ARTIKLER 121

ON THE CAUSES AND EFFECTS OF NON—RESPONSE. NORWEGIAN EXPERIENCES

By/Av Ib Thomsen and Erling Siring

OM ÅRSAKENE TIL OG VIRKNINGENE AV FRAFALL. ERFARINGER FRA NORGE

OSLO 1980

STATISTISK SENTRALBYRÅ

ARTIKLER FRA STATISTISK SENTRALBYRÅ NR. 121

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ISBN 82-537-1107-7
ISSN 0085-431x

PREFACE

During the last ten years non-response has grown into one of the most serious problems in survey work. This article describes the work done by the Central Bureau of Statistics of Norway to gain insight into the effects of non-response, and the efforts made to keep response rates at maximal level through effective operational procedures.

The paper was written at the invitation of National Research Council in USA.

Central Bureau of Statistics, Oslo, 11 March 1980

Petter Jakob Bjerve

FORORD

Gjennom de siste ti år har frafall i Byråets utvalgsundersøkelser blitt et stadig større problem. Denne artikkelen beskriver hva som er gjort for å få innsikt i virkningene av frafall, og redusere frafallet til et minimum.

Artikkelen er på engelsk, fordi den ble skrevet på anmodning av National Research Council i USA.

Statistisk Sentralbyrå, Oslo, 11. mars 1980

Petter Jakob Bjerve

CONTENTS

Explanation of Symbols in Tables

. Category not applicable

1. INTRODUCTION

During the last ten years response rates have been decreasing in the majority of sample surveys performed by the Central Bureau of Statistics of Norway. In an attempt to stop this trend, and to reduce the effects of non-response on the results, a number of studies have been made to gain insight into the reasons for non-response, and its effect on the results published from a survey.

In this paper we shall present some of the results from these studies and the conclusions we have drawn from them.

After having given a short description of the declining response rates in Chapter 2, we present a strategy for the analysis of non-response data in Chapter 3. In this chapter we are primarily concerned with factors that effects non-response. We also present results from studies aiming at estimating the effect of each of the factors on the non-response rate.

In Chapter 4 the effects of non-response on the results are studied. In some surveys information about non-respondents is collected from other sources and compared with the results in the sample. In most practical cases such information is not available, and we therefore describe two methods we often use to analyze the effects of non-response within the sampled data. We also make an attempt to study the effect of non-response when the aim is to analyze the relationship between two and three variables.

In Chapter 5 we present two examples on the use of poststratification to reduce the effects of non-response. In one of the examples the maximum reduction of the bias is estimated, and in the second example we demonstrate that the bias is reduced with a little more than 70 per cent by poststratification.

In Chapter 6 we present a probabilistic model for non-response. The model is newly developed in connection with the Norwegian Fertility Survey, where it is used to study the reduction of the mean square as a function of the number of call-backs. In addition, the model is used to construct a new adjustment for non-response. The model seems very promising in connection with the Norwegian Fertility Survey, but it should be applied to several other surveys before one can give an evaluation of the appropriateness of the model in general.

2. DECLINING RESPONSE RATES

Non-response occurs due to operational difficulties, time and cost restraints, a lack of co-operation from respondents, the inability or unwillingness of interviewers to track down missing respondents, or for some other reason. The non-response rate is often used as a measure of the severity of non-response problems, and it is calculated as the percentage of non-respondent, eligible households or persons out of all sampled households or persons. In this section we shall present a number of examples showing how response rates have changed over the last 10-15 years.

In general it is difficult to compare response rates from one type of survey to another, because target population, collection method, work load, and other factors affecting non-response vary between surveys. We have selected for presentation in the following tables surveys for which response rates are comparable. Information on the reason for non-response is also presented when available.

Since 1969 a number of surveys concerning political opinion have been performed. Table 1 presents some response rates pertaining to these surveys.

