Interaction as intermediary in the development of the European power-distribution

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This article is the second report from the research-project "the development of the European power-distribution since 1813". It contains the outcome of research on the relations between data about economic power-relations, military power-relations and relative distance of every pair of European system-members; and data about the economic, military and political interaction between system-members. These results will be used in subsequent research on the causal effects of the power-relations of nations on their mutual interaction.

Introduction

In recent literature (Singer, 1979; De Vree, 1982) the international conduct, within a system of nations, has been given an extensive theoretical foundation. Singer addresses himself specifically to the outbreak of war, whereas De Vree uses a behavioral set, from which nations choose some combination of behavioral options. The most important components of this behavioral set are: foreign trade, warfare, political conflicts and political cooperation. Both Singer (1979) and De Vree (1982) regard international conduct as an intermediary in the development of the power-distribution within a nations-system. The power-distribution within a system can be expressed by the mutual power-relations between nations in that system. Power should be regarded as a group of factors, which result in interaction between nations when shifts in the relative powerpositions occur.

A nation's power derives its importance from its share in the total power within a nations-system. According to the theoretical conceptions in the

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literature mentioned above, a shift in a nation's position in the international power-distribution will only lead to interaction between that nation and other nations, if the expected balance of costs and benefits of power contains a certain degree of utility for one of these nations, with respect to its position in the power-distribution. Utility should be conceived as the increase of power in relation to the amount of power existing in that nation. Such interactions will result in a new power-distribution.

Causes of shifts in the national shares in the international power-distribution are: interaction, shifts in the intranational power-distribution, and other factors like population-growth, changes in technology and changes in the amount of natural resources.

Figure 1: Relations in the development of the international power-distribution

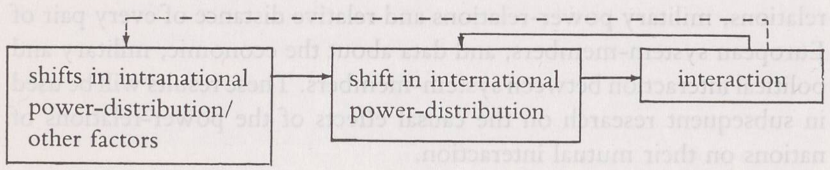

Figure 1 shows that the development of the power-distribution within a nationssystem has a very dynamic and cyclical character.
An overview of differences between the theoretical sources mentioned above (Singer, 1979; De Vree, 1982) will be presented in a related article (Faber, 1984). The rest of this article concentrates on: the operationalization of the power-concepts, the relative distance and the interaction-concepts, the definition of some likely data-relationships between these concepts, the theory of correlation coefficents, which are used to test these relationships, and the results of these tests.

1. Concepts and their relationships

1.1 *Operationalizing the concepts of power, distance and interaction*

1.1.1 *Power and distance* – In a related publication the conclusions are presented from extensive research on the operationalization of the economic and the military power concepts and of the mutual relative distance. These results are obtained by applying factor analysis to groups of possible indicators for these concepts (De Vree, forthcoming), leading to the conclusion, that the economic power of a nation, within the European system, can be measured on the variables 'gross national product', 'crude

steel production' and 'electricity production', which can be substituted for each other. The military power of a nation should be operationalized by two variables, representing the amount of military means available to a nation and the effectivity of these military means. The amount of military means can be represented by taking the total of the military personnel in a nation. For the effectivity of military means no single indicator has been found. For this reason the defense budget has been taken to measure this effectivity. It should be kept in mind, however, that this budget is partly spent to increase the amount of military means, rather than to improve the quality of the existing military means.

The relative distance between nations is taken into account, because it influences, according to De Vree (1982), the probability of interaction between them. With a greater geographical distance between two nations, they must invest more of their power to overcome that distance. As a consequence, the expected balance of costs and benefits of power, from interaction, decreases. Because both the geographical distance between two nations and their capacities for transportation influence the probability of interaction, the geographical distance will be weighted by the two nations' relation in transportation capacity. This is called the relative distance. The transportation capacity of a nation can be measured on the variables gross national product, crude steel production and electricity production.

In the rest of this article the economic power of a nation is measured on its gross national product, its military power on its total military personnel and its defense budget and its transportation capacity on its gross national product.

