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Spatial fertility analysis in a limited data situation: the case of Pakistan

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PREFACE

The authors are indebted to Bruce Currey, Mehtabunisa Ali Currey, Arthur Hampson, and Paul Wright of the Department of Geography, University of Hawaii, and to Robert Gardner and Peter C. Smith of the East-West Population Institute for detailed reviews of early drafts of this article. Cartography was produced by Gregory Chu and Clyde Kanehiro, East-West Population Institute. Funds for publication of this paper were made available by the Office of Population, Agency for International Development.

ABSTRACT From district-level data from the 1951 and 1961 censuses of Pakistan, fertility trend surfaces were constructed to show the spatial distribution of fertility. The positive residuals from the third order trend surfaces were considered to be areas of excess fertility.

The paper argues that family planning targets must be spatial, as well as demographic; the trend surface approach is one means of accomplishing this end in cases of limited data availability. Although many variables not used in this paper would be considered in a decision to allocate family planning resources, the methodology represents a starting point for the allocation process.

The mechanism of fertility decline is an important concern of demographic research because it seems to offer a key to understanding the means by which the human condition, at both the individual and aggregate levels, may be improved. The countries of the Third World increasingly have viewed fertility as a real variable in overall economic development, and many have invested heavily in programs to bring about fertility decline. Our understanding of fertility, and hence of fertility decline, however, is strongly influenced by the historical purposes of censuses and vital registries, the principal sources from which we draw inferences about fertility. Although modern versions of these sources reflect a concern with the needs of fertility research, they still exhibit the broader needs of governments and of other institutions to raise revenues, to provide for defense, and to plan for the future. What has emerged is a view of fertility colored by the influence of socioeconomic variables derived from censuses or vital registers; so strong is the influence that population scholars routinely write of the "socioeconomic determinants" of fertility.

The socioeconomic explanation of fertility is reasonably satisfying. Socioeconomic variables generally account for a high proportion of the variance in fertility, and these variables have a practical meaning within a country which, in turn, permits the formulation of specific policy. Still, other views of fertility may have equal or greater merit. It is possible, for example, that a nutritional explanation of fertility could be advanced that would account for a high proportion of variance in fertility rates (Frisch, 1978). Moreover, some countries might find it easier to alter the nutritional intake of their population than to raise literacy, increase per capita income, or provide contraceptive

technology. It is unlikely, however, that socioeconomic determinism will be replaced by considerations of nutrition, or by other similar explanations of fertility. The censuses and vital registers that provide our view of fertility do not record continuous change within a population. The cross-sectional view afforded by a census is hopelessly inadequate to describe the influence of variables like nutrition. Vital registers, though providing a more longitudinal view, nevertheless record discrete events at a scale much too great to capture the effect of variables that operate on a day-to-day, or even hour-to-hour basis. Although it is possible to conceive of monitoring systems that might permit alternatives to socioeconomic determinism, both their cost and their implied threat effectively rule out their creation on a broad scale.

Ultimately, better understanding of fertility decline will require an expansion of the kind of data collected, but for the present significant expansion of knowledge requires new research orientations within the general framework of socioeconomic determinism. Such a new orientation is exemplified by multivariate areal fertility analysis (Hermalin, 1972, 1975, 1976). The areal approach, while employing conventional demographic data and techniques, affords a view of fertility at a level intermediate to the national and individual (KAP) levels. The areal fertility studies of Demeny (1972) for Austria-Hungary, Fuller (1975) for a Chilean community, and Jones (1977) for Barbados have all shown that the linkages between fertility and socioeconomic variables vary from place to place. Demeny (1972:170), whose study concerns a period before the advent of family planning programs or modern contraceptive technology, has argued that these areal variations resulted from "geographic diffusion" of new fertility norms. Fuller (1975) also considered areal variations in linkages to arise from the diffusion of new norms, but showed that the diffusion process was generated by a family planning clinic. Jones (1977), in a study of Barbados based upon the methodology of Hermalin (1972, 1975), has argued that areal variation in the linkages between fertility and socioeconomic variables arose partially from areal differentials in family planning activity.[1]

The areal approach, apart from illuminating the weaknesses of socioeconomic determinism, provides a means of evaluating and improving family planning programs. Areal variations in linkages can be compared with the areal pattern of family planning investment for evalua-

1 These two conceptualizations of the areal variations in linkages, diffusion and areal differentiation, are similar to the dichotomy between diffusion and adjustment propounded by Carlsson (1966).

tion, or, on the other side of the same coin, areal variations can suggest where future family planning investment ought to be made. Indeed, family planning evaluation has been the principal focus of areal fertility analysis. Unfortunately, the areal approach requires relatively complete and accurate data. Because available data inevitably lead to the socioeconomic determinants of fertility, variations in linkages must appear as residual pieces once the analytic cake has been sliced. Crumbs resulting from poor or incomplete data will not suffice; the unexplained variance in fertility, once socioeconomic variables have been considered, must arise from the influence of variables outside the analytic framework, and not from systematic bias inherent in the data. It is this consideration that has led to the relative rarity of areal fertility studies, and many countries which presumably could benefit from the results of areal analysis lack the necessary data.