Table 1. Non-response rates by components in some political opinion surveys

Survey	Year	Size of sample. Persons	Non-response rates. Percentages	Reasons for non-response. Percentages			
				Total	Refusals	Not at home	Other
Election survey 1969	1969	2 999[1)]	9.9(15.6)	100	..	..	..
Municipal elections survey 1969 .	1971	3 064	12.6	100	..	..	..
The advisory referendum on Norway's accession to the ECE	1972	1 450	19.2	100	..	..	..
Election survey 1973	1973	2 973	19.4	100	46	..	..
Election survey 1977	1977	2 207	21.6	100	44	33	24

1) 170 of the selected persons were substituted.

Even if the substituted persons in 1969 are categorized as non-response, it is obvious from table 1 that response rates have declined significantly since 1969.

In table 2 below, non-response rates pertaining family expenditure surveys are given.

Table 2. Non-response rates by components in the family expenditure surveys since 1967

Year	Size of sample. Households	Non-response rates. Percentages	Reasons for non-response. Percentages			
			Total	Refusals	Not at home	Other
1967	5 008	21.8	100	..	..	..
1973	4 707	28.6	100	39	..	..
1974	1 388	32.6	100	46	19	35
1975	1 648	32.3	100	42	22	36
1976	1 707	31.0	100	44	25	31
1977	1 419	30.0	100	44	27	29

In 1967 the respondent burden was larger than in the following years in that respondents were asked to make a complete record of all expenditures during one month, while the period was reduced to two weeks in the later surveys. In spite of this fact the non-response rate was smaller in 1967 than it is today. Since 1974 nearly fifty per cent of non-response has been due to refusals and about one third to other reasons. The percentages of persons not-at-home shows a small increase.

In 1967 and 1973 surveys were made to study housing conditions in Norway. The two surveys are almost identical. In table 3 non-response rates are presented for these surveys.

Table 3. Non-response rates by components in the surveys of housing conditions

Year	Size of sample	Non-response rates. Percentages	Reasons for non-response. Percentages		
			Total	Refusals	Other
1967	3 126[1)]	9.9	100	47	53
1973	3 773	22.9	100	55	45

1) 144 of the selected households were substituted.

As tables 1 and 2, table 3 shows an increase in non-response rates even when the substituted households are included as non-response. Also table 3 seems to indicate a larger proportion of refusals in 1973 than in 1967. This, however, is not observed in other surveys.

Since 1972 labour force surveys have been performed quarterly. Table 4 presents some non-response rates pertaining to these surveys. Two rates are given; non-response in first stages, which is the amount of non-response after terminating the ordinary data collection. In the second stage extra call-backs are done by telephone and by specially trained interviewers to reduce non-response. The rates of non-response after this collection are called final non-response rates in table 4.

Table 4. Non-response rates by components in the labour force surveys

	Size of sample	Non-response rates in first stage. Percentages	Final non-response rates. Percentages	Reasons for non-response. Percentages			
				Total	Refusals	Not at home	Others
2. quarter 1972	11 206	8.4	7.3	100	53	39	8
3. " 1972	11 180	9.5	8.2	100	45	31	24
4. " 1972	11 039	8.8	7.8	100	..	..	..
1. quarter 1973	10 715	8.3	7.2	100	..	..	..
2. " 1973	10 886	10.5	9.5	100	..	..	..
3. " 1973	11 184	10.6	9.7	100	..	..	..
4. " 1973	11 115	10.9	8.6	100	..	..	..
1. quarter 1974	10 846	9.5	7.2	100	48	42	10
2. " 1974	11 183	10.6	8.8	100	41	42	17
3. " 1974	11 512	8.0	5.6	100	44	45	11
4. " 1974	11 422	9.2	7.3	100	41	36	23
1. quarter 1975	14 153	12.6	8.3	100	48	35	17
2. " 1975	11 921	11.1	7.4	100	45	43	12
3. " 1975	11 727	12.1	8.5	100	46	42	12
4. " 1975	11 866	12.2	7.5	100	42	35	23
1. quarter 1976	11 704	15.0	10.4	100	50	30	20
2. " 1976	11 532	14.5	9.9	100	45	38	17
3. " 1976	11 418	12.8	9.1	100	47	38	15
4. " 1976	11 309	16.5	9.8	100	45	37	18

(cont.)

