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Note

Beyond the ecological fallacy
The Duncan–Davis technique of ecological inference

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Abstract. The analysis of long-term social and political developments in Western countries is often difficult because of a lack of sufficient survey data. Almost always official election and census statistics are available over long periods, yet the use of these data for individual-level inferences runs the risk of the 'ecological fallacy'. In this paper we propose a method to go beyond the fallacy, the Duncan–Davis technique for area-classified data. The method is discussed and used to assess the amount of religious voting among Dutch Catholics in the 1971 general election. While the technique is only moderately helpful in this case, it is expected to be far more useful for the analysis of older elections.

I. Introduction

The empirical study of long-term political and social developments in European countries is often hindered by a lack of sufficient survey data. For example, in the Netherlands only from 1971 onwards national election surveys have been systematically held by inter-university research teams; before 1971 no more than three scattered surveys have been undertaken, all of which the original data have been lost.

One likely alternative source of data are the official election statistics, which in the Netherlands have been collected for every election since 1918 by the Dutch Central Bureau of Statistics (CBS); in addition national population census have been held by the same bureau in 1947, 1960 and 1971. Both counts provide a wealth of data, be it aggregated at the municipal level. Obviously these data may be extremely useful, even indispensable for any longitudinal analysis of socio-political developments. However, since we often are interested in individual-level behavior, we must tackle a problem of aggregate data known as the 'ecological fallacy'.

The danger of ecological fallacy occurs in the case of ecological inference, in which aggregate level data are used to estimate individual behavior. The fallacy was first recognized by Robinson (1950), who demonstrated that

correlations between literacy rate and place of birth or skin color found at the state level were reversed when examined at the individual level. Since then ecological inference has been practically equated with ecological fallacy, and consequently analyses of aggregate data have been relatively rare.

Given the dependence on aggregate data for longitudinal research, two techniques may be employed to avoid fallacious ecological inferences. The first is the use of ecological regression instead of ecological correlations (Goodman, 1953, 1959; Blalock, 1961; see also Przeworski & Teune, 1970). This technique, however, requires complex assumptions about the relationships between an individual's scores on dependent and independent variables and the grouping of individuals into aggregate units, assumptions which are difficult to ascertain in empirical practice (Shively, 1969). More recently ecological regression has also been criticized on mathematical grounds (Schmidt, 1984; Thomsen, 1987).

A second technique is the use of area-classified data for individual-level inferences, developed by Duncan & Davis (1953; see also Shively, 1969). Put shortly, the method involves the addition of individual relationships of maximal and minimal strength in areal subunits with the objective of setting absolute boundaries around the real value of the individual-level relationship. It has the advantage over ecological regression that it requires no postulates and works with real values instead of estimates.

In this article we will discuss the Duncan–Davis technique (hereafter abbreviated as D–D) and apply it to Dutch aggregate election data. As a vehicle for its demonstration the relationship between adherence to the Catholic religion and voting for the Dutch Catholic party (KVP) will serve, expressed in a socalled political orthodoxy index (p.o.-index), the "percentage of enfranchised members of [the Catholic] group supporting that group's political party" (Andeweg, 1982: 48). The first goal of this article is to establish the value of the Catholic p.o.-index with the help of the D–D technique for the national elections of 1971. The second goal is to evaluate the usefulness of D–D for longitudinal research purposes in general.

This article will proceed as follows. In Section II we will describe in more detail the D–D technique and the data to be used. In Section III the empirical results will be presented, while Section IV is reserved for conclusions.

II. Method and data

The application of the D–D technique is only possible in the form of 2×2 contingency tables, like Table 1. The problem of ecological inference can be described as the estimation of one missing cell entry, given the knowledge

Table 1. Religion and party choice

	Roman Catholic	Other religion	
Catholic party	·	·	N1
Other party	·	·	N2
	NI	NII	N

of the values of marginals N1, N2, NI, and NII. Duncan & Davis proposed a calculation technique in which "the individual correlation is approximated by the least maximum and the greatest minimum among the results for several systems of areal subdivision" (1953: 666).

For every subunit those maximum and minimum strengths of an individual-level relationship are calculated which are consistent with that subunit's aggregate marginals; this procedure creates absolute numerical limits between which the real value of the relationship necessarily must lie. Under the condition of uneven distribution, adding up the minima and maxima of the subunits to a higher aggregate level results in narrowing the limits between which the individual relationship may be found.

An example will clarify the method. Imagine a country in which the marginals of Table 1 acquire the following values (in absolute numbers):

N1	(Catholic party vote)	30
N2	(vote for other parties & non-vote)	70
NI	(number of enfranchised Catholics)	50
NII	(number of enfranchised non-Catholics)	50
N	(number of enfranchised inhabitants)	100
N1/NI	(Catholic p.o.-index)	

If we infer an individual-level p.o.-index from these marginals, we see that its value lies between 60.0 and zero, as Tables 2a and 2b show.