These variables are measured for the years 1945, 1950, 1955, 1960, 1965, 1970 and 1975 for the following nations: Finland, Sweden, Norway, Denmark, U.S.S.R., Poland, G.D.R., Czechoslovakia, Hungary, Romania, Bulgaria, Albania, Turkey, Greece, Yugoslavia, Ireland, U.K., Netherlands, G.F.R., Belgium-Luxembourg, France, Switzerland, Austria, Italy, Spain, Portugal, and U.S.A. Belgium and Luxembourg are treated as one spatial unit because of their joint appearance in several international statistics.

1.1.2 *Interaction* – The operationalization of the concepts of economic, military and political interaction for the years 1945, 1950, 1955, 1960, 1965, 1970 and 1975 is limited especially by the number of time series of data, which are necessary to study the entire research-period from 1813 until 1975. The economic interaction is measured as the export from nation i to nation j. The military interaction is measured as the number of warmonths of nation i with respect to nation j and as the number of the battlefield deaths of nation i with respect to nation j. The number of warmonths can be conceived as a measure of the extent of war, while the number of battlefield deaths can be conceived as a measure of the intensity of war (Singer and Small, 1972). By the database from the 'Correlates of War' project (Singer and Small, 1972) these two indicators for the military interaction between nations are measured for the entire research-period 1813-1975.

In political interaction two aspects are distinguished, namely political conflicts and political cooperation between nations. Political conflicts should be conceived as disturbed diplomatic relations between nations, in some cases accompanied by minor armed incidents as frontier disputes (less than 1000 battlefield deaths). Political conflicts of nation i with respect to nation j are measured by the number of conflictmonths (I. I. V. G., 1981). The political cooperation of nation i with respect to nation j is measured by the number of common memberships of intergovernmental organizations (Wallace and Singer, 1970).

The variables 'number of warmonths', 'number of conflictmonths' and 'number of common memberships of intergovernmental organizations' have a symmetric distributi of values, because $x_{ij}=x_{ji}$. The variables 'export' and 'number of battlefield deaths' are expected to be almost symmetric.

1.2 *Relations between interaction and power and distance*

In De Vree (1982) all the explanatory variables are expeted to be exponentially related to the interaction variables. From the symmetric distributions of the interaction variables, mentioned above, it can be derived that they have a squared relationship with the explanatory variables. Both relationships are tested in two ways, namely for all the variables measured at the moment t and for all the variables expressed by the change or difference between the moments t and t-l. (See, for evidence, Bremer, Singer and Stuckey, 1972).

Before giving the theoretical forms of the relationships to be tested, the way of expressing the power-relations of nations has to be made clear. One way of expressing the power-distribution within the nations-system and the power-relation of two nations is

$$p_{ij} = (X_i/\sum_{i=1}^{N} X_i)/(X_j/\sum_{j=1}^{N} X_j) \qquad (1)$$

$$= X_i/X_j$$

because $\sum_{i=1}^{N} X_i$ equals $\sum_{j=1}^{N} X_j$.

Another way of expressing them is

$$p_{ij} = X_i - X_j \qquad (2)$$

with $\sum_{i=1}^{N} \sum_{j=1}^{N} p_{ij} = 0.$

According to formula (1), the relative distance from nation i with respect to nation j, with d_{ij} being the geographical distance, can be expressed as:

$$a_{ij} = p_{ji} d_{ij} \qquad (3)$$

Writing the interaction variables as I_{ij} and the explanatory variables as X_{ij}, the following relationships have to be tested:

in an exponential form,

$$I_{ij} = \exp.(X_i/X_j) \qquad (4)$$

and $I_{ij} = \exp.(X_i - X_j)$ (5)

in an quadratic form,

$$I_{ij} = (X_i/X_j)^2 \qquad (6)$$

and $I_{ij} = (X_{i-j})^2$ (7)

and in a differenced form

$$dI_{ij} = I_{ij}{}^{t} - I_{ij}{}^{t-1} = \exp.\{(X_i/X_j)^t - (X_i/X_j)^{t-1}\} \qquad (8)$$

$$dI_{ij} = \quad = \exp.\{(X_i - X_j)^t - (X_i - X_j)^{t-1}\} \qquad (9)$$

$$dI_{ij} = \quad = \{(X_i/X_j)^t - (X_i/X_j)^{t-1}\}^2 \qquad (10)$$

$$dI_{ij} = \quad = \{(X_i - X_j)^t - (X_i - X_j)^{t-1}\}^2 \qquad (11)$$

The relationships in the formulas (4) to (7) are tested by means of $7(27^2-27) = 4914$ observations (panel data) and the relationships in the formulas (8) to (11) are tested by means of $6(27^2-27) = 4212$ observations.