Table 4 (cont.). Non-response rates by components in the labour force surveys

	Size of sample	Non-response rates in first stage. Percentages	Final non-response rates. Percentages	Reasons for non-response. Percentages			
				Total	Refusals	Not at home	Others
1. quarter 1977	11 401	16.7	12.9	100	41	37	22
2. " 1977	11 465	14.1	10.4	100	47	37	16
3. " 1977	11 429	14.6	10.3	100	45	38	17
4. " 1977	11 273	14.7	10.4	100	46	28	26
1. quarter 1978	11 468	17.5	13.1	100	42	36	22
2. " 1978	11 753	16.4	11.9	100	45	42	13
3. " 1978	11 649	13.6	8.8	100	45	42	13
4. " 1978	11 507	13.3	9.3	100	44	37	19
1. quarter 1979	11 731	14.0	10.7	100	48	39	12

The final non-response rates have increased from about 8 per cent in 1972 and 1973 to about 11 per cent today. If extra call-backs had not been made the increase would have been from about 9 per cent in 1972 to about 14 per cent today. Again refusals amounts to little less than fifty per cent of the total non-response.

It is seen from the tables above that non-response rates are much smaller in the labour force surveys than in other surveys. This, we believe, is due to the nature of the surveys, and the questionnaire, which makes it possible to use proxy procedures, a method which is not used in connection with most other surveys.

Other surveys show the same trends as those seen in tables 1-4 above. We shall summarize the findings in the following points.

(i) Completion rates show a serious decline during the last ten years in most interview surveys done by the Central Bureau of Statistics of Norway.

(ii) Refusals account for approximately fifty per cent of non-response, independent of completion rates.

(iii) If no extra efforts had been made to increase completion rates, the decline in response rates would have been larger than that actually observed.

A number of experiments have been conducted to reduce or reverse the trend towards declining response rate. Such experiments include extensive use of telephone, call-backs by specially trained interviewers, writing letters to refusals to explain the goals of the survey and how important it is that they co-operate, etc. Some of these experiments have produced an increase in the response rate, but they have given very little insight into the reasons why completion rates decline.

Such intensive follow-up of non-respondents leads to a considerable increase in costs, and at present we are uncertain as to whether this increase in costs can be justified in terms of the amount of additional information collected. One way to study this problem is suggested in chapter 6.

3. FACTORS EFFECTING NON-RESPONSE

3.1. Strategies for the analysis of non-response data

To give a complete analysis of which factors affect non-response, and measure their relative contribution to the non-response rates, is a very complex task. For example, non-response rates depend on factors like

a. Contents of survey
b. Data collection methods
c. Attitudes among respondents

The two first factors may be partly controlled by the statistical organization, while the last factor is only indirectly influenced by decisions made by persons responsible for the survey operations.

Nevertheless, in order to bring some structure into the analysis, it is convenient to divide the variables involved into three groups:

a) The dependent variable, non-response.

b) Indirect controlable variables, which are supposed to have an effect on non-response rates, but are only indirect influenced by decisions made by the survey maker.

c) Controlable variables over which the survey maker has more (or less) direct control, for example, selection and training of interviewers, collection methods, etc.

The distinction between category b) and c) can often cause problems, but we believe that the classification used in figure 1 is useful in many interview surveys.

FIGURE 1. A FRAMEWORK FOR THE ANALYSIS OF NON—RESPONSE DATA

CONTROLABLE VARIABLES

- Selection and training of interviewers
- General working conditions for interviewers. Terms of employments
- Use of introduction letters
- Use of incentives
- Use of proxi-interviews
- Public relations
- General instructions
- Respondent burden
- Number of visits per respondent

INDIRECT CONTROLABLE VARIABLES

- Qualifications of interviewers
- Motivation of interviewers
- Availability of respondents
- Motivation of respondents

DEPENDENT VARIABLES

- Total non-response rates
- Refusals
- Temporarely absent
- Not—at—homes
- Other non-response

In most practical cases it is difficult to measure how the controlable variables affect the indirect controlable variables, primarily because it is difficult to measure most of the indirect controlable variables. We believe, however, that there are important conceptual differences between the two kinds of variables, which makes it useful to distinguish between them.

