Numerator Analysis of Fertility Patterns

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IN EPIDEMIOLOGY, as in surveying, triangulation or simultaneous analysis of the several dimensions of a problem is imperative for accurate elucidation of the interrelation between variables.

The most important known determinants of an event must be fixed if we are to study the effects of an unknown factor while varying the intensity of its action. Thus, to study the impact of family planning programs on fertility patterns, the foremost determinants of fertility—age and parity—must be fixed.

For simultaneous consideration of three variables, the grid analysis technique has proved a simple and useful tool (*1*). In attempting to apply this methodology to the study of fertility patterns and family planning programs in developing countries, the need for a further modification and simplication of methodology became apparent (*2*).

Usually, family planning programs would be evaluated by measuring their impact on the birth rate. But, in places where these programs are most needed, such evaluations are least possible. Even if the crude birth rate could be precisely calculated, various factors that influence this rate often make it impossible to interpret minor fluctuations. Therefore, the result would not be an adequate gauge of the effect of family planning programs. Moreover, the lack of numerators and denominators that match in time and place often prevents the calculation of the crude birth rate with a sufficient degree of accuracy for purposes of evaluation. In places where calculation of the crude birth rate is hardly possible, both for lack of an accurate numerator and denominator, it may be impossible to calculate accurate fertility rates by the age of the mother and the order of the birth (parity).

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Age-Specific Parity Ratios

In the absence of adequate routine systems of birth registration and of periodic censuses, analysis of fertility rates specific for age and parity would necessarily depend upon special surveys and censuses to provide matching numerators and denominators. But there are approaches to analysis of the trends in family limitation by age and parity of women which require neither complete reporting of births nor much knowledge of the denominator, that is, of the number of women by age and parity. One such approach, the "numerator analysis" technique, is based on the possibility that we may be able to determine the proportion of first (or first and second) births among all births even where reporting is incomplete and the extent of the incompleteness is unknown (table 1).

Raymond Pearl (*3*) has commented as follows on the relationship between the proportion of first births among all births and the practice of contraception: "Other factors being equal, it is generally true for a given population and time, that a declining crude birth rate has associated with it an increase in the proportionate number of first births to all births. This relationship is to be expected in a population where the practice of contraception is prevalent and increasing, because under such conditions women tend after their first successful pregnancy to have no more children, or only after a greater lapse of issue than would be the case if reproduction were wholly unrestricted. Such procedure naturally tends to weight the births of any particular year unduly heavily with first births."

When only a fraction of the births are being reported, we must assume that a greater proportion of births in the more enlightened families are being reported. But if these families fail to adopt family planning, as would be indicated by an absence of a rise in the proportion of first (or of first and second) births among all births, we can assume that the less enlightened and less accessible families are also not being reached by any program of family planning.

Thus, numerator analysis of fertility patterns may be feasible even in places where the routine system for registration of births is only rudimentary. Of course, this method of age-specific analysis of parity presupposes that the parity is being reported, at least when there is any reporting of births. But, such analysis can also be based on data obtained from clinics or hospitals for any area or any period of time, since we are not matching numerators and denominators.

For purposes of illustration of the method, the age-specific parity ratios in Japan between 1948 and 1963 have been calculated in two different ways—(*a*) according to the percentage of all births accounted for by first and second births and (*b*) by the percentage accounted for by births of third and higher birth orders. These are different ways of presenting the same thing.

Table 2. Percent of live births that were first and second births, by age group of mother, Japan, 1948, 1953, 1958, and 1963

Age of mother (years)	1948 [1]	1953 [1]	1958 [2]	1963 [2]
Less than 20	100	99	100	100
20–24	94	90	96	98
25–29	61	57	76	86
30–34	21	24	41	64
35–39	8	12	22	47
40–44	5	7	13	29
More than 45	7	9	13	23
All ages	52	54	71	83

[1] Birth order is based on the number of previous live and still births.

[2] Birth order is based on the number of previous live births.

SOURCE: Data from Demographic Yearbooks, United Nations, New York.