THE SPATIAL APPROACH

The findings of modern areal fertility analysis permit the advancement of the *a priori* assumption that the linkages between fertility and socioeconomic characteristics vary systematically over space. If this assumption is made, then it is possible to draw inferences about these linkages from incomplete or limited data. Basically, such inferences are drawn in much the same way that topographic maps are created from direct measurements of elevation made at only a few points. The surveyor or cartographer assumes certain features of geologic structure and erosional process, and interpolates between the observation points. The contours on most topographic maps, then, are generalized patterns based on interpolation derived from assumptions about the linkages between structure, process, and elevation.

In topographic mapping there is always the risk that an unknown factor between observation points influences the linkages between controls and elevation. Generally, however, topographic maps achieve a high degree of accuracy, much greater, in fact, than would be expected from any study of human fertility. On the other hand, the variables that "determine" elevation are generally better known and more easily measured than those that influence human fertility. For this reason, the assumption of systematic spatial variation in linkages between fertility and socioeconomic variables should be made only when it is necessary to make it; the standard areal approach is more rigorous and therefore a preferred methodology. In limited-data situations, however, the assumption must be made if any of the advantages of areal analysis are to be gained. We have made this assumption in analyzing Pakistani fertility.

We have applied the spatial approach to fertility patterns in Pakistan, which, like many developing countries experiencing rapid population growth, has viewed the control of human fertility as an important variable in its developmental effort. The creation of a national family planning program and the establishment of ambitious goals for the program are obvious expressions of the government's concern. Although all family planning programs could benefit from greater information about how their efforts may be transformed into significant declines in human fertility, Pakistan's program suffers from unusually severe data limitations concerning fertility patterns and trends. Despite significant contributions to an understanding of Pakistani fertility by the Population Growth Estimation Project begun in 1961 (for example, Alam and Yusuf, 1968), and by Krotki (1964), Hashmi (1963), and Zelnik and Khan (1965), a great many questions of relevance to national family planning remain unanswered.

THE DEARTH OF FERTILITY DATA IN PAKISTAN

Pakistan lacks a vital registry system that would permit conventional calculation of fertility rates. Although this deficiency can be partially compensated for by the analysis of census data and by the use of sample surveys, the dearth of reliable data creates a significant handicap for family planning decision makers. The allocation of fertility control resources cannot be adjusted easily or quickly so as to maximize impact, nor can the impact of the program itself be measured accurately except over limited areas, for limited periods of time.

The censuses of 1951 and 1961, the principal sources available for the calculation of fertility rates, contain some serious shortcomings which apparently arise from age heaping. The reported age intervals for the 1951 census are uneven and are different from the intervals used in the 1961 census. Krotki (1964) reported that the 1951 census collected age data specific to the year, but that heaping at 10, 20, 40, and 60 years was so pronounced that the data were published only in broad age categories (0–9, 10–19, 20–39, 40–59, and 60+). Moreover, the 1961 census reported a 0–4 age group that was smaller than the 5–9 age group; this is highly implausible in light of the age structure of other developing countries in the same region.

CALCULATION OF FERTILITY RATES BY DISTRICT

The administrative divisions of Pakistan are, in order of decreasing size: the nation, the province, the division, the district, the tehsil, and the union council. The district is the smallest unit for which complete

census data were available and therefore is the unit furthest down the administrative hierarchy likely to enter into national planning decisions. In 1951 Pakistan contained 45 districts, each with an average area of about 6,000 square miles and a population of 840,000. The smallest district contained about 42,000 people, and the largest 2,700,000. Figure 1 shows the districts of Pakistan in 1951.

The most commonly used measure of fertility, the general fertility rate, could not be employed in this study since it requires knowledge of the number of births over a given period of time. In the absence of both vital registries and life tables, it was necessary to use an alternative measure of fertility, the child-woman ratio (R).