Below we shall give a description of what is done in Norway to estimate the effects of the controlable variables upon the dependent variables. In most cases we have estimated the marginal or partial effects of each of the controlable variables on response rates, while studies concerning the simultaneous effects of the controlable variables are lacking, due to the practical difficulties involved in doing such studies.

3.2. Selection and training of interviewers

When an interviewer is needed in an area, advertisements are published in the local papers. Every person responding to this advertisement receives a letter in return, in which is enclosed some information about the Central Bureau of Statistics in general, and more specific information concerning the Interview Survey Division. To test whether this information is understood correctly, the person is asked to work out some problems, and the answers are returned to the central staff. Based on the outcome of this test, a second instruction letter with problems to be solved is issued. This procedure is repeated three times before the central staff makes its final choice of interviewer. Shortly after a person is hired as interviewer, he or she is requested to participate in a three days introductory course. The total costs of appointing an interviewer and give him or her the basic training amounts to some N.kr 4 500,- (about US $ 900-).

In general, any interviewer can be assigned to any kind of survey. In connection with the Norwegian Fertility Survey, however, it was decided to make a selection of interviewers. Only female interviewers were assigned to this survey.

3.2.1. Interviewer profile

It seems natural to expect that the interviewers' personal characteristics have an influence on the quality of the results obtained. We know that the sex of the interviewer has a significant influence on the answers to some questions, but when it comes to non-response rates, sex does not seem to have any effect.

In table 5 is given the age and sex distribution of the interviewers.

Table 5. Interviewers by age and sex. Percentages

Age	Total	Males	Females
Total	100	39	61
22 - 29	7	4	3
30 - 39	27	7	20
40 - 49	22	8	14
50 - 59	30	11	19
60 - 69	12	7	5
70 - 77	2	2	-

To test whether the interviewers' personal characteristics, together with such factors as experience, results on the tests in the introductionary letters, turn-over, and size of assignment influence the response rates, a multiple, linear regression was done in connection with the Election Survey 1977. As independent variables were used the size of assignment, years of experience, age, sex, and the number of errors in the test. None of the coefficients were significant. The variable that was closest to be significant was the size of assignment, indicating a small negative correlation between total response rate and size of assignment. Similar results are reported in Platek (1977).

A type of study that should be done is to find whether an interviewer's personal characteristics in conjunction with the personal characteristics of the respondents assigned to this interviewer lead to an interaction effect influencing response rates.

3.3. General working conditions for interviewers

In addition to factors like recruitment and training of interviewers, other factors like load of work, terms of employment, co-operation between the interviewer and the central staff are important for the efficiency of interviewers.

The structure and work-load of interviewers in Norway have changed very little over time. Due to reasons like the low density of the population, the number of interviewers is relatively high compared with for instance Sweden, and therefore the work-load is relatively small, around 200 hours per year. We believe that a reduction of the number of interviewers which would lead to an increase in work-load, would have a positive effect on the efficiency of the interviewers, but due to an expected increase in travelling expenses, this development has been postponed until more studies are done in this area.

3.4. Respondent burden

One should expect that factors like length of questionnaire or interview, amount of work required to fill out the questionnaire, amount of details required, sensitivity of the subject, etc., affect respondent burden, and thereby non-response. However, very few results exist in Norway to support this hypothesis. On the contrary, it seems that for instance amount of work required to fill out the questionnaire has very moderate effect on response rates.

In connection with the Family Expenditure Survey 1973, a pretest was designed in order to find possible effect of respondent burden upon non-response. The sample was divided into three subsamples. In one of the samples households were asked to make a record of all expenditures during two weeks, while the period was three and four weeks in the two other subsamples. Results of this test are presented in table 6 below.