Table 1. Number of live births by birth order of child and age group of mother, United States, 1965

Birth order	Age group of mother (years)								Total births	Median age	Percent in birth order
	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49			
1	7,434	432,228	515,740	140,368	40,536	16,784	4,098	198	1,157,386	21.4	30.8
2	312	124,356	448,538	229,946	74,092	26,326	6,000	252	909,822	23.7	24.2
3	12	27,602	225,774	228,574	109,996	43,848	9,802	414	646,022	26.5	17.2
4	2	5,272	93,788	152,724	102,938	48,718	11,838	522	415,802	28.6	11.1
5	0	746	35,168	85,028	73,926	41,588	11,464	554	248,474	30.2	6.6
6	0	114	11,730	45,678	48,904	31,072	9,222	512	147,232	31.7	3.9
7	0	34	3,616	23,080	31,346	22,060	7,098	370	87,604	32.7	2.3
8 and over	0	28	1,326	18,652	46,598	51,888	22,006	1,786	142,284	35.4	3.8
Not stated	8	514	1,670	1,682	1,040	624	188	6	5,732	27.0	.2
Total births	7,768	590,894	1,337,350	925,732	529,376	282,908	81,716	4,614	3,760,358	24.8	100.0
Median parity [1]	1.0	1.2	1.8	2.9	3.9	4.6	5.3	6.2	2.3		
Percent in age group	.2	15.7	35.6	24.6	14.1	7.5	2.2	.1	100.0		
Percent first and second births	99.7	94.2	72.1	40.0	21.7	15.2	12.4	9.8	55.0		
Percent third or higher birth order	.3	5.8	27.9	60.0	78.3	84.8	87.6	90.2	45.0		

[1] Birth order is treated as a continuous variable whereby first birth order varies between 0.5 and 1.4, and so forth.

SOURCE: Data from the National Center for Health Statistics, Public Health Service.

A comparison of these age-specific parity ratios with more conventional indicators of fertility or reproduction shows that the trends of the numerator patterns correlate with the trends of the birth rates and fertility rates, at least in Japan (tables 2 and 3). As the fertility rate declined from 107 to 52 per 1,000 women, the percent of live births of third or higher birth order declined from 48 to 17 (table 3).

The parity ratios and birth or fertility rates do not always move together. The validity and potential utility of parity ratios may not depend on their tracking ability or the degree of their correlation with conventional indicators of fertility trends. Birth rates and fertility rates measure the incidence of births, whereas parity ratios indicate the prevalence of families by size and show the extent and timing of reproduction.

Although age-specific parity ratios tell us nothing about the women who are not having babies, the ratios may be particularly appropriate for evaluating the need for, or the results of, family planning programs because the ratios indicate the size of families of the women who are having babies, by age of the mother. Incidently, if we are specifically interested in the size of families per se, we may wish to be more precise and use the number of children living, instead of the number of children born alive, in calculating the prevalence of families by size.

The numerator analysis method is based on the assumption that changes which occur in distributions of the birth order over time are produced largely by changes in reproductive behavior rather than as a consequence of changes in the denominator conditions, for example, the shifting age composition of a population or a changing age at marriage.

For the short run and for national populations, changes in the conditions of the denominator might be ignored. This solution may not apply, however, to special subpopulations in which the changes relate to intermediate variables on which the denominator conditions act selectively.

Table 3. Percent of live births of third or higher birth order, crude birth rates, fertility rates, and gross and net reproduction rates, Japan, 1948, 1953, 1958, and 1963

Year	Percent of live births of third or higher birth order	Crude birth rate per 1,000 population	Fertility rate per 1,000 women aged 10–49	Gross reproduction rate	Net reproduction rate
1948	[1] 48	33. 7	107. 2	2. 11	1. 72
1953	[1] 46	21. 5	69. 0	1. 31	1. 18
1958	[2] 29	18. 1	55. 8	1. 03	. 96
1963	[2] 17	17. 3	52. 1	. 96	. 93

[1] [2] and SOURCE: See corresponding footnotes for table 2.

Table 4. Percent of births that were first births by age group of mother and crude birth rates, United States, 1960–65

Year	Age group of mother (years) [1]								Crude birth rate per 1,000 population
	Less than 20	20–24	25–29	30–34	35–39	40–44	45 and over	All ages	
1960	69	34	13	8	6	5	4	26	23. 7
1961	69	34	13	7	5	5	4	27	23. 3
1962	69	34	13	7	5	4	4	27	22. 4
1963	70	35	13	7	5	4	4	28	21. 7
1964	72	37	14	7	6	5	4	29	21. 0
1965	74	39	15	8	6	5	4	31	19. 4

[1] Based on a 50 percent sample of recorded births, excluding births to women of unknown parity.

SOURCES: Table 1 and data from Demographic Yearbook 1965, United Nations, New York.