The relationships between the interaction variables and the explanatory variables are tested by calculating the product-moment correlation coefficients and their levels of significance. The analysis of relationships between variables by means of the product-moment correlation coefficient will be clarified in the next paragraph, which will be followed by the results of this analysis.

2. Analysis by correlation coefficients

In order to determine the coherence of two phenomena, their covariation is calculated. This covariation of two phenomena does not say anything about the causal relations between them. Causal relations have to be specified according to theoretical hypotheses by logical deduction. (Blalock, 1971).

By the covariation of two phenomena is meant the coherence of the deviations from the means of both phenomena. The deviations from the mean for the phenomena or variables Y and X are defined as

$$y_i = Y_i - \bar{Y} \quad \text{, with } \bar{Y} = N^{-1}\sum_{i=1}^{N} Y_i$$

$$y_i = X_i - \bar{X} \quad \text{, with } \bar{X} = N^{-1}\sum_{i=1}^{N} X_i$$

The sum of products of deviations from the mean, y_i and x_i, is called the coveriation of Y and X, i.c. $\sum_{i=1}^{N} y_i x_i$. The sum of squared deviations from the mean y_i is called the variation of Y, i.c. $\sum_{i=1}^{N} y_i^2$. The variation of X is $\sum_{i=1}^{N} x_i^2$.

The degree of coherence of Y and X is defined as the relation of the variation between Y and X to the mean variation within Y and X. The mean variation within Y and X is a geometric mean, namely $\sqrt{(\Sigma y_i^2)(\Sigma x_i^2)}$ or $\sqrt{\Sigma y_i^i}\sqrt{\Sigma x_i^2}$. The degree of coherence of Y and X is called the product-moment correlation coefficient (Blalock, 1972) and can be calculated by

$$r_{yx} = \frac{\Sigma y_i x_i}{\sqrt{\Sigma y_i^2}\sqrt{\Sigma x_i^2}} \qquad (12)$$

This product-moment correlation coefficient, henceforth called the correlation coefficient, takes some value on the interval (-1.00; 1.00). The squared correlation coefficient is called the coefficient of determination, which represents the degree of association between the variation of Y and the variation of X.

The coefficient of determination takes some value on the interval (0.00; 1.00), the value 1.00 indicating that the variation of Y is associated for 100 per cent with the variation of X and that the variation of Y is not associated with another variable.

In order to determine the level of significance of the coherence of Y and X variance analysis is used. Variance analysis compares the distribution of the values of Y associated with the values of X, with the distribution of the values of Y not associated with the values of X, i.c. the errors, which are expected to be normally distributed. This ratio is calculated by dividing the explained sum of squares $\{r^2\Sigma y_i^2\}$ through the error sum of squares $\{(1-r^2)\Sigma y_i^2\}$. If this ratio is greater than 1.00 (in case of an infinite number of observations) the explained sum of squares differs systematically from the

randomly distributed error sum of squares. This ratio is called the F-ratio and will be compared with the known F-distribution of samples. When this F-ratio exceeds or equals the theoretical value of the distribution of samples, the estimated variances differ significantly from each other.

A correlation coefficient calculated from a sample of random observations is supposed to be an unbiased estimator of the unknown correlatic coefficient in the population, i.c. $r = \hat{p}$.

The hypotheses to be tested are:

$$H_0 : p = 0 \qquad (13a)$$

$$H_1 : p = 0 \qquad (13b)$$

In order to compare the explained sum of squares with the error sum of squares both have to be standardized according to the number of parameters to be estimated i.c. 1 and N-2. In this way estimates of the variances are obtained, that determin the F-ratio by their mutual relation.

In the formulas (4) to (7), with 4914 observations (N=4914), the F-ratio has to equal or to exceed the value 3.84 from the sampling-distribution; only then is can be stated that the correlation coefficient in the population thakes a value that maximally differs 2,5% from the estimated correlation coefficient (a 95% confidence interval). In order to satisfy this condition the estimated correlation coefficient has to take a value of:

$$F = \frac{r^2(\Sigma y_i^2)\,(N-2)}{(1-r^2)\,(\Sigma y_i^2)\,(1)} = \frac{r^2\,(N-2)}{(1-r^2)} = 3.84$$

from which can be derived that $r = \pm 0.02797$.