Table 6. Non-response rates in three subsamples. Percentages

	Total	2 weeks	3 weeks	4 weeks
Non-response rates ...	47.1	47.1	41.6	51.7

Refusals rate was relatively largest for households recording expenditures during a two-week period. This, together with the results in table 6, give little evidence to the hypothesis that response rate is affected by the amount of work required to fill out the questionnaire. Similar results are found in connection with a Norwegian time use survey.

3.5. Use of other means to increase response rates

The most common and successful method for reducing the non-response rate is to make several attempts to contact the non-respondents. Particularly the proportion of not-at-homes is reduced significantly, but often even the refusal rate can be reduced by making new attempts to obtain responses, in particular if specially trained interviewers are used. This subject has been treated in many articles. Zarkovich (1963). In chapter 6 we shall treat one important problem in connection with call-backs, namely the optimal allocation of resources between the initial sample and the efforts to reduce non-response by call-backs. There we present a method which can be used to find an "optimal" solution to this problem.

The effect of incentives on the response rates has been studied in some pretests, but the results from these studies have not given any clear indications of the effectiveness of response incentives in terms of higher response rates. However, there seems to be a positive effect in terms of the interviewers' attitudes towards their own work.

Two of the most important factors affecting non-response are the attitude of the general public towards the usefulness of the surveys and the ability of the statistical office to keep selected information confidential. It is therefore important to inform the general public about how the results from the different surveys are applied by governmental and other organizations, and what is done to improve confidentiality safeguards and computer security within the statistical office. To give quantitative measures of the efficiency of such activities is, however, very difficult.

4. NON-RESPONSE EFFECTS ON SURVEY RESULTS

4.1. Introduction

In the preceding chapters we have been concerned with factors affecting response rates. In this chapter we shall discuss an even more complex problem, namely the effects non-response have on the results from a survey. We shall first present some examples in which information about non-respondents is collected from other sources. Cases where this is possible are rare in practice, even in countries with good registers, like the Scandinavian countries. Therefore, we shall suggest two methods by which the effects of non-response can be analyzed within the sampled data. One of the methods, which is widely used, consists of comparing the distribution of one or two variables in the sample with that or those in the population when available. The second method, which only has received little attention in the sampling literature, consists of making separate analysis of data collected on the first call, the second call, etc. By studying the differences between the results from such analysis, one can often gain considerable insight into the effects of non-response. In chapter 6 we formalize this approach into a probabilistic model for non-response.

4.2. Use of alternative data sources for determining effects of non-response

In Norway a number of registers are available, which makes it possible in some cases to obtain information on variables concerning non-responses. This possibility has only been used in a few cases due to costly data processing. In the future with more efficient data processing systems, we expect to conduct a number of studies using register-data to determine the effects of non-response. In this section we shall give some examples of such studies.

4.2.1. Some effects of non-response in the Norwegian Election Survey 1969

In 1969 the Central Bureau of Statistics conducted an interview survey in order to study the relationship between voting behaviour and other variables, such as sex, age, income, education, and occupation. After three calls followed by a mail survey among persons not reached by the interviewer, non-response was 9.9 per cent. The sample size was 2,999 persons.

In the voting register it is possible to find out whether a person voted or not in the election. It is therefore possible to find the rate of voting among non-respondents and compare it with that of the respondents. In table 7 we present the results from such a comparison. Thomsen (1971).

Table 7. Rate of voting among non-respondents and respondents by age.

	All ages	Age				
		20-24	25-29	30-49	50-69	70-79
Rate of voting in the non-response	71	59.0	55.6	72.4	78.3	73.5
Rate of voting in the selected sample	88	81.0	84.0	90.0	91.0	84.0

From table 7 it is seen that the percentage of voters is smaller among non-respondents than in the whole sample and that the difference is bigger among young people than among older people.

In an attempt to study why the rate of voting was lower among non-respondents than in the selected sample, the rate of voting was found for three different groups of non-respondents according to the reason for non-response. Among refusals the rate of voting was 81 per cent, while it was 65.1 per cent and 55.1 per cent among not-at-homes and mentally or physically ill persons, respectively. The interesting finding here is that the voting rate among refusals is close to the voting rate in the population. This means that the non-response bias is primarily due to the not-at-homes and mentally or physically ill persons in the non-response. A similar result is found in the next section.