Now suppose this country consists of two districts, A and B, in which the marginals are distributed as follows:

	District A	District B
N1	25	5
N2	25	45
NI	40	10
NII	10	40

Tables 3a–d show the maximal and minimal relationships in both districts. Adding the maxima and minima of the districts up to the national level yields Tables 4a and 4b. We see that the range of possible values of the indvidual-

Table 2a. Maximum relationship religion and voting

	Catholic religion	Other religion	Total
Catholic party	30	–	30
Other party	20	50	70
Total	50	50	100

P.o.-index = 60.0.

Table 2b. Minimum relationship religion and voting

	Catholic religion	Other religion	Total
Catholic party	–	30	30
Other party	50	20	70
Total	50	50	100

P.o.-index = 0.0.

level p.o.-index has been halved, simply by disaggregating the national unit in two subunits. A further breakdown into more subunits would yield still narrower limits.

The success of D–D is dependent upon the distribution of variables among the disaggregate subunits. If variables are evenly spread among the subunits, disaggregation will not help us in limiting the value range of the individual relationship. If, on the other hand, variables are not uniformly distributed over the subunits, then application of the D–D technique will lead to narrower limits for both the subunits and the aggregate level, as Tables 2, 3 and 4 show. The more homogeneous on a variable a given subunit is, the closer maximum and minimum values will approach one another.

The data for our analysis stem from two CBS counts in 1971, the official election statistics (CBS, 1972) and the national population census (CBS, 1982). The election statistics were collected on the basis of municipal voter registration and ballot counting, and presented at the municipal level. Data on religious affiliation were collected for every Dutch municipality during the census.

The Catholic p.o.-index is operationalized by dividing the number of Catholic votes by the share of Catholics in the total eligible electorate (Nl/NI in Table 1). Although traditionally there were differences in birth rates between the different denominations in the Netherlands, leading to differences in electoral and popular proportional shares, these differences had lost much of their sharpness in 1971. Bakvis (1981) used a correction factor of 0.982 to estimate the right proportion of voting-age Catholics in 1971 as compared to the total Catholic share of the Dutch population; we assume that the

Table 3a. District A, maximum

	Catholic religion	Other religion	Total
Catholic party	25	–	25
Other party	15	10	25
Total	40	10	50

P.o.-index = 62.5.

Table 3b. District A, minimum

	Catholic religion	Other religion	Total
Catholic party	15	10	25
Other party	25	–	25
Total	40	10	50

P.o.-index = 37.5.

Table 3c. District B, maximum

	Catholic religion	Other religion	Total
Catholic party	5	–	5
Other party	5	40	45
Total	10	40	50

P.o.-index = 50.0.

Table 3d. District B, minimum

	Catholic religion	Other religion	Total
Catholic party	–	5	5
Other party	10	35	45
Total	10	40	50

50 P.o.-index = 0.0.

number of enfranchised Catholics is proportional to their share of the total population.

III. Results

In order to assess the applicability of D–D to the Dutch socio-political situation we have determined the degree of homogeneity for the two sub-levels of aggregation that we consider here, i.e. provinces and municipalities.

Table 4a. Country, maximum

	Catholic religion	Other religion	Total
Catholic party	30	–	30
Other party	20	50	70
Total	50	50	100

P.o.-index = 60.0.

Table 4b. Country, minimum

	Catholic religion	Other religion	Total
Catholic party	15	15	30
Other party	35	35	70
Total	50	50	100

P.o.-index = 30.0.

Table 5. Homogeneity of provinces and municipalities, 1971

	Provinces	(%)	Municipalities	(%)
Homogeneous Catholic	1	(9)	207	(24)
Homogeneous non-Catholic	2	(18)	264	(30)
Heterogeneous	8	(73)	402	(46)
Total	11	(100)	873	(100)

A sublevel is considered homogeneous Catholic when more than 90 percent of its population adheres to the Catholic religion. A sublevel is regarded as homogeneously non-Catholic when less than 10 percent of its population is Catholic. The results can be glanced from Table 5. At first sight especially at the municipal level the distribution of Catholics and non-Catholics seems to be uneven enough to make a D–D analysis useful.

For the Netherlands as a whole the marginals of Table 1 have the following values in 1971:

N1	(vote for Catholic party, KVP)	1,380,392
N2	(vote for non-Catholic parties & non-vote)	6,666,577
NI	(number of enfranchised Catholics)	3,181,293
NII	(number of enfranchised non-Catholics)	4,865,676
N	(total number of enfranchised inhabitants)	8,046,969

From Tables 6a and 6b it can be seen that the Catholic p.o.-index, measured

Table 6a. The Netherlands, maximum, 1971

	Catholic religion	Other religion	Total
Catholic party	1,380,392	–	1,380,392
Other pt. & non-vote	1,800,901	4,865,676	6,666,577
Total	3,181,293	4,865,676	8,046,969

P.o.-index = 43.4.