In order to apply this method comparably to both censuses, it was necessary first to create comparable age intervals. This was accomplished by use of the halving method and Newton's Method (Bogue and Kitagawa, 1967); a complete description of the application of these methods has been given elsewhere (Khan, 1973). Although these procedures should minimize the influence of age heaping on the calculation of fertility, to insure the least possible error, we combined the first two age groups derived from the census (0–4 and 5–9). Thus, the child-woman ratio (R) became

$$R = \frac{C(0-9)}{W(15-49)} \times 1{,}000$$

where $C(0-9)$ is the number of children aged 0–9 years, and $W(15-49)$ is the number of women in the childbearing years (ages 15–49). This formula was further modified so that R might be read to approximate the general fertility rate and become

$$R = 1/10 \frac{C(0-9)}{W(15-49)} \times 1{,}000$$

The modified child-woman ratios (R) for the districts of Pakistan are contained in Table 1.

TREND SURFACE ANALYSIS OF FERTILITY

Trend surface analysis is a variety of multiple regression in which two independent variables define the location of a control, or observation point, and where the dependent variable is measured only at the control points. The independent variables may be thought of as longitude and latitude when the dependent variable, as in the case of Pakistani fertility, varies spatially. The control points used for this study were the centroids of the districts of Pakistan. Although some error is intro-

FIGURE 1 Districts of West Pakistan: 1951

1 Hazara
2 Mardan
3 Peshawar
4 Campbellpur
5 Rawalpindi
6 Jhelum
7 Gujrat
8 Sialkot
9 Gujranwala
10 Sargodha
11 Mianwali
12 Kohat
13 Bannu
14 D.I. Khan
15 Zhob
16 Loralai
17 D.G. Khan
18 Muzaffargarh
19 Jhang
20 Sheikhupura
21 Lyallpur
22 Lahore
23 Sahiwal
24 Multan
25 Bahawalnagar
26 Bahawalpur
27 R.Y. Khan
28 Sukkur
29 Khairpur
30 Sangar
31 Tharparkar
32 Hyderabad
33 Tatta
34 Karachi
35 Dadu
36 Larkana
37 Nawabshah
38 Lesbela
39 Mekran
40 Kharan
41 Chagai
42 Kalat
43 Sibi
44 Quetta
45 Jacobabad

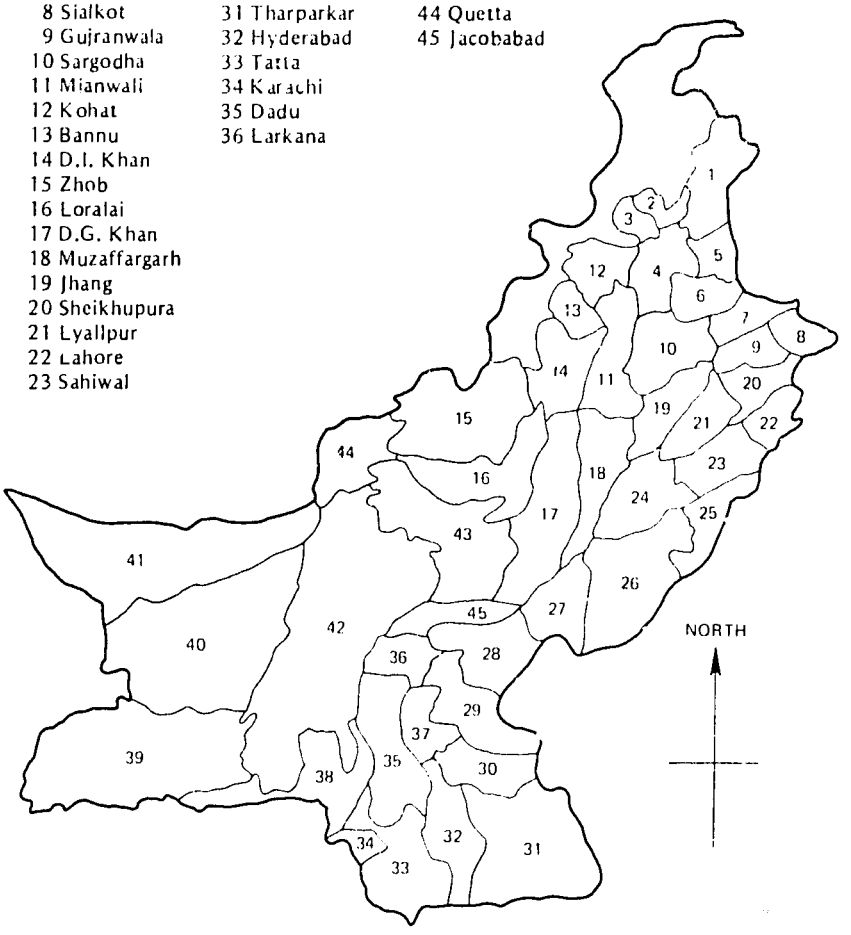


TABLE 1 Fertility rates (child-woman ratios) for the districts of Pakistan: 1951 and 1961