For example, if a change in hospital maternity admissions was selective by age, the indicator would be affected independently of any trend of fertility. The effects of any age bias on parity ratios might be eliminated, or at least minimized, by computing parity ratios for specific age groups of mothers. And, of course, fertility patterns and trends made apparent by analyses of hospital data should be confirmed by analyses of data from an independent source, such as from the registration of births or from surveys of fertility, particularly if only a small proportion of infants are delivered in hospitals.

Using the data presented for Japan, members of the Population Council—W. P. Mauldin, K. Kantner, and L. Polissar—independently performed two tests of the stability of parity ratios as an indicator of changing fertility patterns. The purpose of the tests was to determine the robustness of the indicator in the face of certain biases that might affect the tests. In one test, a differential increase in the improvement of birth registration by birth order was assumed. The distortion caused by age-selective misreporting of birth order was incorporated into the second test. According to a personal communication dated August 18, 1967, these three researchers found that, on the basis of the arbitrary values used in these tests, the indicator was only modestly influenced by the test distortions and was reasonably robust relative to the combined effects of both types of error.

Grid presentation of live births in the United States in 1965 by the age and parity of the mother demonstrates how basic data might be presented to facilitate numerator analyses of fertility patterns (table 1). The impact of family planning programs could be indicated by a time series of age-specific parity ratios at given points in time and place, for example, by the proportion of births in a population that are first births (tables 4 and 5).

The age-specific parity ratios for the Ryukyu Islands, as well as for the United States and for Japan, indicate that a similar relationship exists between parity ratios and crude birth rates, or fertility rates, in areas culturally distinct from one another and at different stages of economic and demographic transition. In the United States, as the birth rate declined from 24 to 19 per 1,000 population between 1960 and 1965, the proportion of first births rose

Table 6. Median parity by age group of mother at childbirth, United States, 1935, 1960, and 1965

Age group of mother (years)	1935	1960	1965
10–14	1.0	1.0	1.0
15–19	1.1	1.2	1.2
20–24	1.6	2.0	1.8
25–29	2.4	3.0	2.9
30–34	3.6	3.7	3.9
35–39	5.5	4.3	4.6
40–44	7.5	5.2	5.3
45–49	7.7+	6.2	6.2
All ages	2.2	2.5	2.3

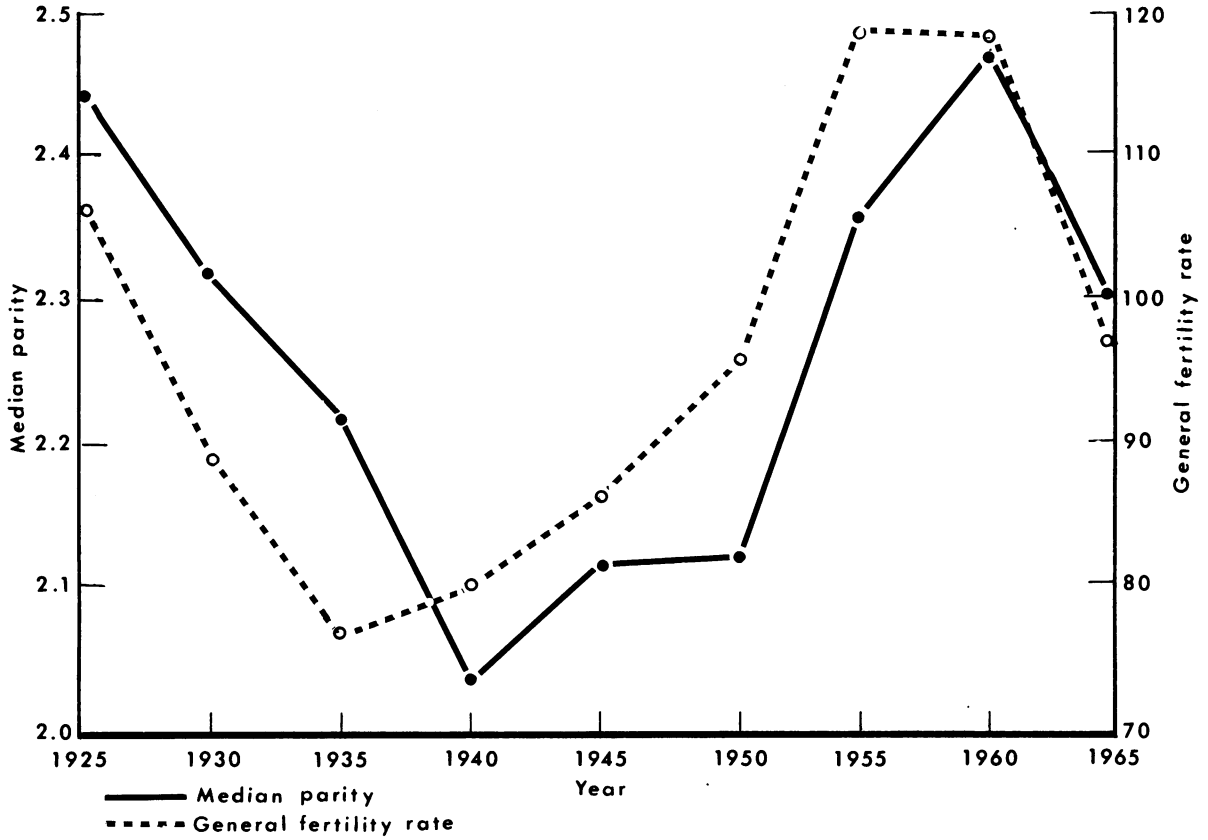
SOURCE: Data from National Center for Health Statistics, Public Health Service, Washington, D.C.