To satisfy the condition mentioned above for the formulas (8) to (11), the estimated correlation coefficient has to take a value of ± 0.03022 (N=4212).

3. Results

The correlation coefficients of the relationships of the interaction variables and the explanatory variables, as given by the formulas (4) to (7), are presented in table 1. The t-values of every coefficient, given within brackets, are related to the F-ratios as $t^2 = F$, with 1 and N-2 degrees of freedom. The explanatory variables 'gross national product', 'defense budget' and 'total military personnel' are represented by the codes gnp, db and tmp. The variables 'relative distance' and 'absolute distance' have been brought into the analysis at a later stage. This was done after the relationship had been determined between interaction and power variables, yielding the highest correlation coefficients. The reason for this is that the relative

Table 1: Correlations of interaction variables and explanatory variables, which are related to each other in four, non-differenced ways (t), with t-values within brackets

	trade	war months	battlefield-deaths	conflict months	inter-govern. org.
exp. (X_i-X_j)					
gnp	0.025(1.753)	0.000(0.000)	−0.003(−0.210)	0.000(0.000)	−0.001(−0.070)
db	0.025(1.753)	0.000(0.000)	−0.013(−0.911)	0.000(0.000)	0.000(0.000)
tmp	0.022(1.542)	0.000(0.000)	−0.024(−1.683)	0.000(0.000)	−0.001(−0.070)
exp. (X_i/X_j)					
gnp	−0.090(−6.334)	0.045(3.157)	0.046(3.228)	0.026(1.823)	−0.045(−3.157)
db	0.069(4.848)	0.002(0.140)	−0.005(−0.350)	−0.018(−1.262)	−0.026(1.823)
tmp	0.000(0.000)	0.168(11.945)	0.157(11.143)	0.103(7.280)	−0.071(−4.989)
$(X_i-X_j)^2$					
gnp	0.197(14.084)	−0.019(−1.332)	−0.007(−0.241)	−0.023(−1.613)	0.042(2.946)
db	0.144(10.200)	0.110(7.757)	0.018(1.262)	0.069(4.848)	−0.060(−4.213)
tmp	−0.013(−0.911)	0.331(24.587)	0.079(5.555)	0.249(18.021)	−0.084(−5.909)
$(X_i/X_j)^2$					
gnp	−0.012(−0.841)	0.008(0.561)	−0.001(−0.070)	0.003(0.210)	−0.053(−3.720)
db	0.046(3.228)	0.006(0.421)	−0.005(−0.350)	0.000(0.000)	−0.013(−0.911)
tmp	−0.008(−0.561)	0.157(11.143)	0.018(1.262)	0.106(7.472)	−0.037(−2.600)

Tabel 2: Correlations of interaction variables and explanatory variables, which are related to each other in four, differenced ways ($t-t_{-1}$), with t-values within brackets

	trade	war months	battlefield-deaths	conflict months	inter-gov-org.
$\exp(d(X_i-X_j))$					
gnp	0.021(1.363)	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.002(0.130)
db	0.014(0.909)	0.000(0.000)	−0.001(−0.165)	0.000(0.000)	−0.002(−0.130)
tmp	0.028(1.818)	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.000(0.000)
$\exp(d(X_i/X_j))$					
gnp	0.008(0.519)	−0.078(−5.077)	−0.084(−5.470)	−0.039(−2.533)	0.006(0.389)
db	0.065(4.227)	−0.013(−0.844)	−0.012(−0.779)	−0.020(−1.298)	0.028(1.818)
tmp	0.025(1.623)	−0.141(−9.242)	−0.151(−0.912)	−0.061(−3.966)	0.031(2.013)
$(d(X_i-X_j))^2$					
gnp	0.207(13.730)	0.019(1.233)	0.007(0.454)	0.016(1.038)	0.057(3.705)
db	0.021(1.363)	−0.182(−12.011)	−0.080(−5.208)	−0.119(−7.777)	−0.014(−0.909)
tmp	−0.024(−1.558)	−0.304(−20.707)	−0.058(−3.770)	−0.206(−13.661)	−0.063(−4.096)
$(d(X_i/X_j))^2$					
gnp	−0.006(−0.389)	−0.013(−0.844)	−0.001(−0.065)	−0.008(−0.519)	−0.013(−0.844)
db	0.088(5.733)	0.005(0.324)	0.002(0.130)	0.004(0.260)	0.014(0.909)
tmp	−0.016(−1.038)	−0.152(−9.980)	−0.023(−1.493)	−0.089(−5.798)	−0.042(−2.728)