4.2.2. Some effects of non-response in the Fertility Survey

In 1977 a fertility survey was performed in Norway. A sample of 5,047 women between 18 and 44 years of age was selected from the central register of persons. To reduce the non-response rate to a minimum it was decided to make up to 8 calls. After this phase of collection, specially trained interviewers were used in an attempt to further reduce non-response. After terminating the first phase in the data collection, the response-rate was 76 per cent. The final response-rate was 82 per cent.

In order to evaluate the effects of non-response, information concerning number of live births and income for non-respondents was found in administrative registers.

In table 8 the mean number of births per woman in the non-response is presented for three age groups and compared with the same means among respondents.

Table 8. Fertility in the response and non-response by age

	All ages	Age		
		18-24	25-34	35-44
Mean number of live births among respondents	1.57	0.40	1.68	2.55
Mean number of live births among non-respondents	1.19	0.26	1.21	2.10

From table 8 is seen that fertility is higher among respondents than among non-respondents in all age groups. This, we believe, is due to the fact that women with children are more available for interviews than women without children. Among refusals the mean number of live births is 1.43. As was the case with voting rate, fertility among refusals seems to be closer to the fertility in the population than fertility within the rest of the non-response.

In table 9 the mean income among non-respondents is compared with that among respondents.

Table 9. Mean income in the response and non-response by age. N.kr. 100.00

	All ages	Age		
		18-24	25-34	35-44
Mean income among respondents	677.3	340.4	757.8	888.8
Mean income among non-respondents	581.7	272.4	612.0	862.2

It is seen in table 9 that income among non-respondents is lower than income among respondents, a finding for which we do not have any good explanation. If we again divide non-response into two groups, "refusals" and "others", we find that mean income among refusals is 100 N.kr. 716.1, while the same figure for others is 100 N.kr. 406.5. As was the case concerning fertility, refusals are more like the population in income than other non-respondents.

We have presented three examples in which refusals seem to be more like the population than the rest of the non-respondents. Further research is planned to test this important and for many variables reasonable hypothesis, as it is of great practical interest. See also chapter 6.

4.3. Indirect measurement of the effects of non-response

It is seldom that information concerning non-respondents can be found in existing registers, and therefore other techniques are usually used to gain insight into the effects of non-response upon the results from a survey. The simplest and most commonly used method, is to look at the age and sex distributions in the sample and compare these with distributions for the non-respondents. In addition, one can estimate the correlation between the study variable and sex and/or age in the sample, and thereby estimate the effect of non-response by assuming that the correlation among non-respondents is the same as that found in the sample.

In the rest of this chapter, we shall describe another method which, in our opinion, can provide insight into the effects of non-response and also lead to good weighting procedures to reduce the effects of non-response. The method consists in conducting separate analysis on data collected in the first call, the second call, the third call, etc. The method has the advantage that it can give insight not only into the effect of non-response when the aim is to estimate a mean in the population, but also when the aim is to estimate relationships between two