District	Fertility rate 1951	1961
Hazara	146	211
Mardan	177	210
Peshawar	149	207
Campbellpur	149	143
Rawalpindi	137	140
Jhelum	124	131
Gujrat	120	148
Sialkot	115	136
Gujranwala	106	147
Sargodha	138	158
Mianwali	159	170
Kohat	153	187
Bannu	190	193
D.I. Khan	170	138
Zhob	158	179
Loralai	170	186
D.G. Khan	136	130
Muzaffargarh	138	172
Jhang	123	159
Sheikhupura	132	148
Lyallpur	133	152
Lahore	177	154
Sahiwal	87	106
Multan	151	166
Bahawalnagar	140	163
Bahawalpur	143	171
R.Y. Khan	152	184
Sukkur	229	155
Khairpur	144	178
Sangar	138	156
Tharparkar	136	144
Hyderabad	125	141
Tatta	143	157
Karachi	130	151
Dadu	129	131

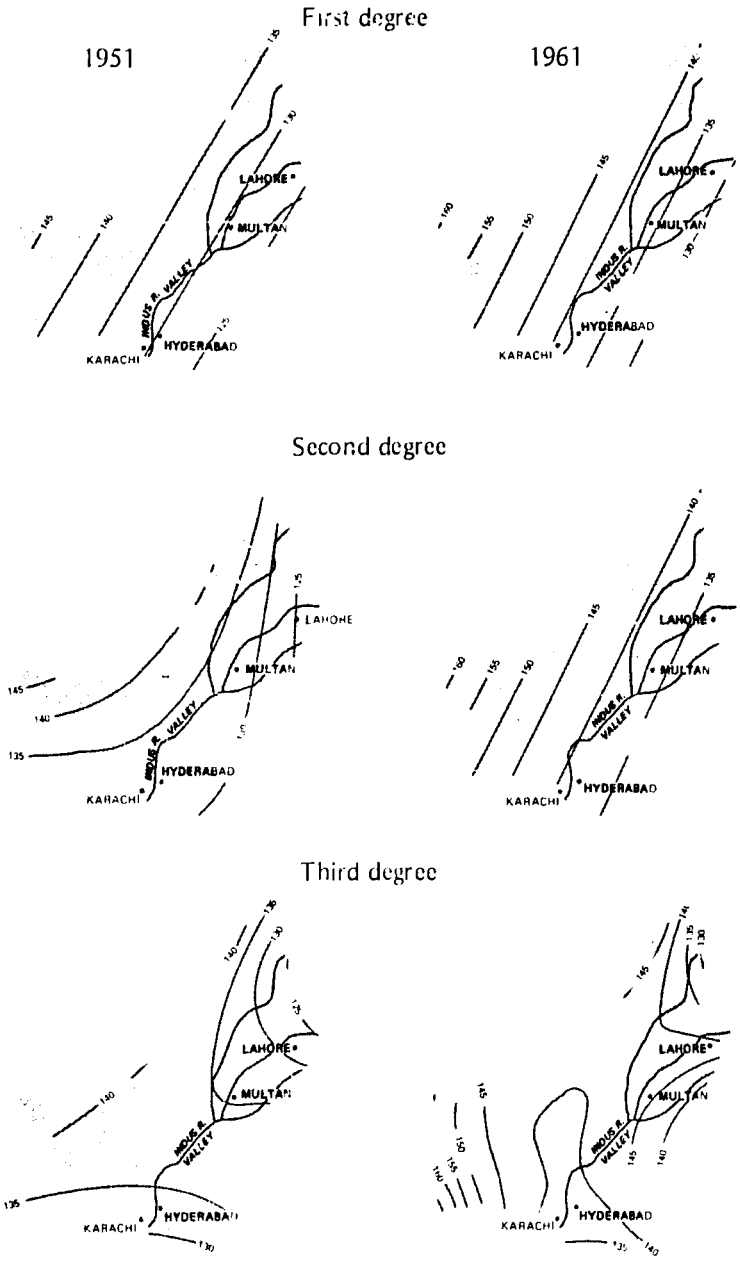
TABLE 1 *(continued)*

District	Fertility rate 1951	1961
Larkana	152	147
Nawabshah	140	175
Lesbela	147	167
Mekran	147	247
Kharan	167	183
Chagai	176	201
Kalat	135	161
Sibi	156	161
Quetta	153	161
Jacobabad	141	172