Table 6b. The Netherlands, minimum, 1971

	Catholic religion	Other religion	Total
Catholic party	–	1,380,392	1,380,392
Other pt. & non-vote	3,181,293	3,485,284	6,666,577
Total	3,181,293	4,865,676	8,046,969

P.o.-index = 0.0.

Table 7. The Netherlands, minimum, by provinces, 1971

	Catholic religion	Other religion	Total
Catholic party	425,593	954,799	1,380,392
Other pt. & non-vote	2,755,700	3,910,877	6,666,577
Total	3,181,293	4,865,676	8,040,969

P.o.-index = 13.4.

at the national level, must lie between 43.4 and 0.0. Disaggregation of the national totals to the level of the provinces and the addition of provincial minima and maxima in the way described in Section II gives us an identical maximum score, and a moderately higher minimum score of 13.4. Since the aggregated maximum score, following the definition of the p.o.-index as N1/NI (from which follows that N1 < NI), will be the same no matter from how many subunits it is calculated, Table 7 only displays the minimum limits. Given the low numbers of homogeneous Catholic and non-Catholic provinces, the moderate size of the increase of the minimum score could be expected: the less homogeneous the subunits, the more even a variable is spread among them, the less the minimum value will approach the maximum value.

We might expect that an identical disaggregation to the level of municipalities and addition of their maximal and minimal scores would give a much higher p.o.-index, given the higher degree of homogeneity within the municipalities. This is not the case. The D–D procedure yields a minimum score of 17.5, only slightly more than the provincial one (Table 8). Since we

Table 8. The Netherlands, minimum, by municipalities, 1971

	Catholic religion	Other religion	Total
Catholic party	555,651	823,741	1,380,392
Other pt. & non-vote	2,625,642	4,040,935	6,666,577
Total	3,181,293	4,865,676	8,040,969

P.o.-index = 17.5.

Table 9. Catholic p.o.-index, minimal and maximal values by three levels of aggregation

Level	Maximal	Minimal	Difference
National	43.4	0.0	43.4
Provincial	43.4	13.4	30.0
Municipal	43.4	17.5	25.9

cannot reach beneath the municipal level on the basis of the CBS data, the conclusion is that the percentage of enfranchised Catholics voting for the Catholic party in 1971 lies between a minimal value of 17.5 and a maximum of 43.4. Table 9 summarizes the different scores for the different levels.

IV. Conclusions

How useful has the application of the D–D technique been for the calculation of p.o.-indices? As Table 9 shows, the application of the D–D technique resulted in a substantial limiting of possible values of the Catholic p.o.-index. At the same time, however, the difference left is still too large to permit firm conclusions about the relationship between religion and party choice in 1971. At first sight the D–D method has not been of tremendous help.

One reason for its limited utility is based on a particular property of the minimum p.o.-index as calculated in this paper. Recalling the notations of marginals in Table 1, it can be seen that a minimum p.o.-index may be zero in three cases. The first cases occur when a subunit is totally non-Catholic (NI = 0) or when it contains no Catholic party voters (N1 = 0), cases also mentioned by Duncan & Davis. The third case exists when the number of voters for the Catholic party is smaller than the number of enfranchised non-Catholics (N1 < NII), a property inherent in the 2×2 calculation of the p.o.-index. Since by definition in the index the number of Catholic party voters is smaller than the number of enfranchised Catholics (N1 < NI), it follows that for all subunits containing enfranchised Catholics, the minimum

p.o.-index exceeds zero only when the number of Catholic party voters exceeds the number of enfranchised non-Catholics (N1 > NII, or put differently, N1 > N − NI). Tables 3b and 3d provide examples of the two situations, Table 3b for when N1 > NII and Table 3d for when N1 < NII.

This property of the subunits' minimum p.o.-scores affects the number of subunits that contribute to the minimum p.o.-score of the unit as a whole. If we assume that for 1971 the minimum p.o.-index is 43.4 or less, it follows that in order for N1 > NII, NI must at least be 70 percent of N in every subunit. In concrete terms this means that in our research only two out of eleven provinces and 304 out of 873 municipalities have yielded a minimum score greater than zero, and thus have contributed to the national minimum p.o.-indices of respectively 13.4 and 17.5. Since in general municipalities with such large numbers of religious adherents are predominantly small and rural (with exceptions mainly in the Southern part of the Netherlands) the minimum p.o.-index as calculated in this paper has included only a relatively small number of people.

For the broader purpose of longitudinal research the use of the D–D technique is best reserved for the analysis of homogeneous subunits within a given unit (e.g., homogeneously Catholic, Protestant, or working class areas of a country). For example, an extension of the research presented here to the 1950s and 1940s would include a greater number of provinces and municipalities in the calculation of the national p.o.-indices, since in those days more people were religious and the religious parties received far more votes than in 1971. Thus, within the limits we have discussed, the application of the Duncan–Davis technique may make a fair contribution to the unravelling of the socio-political developments of the past and present.

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