FIGURE 2. MEAN NUMBER OF LIVE BIRTHS BY AGE GROUPS AND NUMBER OF CALLS

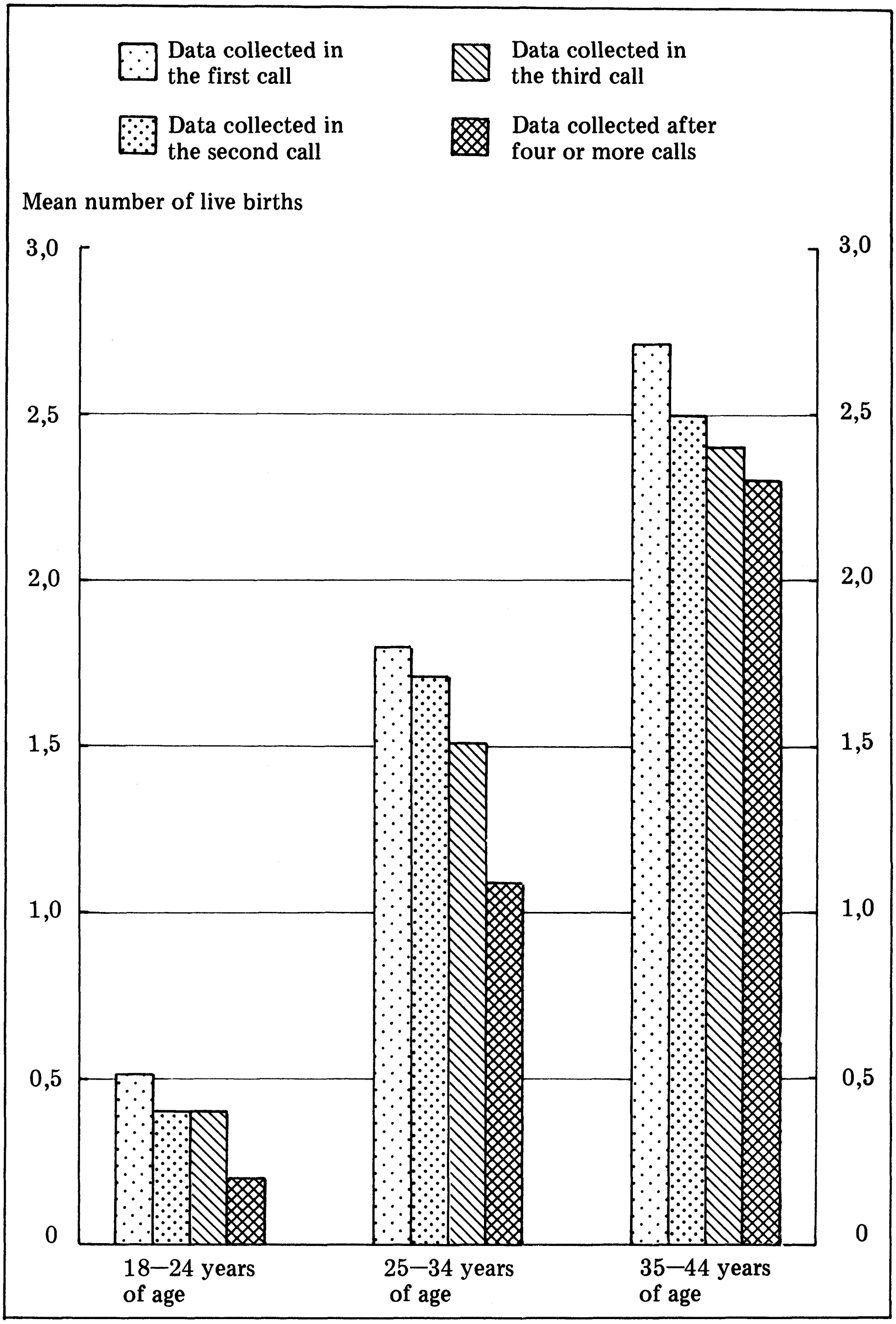
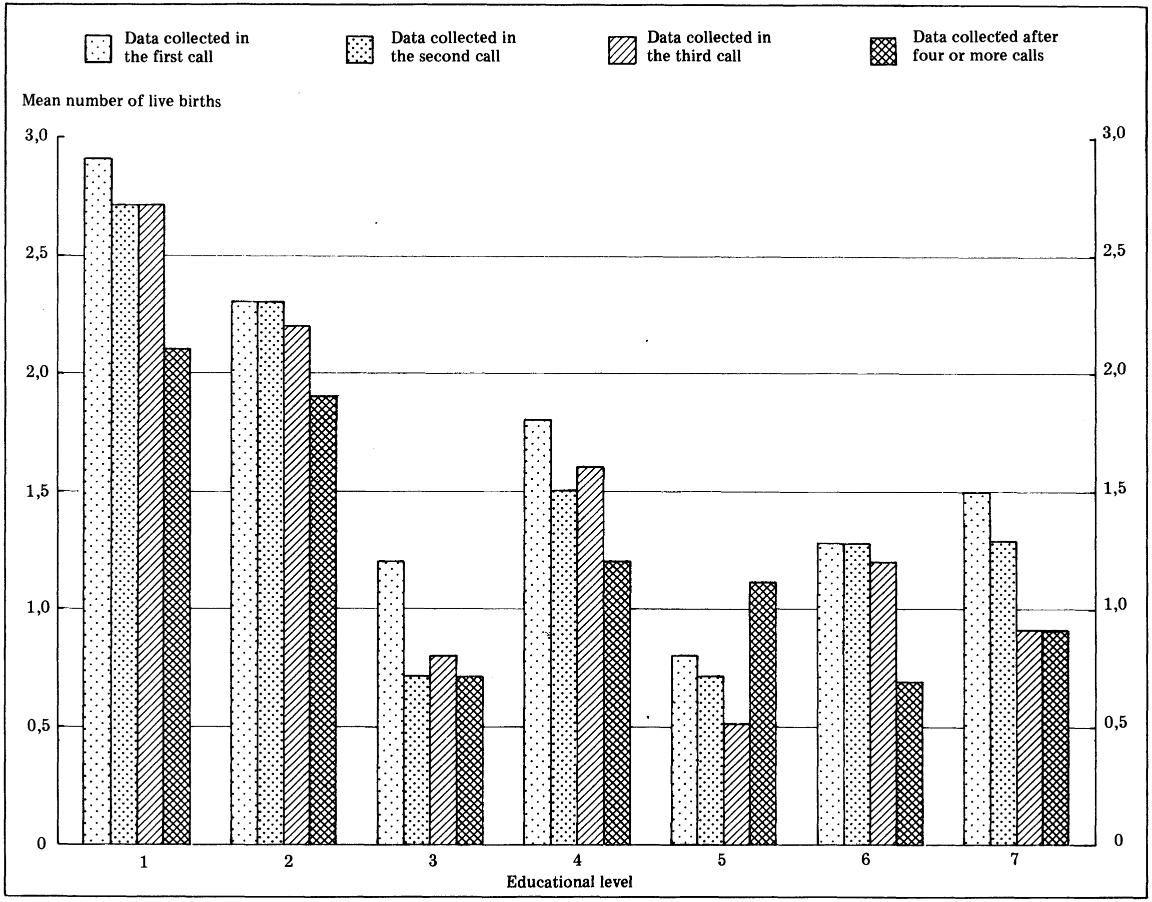