distance is a product of the power-relation and the absolute distance between nations, which will be directly influenced by the relationships given in table 1.

Inspectation of the correlation coefficients and t-values in table 1, leads to the conclusion that the mathematical formula, yielding the highest correlation coefficients (and t-values), can be written as

$$I_{ij} = (X_i - X_j)^2 \tag{14}$$

The correlation coefficients (with t-values within brackets) of the differenced interaction variables (dI_{ij}) and the differenced explanatory variables, as given by the formulas (8) to (11), are presented in table 2. From table 2 it can be concluded, that the mathematical formula, yielding the highest correlation coefficients, can be written as

$$dI_{ij} = \{d(X_i - X_j)\}^2 \tag{15}$$

Those parts of the tables 1 and 2 that represent the correlation coefficients from the formulas (14) and (15), lead to the conclusion that both formulas result in correlation coefficients, which do not differ thoroughly from each other.

From computational convenience, in the rest of the research and of this article formula (14) will be used to represent the relationship between the interaction and explanatory variables.

To decide which distance concept, i.e. the relative distance or the geographical distance has to be used in subsequent research, the following mathematical formulas have been tested for their correlations

$$I_{ij} = \frac{(gnp_j - gnp_i)^2}{(pop_j - pop_i)^2} d_{ij} \tag{16}$$

$$I_{ij} = (gnp_j - gnp_i)^2 d_{ij} \tag{17}$$

$$I_{ij} = d_{ij} \tag{18}$$

Formula (16) represents the conception that the gross national product per head of the population is highly correlated with the possibilities of overcoming distances within a nation. So, the relative distance from nation i to nation j becomes greater when the transportation capacity of nation j exceeds that of nation i. The same reasoning holds for formula (17).

The correlations (with t-values within brackets) of the interaction variables and the distance concepts, as given in the formulas (16) to (18), are presented in table 3.

Table 3: Correlations of interaction variables and distance concepts, which are related to each other in three ways, with t-values within brackets

	trade	war months	battlefield-deaths	conflict months	inter-gov-org.
$\frac{(gnp_j - gnp_i)^2}{(pop_j - pop_i)^2} d_{ij}$	0.053(3.720)	-0.005(-0.350)	-0.002(-0.140)	-0.005(-0.350)	0.055(3.861)
$(gnp_j - gnp_i)^2 d_{ij}$	0.155(10.996)	-0.017(-1.192)	-0.006(-0.421)	-0.019(-1.332)	0.028(1.963)
d_{ij}	0.049(3.439)	0.103(7.258)	0.047(3.298)	0.082(5.767)	-0.112(-7.900)

From table 3 it can be concluded that the mathematical formula, yielding the highest correlation coefficients (ant t-values) can be written as

$$I_{ij} = d_{ij} \tag{19}$$

4. Conclusion

As presented above, extensive research has been undertaken to establish the mathematical formulation of the power and distance concepts. Reasons for this research were the different theoretically derived formulations for these concepts (see inter alia Singer, Bremer and Stuckey (1972) and De Vree (1982)). In deviation from these sources, squared power concepts are the highest ones correlated to the interaction variables. This is caused by the (almost) symmetric distribution of the interaction variables, when related to the power concepts. Even the results from differenced observations do not differ significantly from those from non-differenced observations. Another result, presented in the foregoing paragraph, is that the power-relations of nations are better represented by the differences in their power than by their power-ratios. The distance concept, yielding the highest correlations with the interaction variables, is the geographical distance between nation i and j; this geographical distance should neither be weighted according to its relation in squared differences in gross national product and population, nor according to the squared differences in gross national product.

The results presented in this article will be used in subsequent research on the causal relationships of the interaction variables and the power- and distance concepts. Results from that research will be presented in a subsequent article.

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