duced by the use of an areal centroid rather than a center of population, the surfaces to be examined are not sufficiently complex to be affected materially by the error factor. Trend surface analysis finds a best fitting surface (by least squares estimation) to fit the values observed for the dependent variable at the control points. The created surface may be planar (as in linear regression), or of a higher order; the investigator may allow the surface to warp, as in curvilinear regression, to provide increasingly better fit of the surface to the observed values. Pioneering work in trend surface analysis was conducted by Krumbein(1959), with specific application to petroleum exploration. Some applications of the technique have occurred in demographic and geographic research, but less expensive computer cartographic routines have tended to supersede it.

The principal advantage that trend surface analysis has over other computer cartographic techniques and surface-fitting algorithms derives from its regression heritage. A measure of goodness of fit, usually percentage of variance explained (R^2), can be determined and the deviations of the observed values from those predicted (i.e., the residuals), may be calculated and plotted. This feature is particularly important in limited data situations because the distribution of the residuals may suggest the influence of specific variables not included in the analysis. Figure 2 shows the planar, second order, and third order fertility trend surfaces for Pakistan based on the 1951 and 1961 data contained in Table 1.

FIGURE 2 Fertility trend surfaces



The first order, or planar, surfaces are the simplest configurations and show a great deal of similarity for the two years. In both the 1951 and 1961 surfaces, there is a general trend toward lower fertility extending from the northwest to the southeast; the principal difference between the two surfaces is a steeper fertility gradient for 1961, indicating the emergence of an apparent greater regional disparity in fertility rates. The variance explained by the two surfaces suggests that the disparity results from a more complex pattern of fertility in 1961. The planar surface based on the 1951 data accounts for 32 percent ($R^2 = 0.32$) of the variance; this is a remarkably high percentage when viewed in light of the simplicity of the surface and seeming complexity of the data in Table 1. By contrast, the planar surface for 1961 accounts for only 19 percent ($R^2 = 0.19$) of the variance. The most likely explanation for the better fit of the 1951 surface is that it has been "smoothed" by the estimation techniques applied to the 1951 census data. Such techniques have the effect of eliminating extreme values from the distribution of fertility and producing the appearance of regularity.

A comparison of the two columns in Table 1 reveals that substantial increases or decreases in fertility occurred in virtually every district of Pakistan in the decade 1951–61. Despite these changes, and despite the greater spatial complexity of the 1961 fertility data, the planar surfaces show that the principal generalization about areal fertility remains substantially the same, with highest fertility in the northwest, and lowest in the southeast. Herein rests an important contribution of the spatial approach to fertility, for durability of the generalization is not evident directly from Table 1; moreover, the durability offers presumptive evidence that the processes influencing fertility are imbedded within the spatial fabric of the nation. Although these processes may wax and wane, there is reason to suspect that their influence spreads throughout Pakistan in similar patterns.

The second order surfaces provide a minimum of information beyond that obtained from the planar surfaces. Again the surfaces for 1951 and 1961 are similar, and the northwest-southeast trend is confirmed. The 1951 surface has increased the variance explained by only 7 percent (from $R^2 = 0.32$ to $R^2 = 0.39$), indicating the strength of the generalization provided by the planar surface. By contrast, the second degree surface for 1961 shows a substantial explanatory improvement; variance explained has increased from $R^2 = 0.19$ to $R^2 = 0.37$. The second degree surface for 1961 differs from the planar surface for 1961 only by increasing steepness in the fertility gradient.

This slight visual change, combined with the substantial increase in percentage of variance explained, probably indicates growing regional inequality in fertility rates and implies that processes influencing fertility which may be under way in one part of the country have not yet reached other parts (i.e., geographic diffusion). On the basis of the surfaces alone, it is not possible to conclude which regions have encountered these processes and which have not. With an eye to general economic development within Pakistan, however, it seems likely these processes have been generated along the north-south axis of the Indus River valley and had not reached the more mountainous northwest by 1961.