Table 5. Percent of births that were first births by age group of mother and crude birth rates, Ryukyu Islands, 1955–64

Year	Age group of mother (years)								Crude birth rate (per 1,000)
	Less than 20	20–24	25–29	30–34	35–39	40–44	45 and over	All ages	
1955	81	45	12	3	2	2	3	15	31.3
1956	86	44	12	3	2	1	2	16	31.1
1957	84	47	14	4	2	2	4	18	27.8
1958	84	47	16	4	2	2	4	18	28.7
1959	87	49	18	4	2	2	4	19	27.4
1960	91	51	20	6	2	3	5	21	25.0
1961	85	52	22	6	2	2	3	22	25.2
1962	85	53	24	7	3	1	1	23	23.4
1963	83	54	25	8	4	2	5	24	23.7
1964	87	58	26	10	3	2	10	26	21.5

SOURCE: Data from Demographic Yearbook 1965, United Nations, New York.

Figure 1. Median parity and general fertility rates—births per 1,000 women—among women 15–44 years of age, United States, 1925–65



SOURCE: Based on data from National Center for Health Statistics, Public Health Service, and from Bureau of the Census.

Table 7. Median age of mothers at childbirth by live birth order of child, United States, 1935, 1960, and 1965

Live birth order	Median age at childbirth [1] computed from—					
	1935		1960		1965	
	Births	Birth rates	Births	Birth rates	Births	Birth rates
1	22.4	22.6	21.5	21.8	21.4	21.9
2	24.9	25.3	23.9	24.0	23.7	24.2
3	27.1	27.6	26.8	26.6	26.5	27.0
4	28.8	29.3	28.7	28.5	28.6	28.8
5	30.5	31.1	30.2	29.8	30.2	30.3
6	32.4		31.5		31.7	
6 and 7 [2]		33.5		31.6		32.0
7	34.1		32.5		32.7	
8 and over	37.4	37.7	35.2	35.0	35.4	35.1
All birth orders	26.3	26.9	25.5	25.4	24.8	25.8

[1] Computed from numbers of births and birth rates by 5-year age groups of mothers.
[2] Birth orders 6 and 7 are combined because the basic data did not permit separate computation.

SOURCE: Data from National Center for Health Statistics, Public Health Service.

from 26 to 31 percent (table 4). In the Ryukyu Islands, as the birth rate per 1,000 declined from 31 to 22 between 1955 and 1964, the proportion of first births rose from 15 to 26 percent (table 5).

Median Parity by Age and Vice Versa

There are other methods of analyzing parity by age (table 1). For example, we might calculate the average parity of mothers by age and the average age of mothers by parity. But these calculations would require fairly accurate data on age and parity for women with high, as well as with low, parity. The median age of the mother in respect to parity and the median parity by age would be less affected by inaccurate data. Of course the calculation of median parity would require the treatment of parity as a continuous variable whereby first birth order varies between 0.5 and 1.4, and second birth

Table 8. New female beneficiaries of family planning services of Division of Indian Health, Public Health Service, by parity and age group, February–June 1967

