81340	-0.28791	-0.46732	0.29632
D	0.77634	1.89794	-0.05356	0.11683	0.29632
E	0.39578	0.64655	-0.28791	-1.05147	-1.18528
F	0.77634	0.64655	-0.68964	-1.05147	1.03712
G	0.01522	-0.39627	-0.99093	-0.19243	-1.92607
H	-1.50701	-1.43910	1.11815	-0.19243	-0.44448
I	0.77634	-0.64655	-1.25875	-1.08583	-0.44448
J	-2.03979	-1.02197	2.08899	1.42258	0.29632

	V	W	X	Y
W	-0.793			
X	-0.852	-0.538		
Y	-0.379	-0.289	0.644	
Z	0.120	0.096	0.277	0.445

Step 24: For each of the ten congresspeople, calculate the average of the five adjusted issue dimensions.

A	-0.409412	F	-0.143780
B	-0.702995	G	0.698097
C	0.251417	H	0.492973
D	-0.606773	I	0.273234
E	0.296464	J	-0.149226

Step 25: Regress each of the issue dimensions X-Z on the means calculated above, preserving the R^2 values and the residuals for each of the five regressions involved.

V	8.3	W	20.0	X	5.0	Y	35.9	Z	66.7

Step 26: Calculate the average of the R^2 values of the set of regressions. in this example, the average for the R^2 values is 27.2.

(Repeat the procedure described above until the same treatment has been done for each of the issue dimensions being explored. In this case, all five issue dimensions have been treated, though in the study described in the main text, another 16 dimensions would remain to be described.)

Step 27: Compare the average R^2 values calculated in the previous steps, and preserve the residual values for the set of regressions which provided the highest average R^2 values. This set of regressions is the best first predictive dimension. The residuals from the other sets of regressions may be deleted. In the example the average R^2 value resulting from the regression based on the X (and Y) issue dimension was the greatest, and left the following residuals:

	V	W	X	Y	Z
A	-0.64272	-0.14910	-0.30026	0.38029	0.71180
B	-1.11218	-0.52130	-0.43643	1.20691	0.86301
C	-0.09101	0.74754	-0.37431	-0.53925	0.25703
D	-0.25929	-1.44856	0.53590	0.60758	0.56437
E	0.40100	0.04595	0.62046	-0.29522	-0.77220
F	-0.30124	-0.23363	-0.14800	-0.60054	1.28342
G	0.59423	0.92597	-0.29611	0.38603	-1.61011
H	0.74142	0.77370	0.24534	-0.91907	-0.84139
I	0.16451	0.17117	-0.18614	-0.19284	0.04329
J	0.50527	-0.31172	0.33957	-0.03389	-0.49923

Step 28: Alter each of these scores to deviation form by expressing each in terms of standard deviations from the mean of the relevant issue dimension. This guarantees that the residual scores will measure from the same mean (0) and to the same scale (standard deviations from the mean). In the example, the results of this procedure are:

	V	W	X	Y	Z
A	-0.01522	0.39627	0.41512	0.97587	1.03712
B	-0.77634	-0.22942	-0.05356	1.52566	1.03712
C	-0.01522	0.81340	-0.28791	-0.46732	0.29632
D	-0.77634	-1.89794	-0.05356	0.11683	0.29632
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F	-0.77634	-0.39627	-0.68964	-1.05147	1.03712
G	-0.01522	0.39627	-0.99093	-0.19243	-1.92607
H	1.50701	1.43910	1.11815	-0.19243	-0.44448
I	-0.77634	-0.64655	-1.25875	-1.08583	-0.44448
J	2.03979	1.02197	2.08899	1.42258	0.29632

To determine the second predictive dimension, use the adjusted residual scores above and repeat the procedure used to determine the first predictive dimension, regressing each issue dimension on the first best predictive dimension and the potential second best predictive dimension. The third best predictive dimension is determined in the same way, and so on.