Although the third order surfaces show the same general trends evident in the lower order surfaces, the basic northwest-southeast generalization has been modified by the influences of urbanization and of the Indus River, the ecumene of Pakistan. In the south, a region of modestly lower fertility had just begun to develop in 1951; by 1961, this region, apparently representing the influence of Karachi and Hyderabad, had extended much further north, generally following the Indus River valley. Similarly, another region of lower fertility is evident for both years in the east and northeast and apparently resulted from the urban influence of Lahore and Multan. Although there are substantial changes between the second order and third order surfaces for both years, these changes have been approximately the same so that the 1951 and 1961 third order surfaces are nearly identical. Such differences as do exist tend to confirm the previous observation: the 1961 surface has greater relief, implying greater regional disparity in areal fertility. The 1951 third order surface accounts for approximately 42 percent of the variation, and the 1961 surface for 51 percent.

It is possible to continue warping the surfaces so as to account for increasingly greater proportions of the variance in fertility. Each additional warp, however, lends greater complexity to the surfaces, which, in turn, renders it increasingly more difficult to generalize visually from the patterns. In the case of the 1951 data, the fourth order surface adds slightly less than 2 percent to the total variance explained; this small increase does not seem justified. Since the intention here is to compare the patterns for 1951 with those for 1961, it is prudent to halt surface development at the third degree level. If we were concerned only with the 1961 fertility data, however, then we should progress to higher order surfaces, since both the fourth and fifth order surfaces each add in excess of 5 percent to the total variance explained.

RESIDUALS FROM THE THIRD ORDER TREND SURFACES

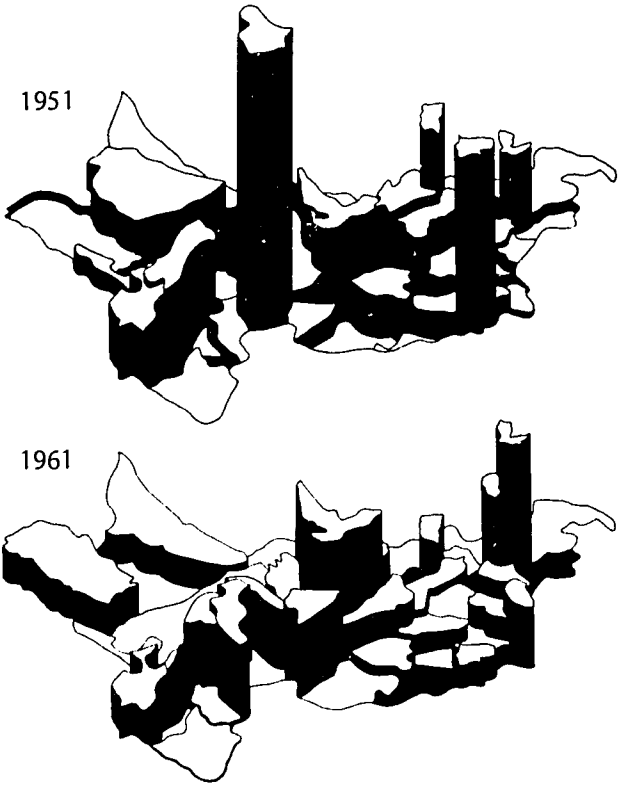
The third order trend surfaces are the most accurate surfaces we have considered explicitly here, yet they account for only about half of the variance in fertility rates. The unexplained variance, the residuals, can be mapped so as to show the spatial distribution of inaccuracy. We may consider the trend surfaces as generalizations about fertility in Pakistan, and the residuals as exceptions to the generalizations. Figure 3 shows an oblique transformation of Figure 1, and Figure 4 renders in three dimensions the distribution of residuals from the third degree surfaces. The oblique transformation highlights the positive residuals--that is, those districts where actual fertility rates were higher than the rates generated from the third degree surfaces. Although some benefit might accrue to decision makers from the knowledge of where fertility rates were lower than those generalized, the traditional focus of family planning programs has been upon excess fertility; in this instance, the positive residuals are indeed an excess over the values defined by the surfaces.

The positive residuals have practical value when they are considered in light of the choices available to the national family planning program. These choices may be divided into two categories: those dealing with the operation of the program at the local level, usually through individual clinics, and those dealing with the allocation of resources among the various clinics. The former category involves tactical decisions about such things as the type of contraceptives offered, the style and intensity of motivational campaigns, the frequency and extent of outreach visits, and the level and type of training required of clinic personnel. The latter category of choices is labeled properly as family planning strategy and is concerned with the creation and attainment of national fertility goals through the allocation of money, equipment, and manpower so as to maximize impact upon fertility levels.