Parity	Age group of beneficiaries (years)									Percent in parity group
	15–19	20–24	25–29	30–34	35–39	40–44	45 and over	All ages	Median age	
0	101	42	18	7	2	1	0	171	19. 3	4. 9
1	206	220	90	9	3	0	1	529	21. 3	15. 1
2	69	291	168	56	11	5	4	604	24. 0	17. 2
3	13	195	233	62	17	11	3	534	26. 3	15. 2
4	6	109	226	106	23	23	3	496	27. 9	14. 1
5	2	52	119	115	31	25	3	347	30. 0	9. 9
6	0	8	69	72	43	36	4	232	32. 7	6. 6
7	0	6	43	64	48	18	7	186	33. 4	5. 3
8 and over	0	2	38	109	146	104	14	413	37. 0	11. 8
All parities	397	925	1, 004	600	324	223	39	3, 512	27. 2	100. 0
Median parity	1. 0	2. 2	3. 5	5. 0	7. 2	7. 1	6. 7	3. 3		
Percent in age group	11. 3	26. 3	28. 6	17. 1	9. 2	6. 3	1. 1	100. 0		

SOURCE: Data from Division of Indian Health, Public Health Service.

Table 9. Women accepting intrauterine loop by number of living children and age group, Tiawan, 1965

Number of living children	Age group of loop accepters (years)								Median age	Percent in family size
	Less than 25	25–29	30–34	35–39	40–44	45 and over	Unknown	Total		
0	160	51	12	10	1	0	4	238		0. 2
1	1, 249	746	106	37	12	1	8	2, 159		2. 2
2	3, 174	5, 231	1, 281	289	66	6	59	10, 106	26. 8	10. 2
3	1, 841	10, 198	6, 292	1, 471	278	19	98	20, 197	29. 2	20. 3
4	379	6, 574	11, 308	4, 396	816	52	117	23, 642	32. 1	23. 8
5	58	1, 715	7, 973	6, 243	1, 582	103	83	17, 757	34. 4	17. 9
6	16	338	3, 225	5, 256	2, 027	160	54	11, 076	36. 8	11. 2
7	5	72	860	2, 756	1, 612	146	25	5, 476	38. 2	5. 5
8 and over	0	28	272	1, 532	1, 764	257	15	3, 868	40. 3	3. 9
Unknown	472	1, 239	1, 341	919	397	34	332	4, 734	31. 8	4. 8
Total	7, 354	26, 192	32, 670	22, 909	8, 555	778	795	99, 253	32. 4	100. 0
Median number of living children	2. 1	3. 1	4. 2	5. 3	6. 2	6. 7	4. 0	4. 1		
Percent in age group	7. 4	26. 4	32. 9	23. 1	8. 6	. 8	. 8	100. 0		

SOURCE: Data from Taiwan Population Studies Center, Taichung.

Figure 2. Median parity and number of children ever born per woman 15–44 years of age ever married, United States, 1910–65

[1] The number of children ever born per woman 15–44 years ever married is based on a sample of the decennial censuses of 1910, 1940, 1950, and 1960. In the 1920 and 1930 censuses, comparable questions about children ever born were not asked.

SOURCE: Based on data from National Center for Health Statistics, Public Health Service, and from Bureau of the Census.

order varies from 1.5 to 2.4, and so forth. Such treatment lets the median value approximate the mean. We have used this method of converting birth order to a continuous variable throughout the paper.

In places where adequate data on the age and parity of mothers are available, but matching denominators are lacking, various analyses, such as of the median parity by age and of the median age by parity, might provide some indications of the relative contributions to fertility patterns of temporal and quantitative determinants (fig. 1 and tables 6 and 7).

Comparison of the median age of mothers by live birth order, computed from births and from birth rates (table 7), indicates to what extent the computation of median age by parity might be affected when denominators are lacking to control changes in the age distribution of the denominator population. Apparently, relatively large changes in the age distribution in the denominator population between 1935 and 1965 had relatively little effect on the computation of median age from births.

As might be expected, a comparison of median parity with the general fertility rate indicates that changes in the trends of median parity tend to follow changes in the trends of fertility rates (fig. 1). A measure of prevalence would lag behind a measure of incidence.

Comparison of a time series of the median parity with a time series of another measure of prevalence, such as the number of children ever born per woman 15–44 years of age ever married, indicates that numerators and rates of fertility correlate temporally, as well as quantitatively, when both are measures of prevalence (fig. 2).

Other Numerator Analyses

The numerator analysis technique might be applied to service statistics as well as to vital statistics, and for much the same reason, namely, a lack of matching numerators and denominators. The age and parity of new female beneficiaries of family planning services (table 8) might be compared with the age and parity of mothers at childbirth in a series of hospital deliveries and in a series of birth registrations for the same period and place.