The dichotomy created here between tactics and strategy should not be belabored, since a viable strategy must consider tactical realities and because tactics that ignore strategy can disrupt a program's efficiency. Moreover, for some national programs the distinction between tactics and strategy is unimportant. This is particularly true for countries that have relatively small populations or are territorially small, and are relatively uniform culturally. It is probably also true in countries whose family planning programs have attained a level of maturity that permits unencumbered decisions concerning the allocation of resources. For Pakistan and many other countries, however, the dis-

FIGURE 3 Oblique transformation of base map of Pakistan

FIGURE 4 Residuals from third degree surfaces



tinction between tactics and strategy is significant and will remain so as long as it is necessary to decide where the next clinic will be opened and which district should receive additional resources as they become available. The residuals from the third order trend surfaces are of little value in the selection among tactical alternatives, but they can aid in the formulation of strategy.

The residuals for 1951 show four districts with exceptionally high values and several with moderately high values. These districts do not necessarily have the highest fertility levels, but rather emerge as exceptions once a generalization about spatial trends in fertility has been taken into account. The generalization is similar conceptually to the generalization of the linkages between socioeconomic variables and fertility created in areal fertility studies. Here, however, it has been assumed that the variations in linkages are described by the trend surface; the residuals, therefore, emerge as exceptions to the generalization, or specifically as districts where fertility is higher than expected. A decision maker should therefore suspect that these are districts where the linkages between socioeconomic indices are abnormal and that family planning resources allocated there have a higher probability of yielding favorable results. Because there is the possibility of unknown variables and processes operating between the observation points, local-level investigation would be required before specific allocations were made to the high residual districts.

The suggested use of the residuals as an allocation model is a logical consequence of the family planning evaluation orientation of areal studies of fertility (see especially Hermalin, 1972, 1975). The consequence of evaluation is the improvement of those aspects of a program that are not achieving reasonable goals, and "improvement" necessarily implies the allocation of resources. Traditionally, allocation in national family planning programs has involved attempts to reach elements of the population that are defined by demographic characteristics only. Spatial allocation is implicit in any national-level allocation model, regardless of how the "targets" are defined. The approach advocated here makes the spatial dimension explicit (at least at the district level); nonspatial aspects such as demographic criteria must still be considered within the targeted districts.

Allocation models employed for economic development in general are subject to the realities of both their own shortcomings and the tendency of decision makers to seek ends apart from those at which allocation is directed. The real utility of such models is to raise planning considerations that have been overlooked and to provide a basis of as-

sessing the costs of deviation from an economically optimal planning scheme. We can assume that there exists an economically optimal strategy for the reduction of fertility in any country, and that a particular spatial allocation of resources is a part of such a strategy. The history of family planning, however, is such that it has come to be identified with the practice of medicine. We are thus faced with the situation of distributing medical resources, albeit medical resources aimed at a social goal. It is one thing to suggest that these medical resources ought to be targeted for a subgroup of the population, but quite another to suggest the target should also be specific areas of the country. The political implications are double-edged, for a nontargeted area may charge neglect, while a targeted area may claim genocide. In fact, any national family planning program has to engage in spatial allocation, even a program that has achieved virtual saturation levels. Usually the spatial dimension is not explicit, but it is present. The allocation scheme advocated here has a virtue in this regard, for the assumption of systematic spatial variation in linkages allows fertility to be examined directly, without explicit consideration of the socioeconomic characteristics of the districts' populations. Thus, it cannot be charged fairly that allocation has been based upon considerations of ethnicity or ideology; the criteria have been location and a measure of fertility.

In any case, such investment would be hypothetical because the 1951 residuals reflect conditions at a time before national family planning was a reality in Pakistan. Although a privately organized national program was under way in 1953, it was not until the second five-year plan (1960–65) that significant resources through government contributions were made available (Pakistan, Ministry of Health, 1964). The 1951 residuals, then, have planning value only as they provide background to more recent developments.

The values of the positive residuals for 1961 are less extreme, thus making the selection of target districts more difficult. Two of the districts that had very high residual values in 1951 (Sukkur and Sahiwal) had become subdued by 1961. Two others (Bannu and Mardan) show high residuals for both years; similarly, Loralai district, with reasonably high values for 1951, had exceptionally high values for 1961. The residuals for these latter three districts indicate a need for special attention from national planners since they demonstrate a sustained pattern of excess fertility. In particular, it would be necessary to know whether excess fertility could be counteracted by improved allocation to clinics in those districts (i.e., has family planning been neglected in those districts?), or whether other factors beyond the scope of family planning

(e.g., the lack of connection between these districts and the rest of the country) has been responsible. Note that a view of the spatial pattern of fertility virtually forces the integration of family planning with broader developmental considerations. Districts with higher than expected fertility may be suffering from a shortage of investment in family planning, or cultural or topographic barriers may have presented the diffusion of lower fertility norms. In either case, tactical-level determinations have to be made (including a consideration of socioeconomic characteristics) and appropriate action taken. Under ideal conditions, the family planning target gives way to a general developmental target.