Family planning statistics on the women accepting a specific contraceptive by age and number of living children (table 9) might be compared with similar statistics on birth registrations and hospital deliveries by the age of mother and by the number of children living instead of by the number born alive.

As a parameter, the number of children still living may be more than a satisfactory substitute for the number of children ever born; it might even be preferable. A count of the number of children living presumably would be more reliable than a number based on a woman's recollection of previous pregnancies and their outcome. Moreover, the number of children surviving, rather than ever born, may be the determining factor in a woman's attitudes toward fertility and contraceptive practices.

Furthermore, hospital deliveries might be compared in time and place by the age and parity of the mother and also by her economic status, religion, and race.

Following is a comparison, by age group and race, of the median parity of obstetric patients at 18 hospitals in the United States in 1962:

Age group (years)	*White* ($N=52,840$)	*Nonwhite* ($N=17,044$)
15–19	1. 2	1. 3
20–24	1. 4	2. 4
25–29	2. 3	3. 7
30–34	3. 0	4. 7
35–39	3. 3	5. 3
40–44	3. 9	5. 8
All ages	2. 1	2. 7

SOURCE: Data from Obstetrical Statistical Cooperative, Department of Obstetrics and Gynecology, State University of New York, Brooklyn.

Such comparisons might also be made of the accepters and nonaccepters of postpartum family planning services, as well as of all obstetric patients.

Of course the births by age and parity of the mother can serve as denominators as well as numerators. For example, we would be able to determine neonatal or infant mortality rates specific for age and parity if we could match, say for a month or a year, all reported births and deaths within a registration area having virtually complete reporting of these events. The number of deaths to these births by the age and parity of the mother would then provide numerators specific for age and parity to match the denominators, in this instance, the births by age and parity of the mother over the same period of time.

Conclusions

The validity and utility of the numerator analysis technique remains to be fully explored and exhaustively tested. But the relative abundance of incomplete numerators, for which matching denominators are lacking, suggests that numerator analysis of fertility patterns should be considered as a possible method for measuring the impact of family planning programs. So far, it seems that a change, or a lack of change, in the age-parity-specific fertility patterns for a country or area may indicate the results of, or the need for, family planning programs. Numerator analysis of vital and service statistics should be used in conjunction with whatever other approaches are feasible in the circumstances for evaluating the coverage, effectiveness, and efficiency of such programs.

Summary

When the impact of family planning programs on fertility patterns is being measured, it is essential that age and parity, the two foremost determinants of fertility, be fixed. Usually such programs are evaluated by ascertaining their impact on the birth rate. But a lack in some countries of matching numerators and denominators may make calculation of even crude birth rates impossible, let alone of fertility rates by age and parity. In these circumstances, "numerator analysis" by means of age-parity grids provides an alternative.

The effect of a family planning program upon fertility can be indicated by a time series of age-specific parity ratios, for example, the proportion of births that are first births by age of the

mother. Analyses such as of median parity by age and of median age by parity may reveal the relative contributions to fertility patterns of the spacing of children and of the number that couples desire. The numerator analysis technique can also be applied to service statistics, and its application to these data is appropriate for much the same reason, namely, the lack of matching numerators and denominators.

The technique of numerator analysis is exemplified in age-parity grids showing the U.S. fertility pattern for 1965, the pattern of acceptance of intrauterine devices in Taiwan in 1965, and the pattern of acceptance among American Indians of family planning services offered by the Division of Indian Health of the Public Health Service in 1967. Illustrative time series of age-specific parity ratios and of median parity by age are also included.

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Gaseous Tracer System

Scientists of the Public Health Service's National Center for Air Pollution Control have developed a gaseous tracer system so sensitive that the gas used can be detected miles from the source in concentrations of 1 part per 100 trillion parts of air.

The gas, nontoxic sulfur hexafluoride, can be released in a known concentration and measured downwind to determine how much it has been diluted by the atmosphere. Successful experiments have been conducted over a range of up to 70 miles from the source.

Scientists of the National Center, by using the gaseous tracer system, expect to expand present knowledge of the dispersion and dilution forces of the atmosphere on gaseous pollution transported from one city to another.

The new technique can be used to measure dispersal effectiveness of tall smokestacks by releasing the tracer gas from the stack. Air pollution control authorities may also be able to use the method to show transport of pollution across jurisdictional lines, either interstate or intrastate. By releasing a known trace material such as sulfur hexafluoride that is usually absent in the atmosphere and then sampling and capturing it at another point downwind, they can obtain information on the transportation of harmful pollutants in the air.