The overall pattern of high residuals for 1961 is clustered along the Indus River, and extends into the northeast. A clustering of residuals usually indicates that a spatial process affecting the dependent variable has not been taken into account. Here, the shape and extent of the pattern suggests that economic development along the Indus River valley may be responsible, perhaps by inducing the migration of young people to the region. If tactical-level observation confirms the influence of migration or of other influences related to development, then strategic response is implied. Such a response might involve the addition of fertility reduction costs to the total costs of developmental projects. A new irrigation project or factory would include the means of fertility reduction, in much the same way as industrial expansion in the United States has required decision makers to build into their plans the costs of environmental impact. From a family planning perspective, such a step would be based upon the realistic assumption that those who take advantage of the opportunities afforded by economic development tend to have higher fertility and to be receptive to the means of reducing it.

The strategic actions advocated here are based on the notion that it is not practical for Pakistan to focus its attention on a broad target population. The stated goal of the national program, in the period 1965–70, to reach one-quarter of the nation's couples in the reproductive ages (Ministry of Health, 1964) was not only unrealistic but probably grossly inefficient. On the one hand, if it were possible for Pakistan to "reach" quickly a large segment of its population in such a way as to bring about the behavioral change implied by family planning, it is doubtful that there would be a need for a family planning program. On the other hand, attempts to attain this unattainable goal will insure that those couples reached will, in general, be those easiest to reach. It is possible that this "least effort" approach will have the

minimum possible impact on fertility within the potential of available resources. In any case, the approach implied by the goal is not an optimal strategy for Pakistan because the statement of general goals or specific objectives in strictly demographic terms tends to lead to inefficiency. Although it is necessary to know the characteristics of any target and to know what weaponry should be employed, it is also necessary to know where the target is. Some countries have developed sophisticated family planning "weaponry" to the point where the location of the target population is not important; this is not the case in Pakistan. Decision makers there still must decide where each new step in the development of the program will be taken.

IMPROVING THE METHODOLOGY

Although this study has suggested a methodology for approaching the problem of the allocation of family planning resources, it is an embryonic methodology that must be developed. As with any research involving Pakistan fertility, the quality and incompleteness of data limit the conclusions that may be drawn. The eventual publication of complete district-level data for the 1972 census will provide the opportunity for further comparisons and considerations. Even with better data, however, two major improvements are needed: the creation of more reliable fertility surfaces, and improved criteria for the selection of target areas.

The fertility surfaces used in this study were formed without regard for theoretical underpinnings. There is no evidence to suggest that spatial processes affecting fertility either spread by, or are manifest in, regular mathematical surfaces. We do not yet understand fully the mechanism by which fertility change is spread, nor have we good justification for interpolation between control points. With a greater understanding of the role of communication linkages and of the differential tendency of individuals to act upon fertility control information, it will be possible to produce fertility surfaces that more nearly model generating processes. Despite this shortcoming in the surfaces, it is likely that error arising from their creation is no greater than the error implicit in the censuses from which they were derived.

The residuals that have been used to suggest targets for family planning should be weighted in order to allow consideration of other variables. Although decision makers would consider these variables implicitly, their explicit consideration would tend to make planning less dependent upon the expertise of individuals, a crucial factor in a long-range program. Among the variables that should be considered are:

1. The population size of a target district; investment in a larger district would tend to yield a greater net impact on fertility.
2. The distribution of population within a district; it would be more efficient to reach a concentrated population, less efficient to reach scattered rural communities.
3. Barriers to effectiveness; linguistic differences and other cultural factors can raise costs significantly, particularly in attempts to allocate personnel resources.
4. The mobility of the population; a district population that is traditionally mobile (e.g., seasonal wage labor) may be more costly to reach than a sedentary population.

These, and possibly other, factors are desirable additions to the analytic framework, but the cost of collecting the necessary data may exceed the value of any benefit derived. At present, few national planning programs undertake a rational, explicit family planning strategy; even modest improvements in strategy seem certain to improve program efficiency.

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