FIGURE 3. MEAN NUMBER OF LIVE BIRTHS BY EDUCATION GROUPS AND NUMBER OF CALLS



or more variables.

In table 10 below data from the Norwegian Fertility Survey are presented. The average number of live births is given by the number of calls.

Table 10. Mean number of live births per woman by the number of calls

	Number of calls							
	1	2	3	4	5	6	7	8
Mean number of live births per woman	1.84	1.56	1.47	1.30	1.28	1.08	0.85	0.75

It is seen that the mean declines substantially as the number of calls increases. This, we believe, is due to the fact that women with children are more available for interview than women without children. This also seems to indicate that the mean number of live births is smaller in the non-response than that observed among the respondents. We shall return to this problem in chapter 6.

4.4. The effect of non-response on multivariate analysis

Very few examples exist in which the effect of non-response on the relationship between two or more variables is studied. In this section we will look at the relationships between fertility (measured by mean number of live births per woman), and age[1)] and education. In order to study the effect of non-response we shall conduct separate analysis for data collected after one call, data collected on the second call, etc.

In fig. 2, an attempt is made to study the effect of non-response on the relationship between age and fertility. Within each age group it is seen that fertility declines when the number of calls increases, a result we found for the whole sample in table 10. The difference in fertility between age groups, however, seems to be independent of the number of calls. This, we find encouraging, as it seems to indicate that the relationship between age and fertility is less affected by non-response than fertility itself.

1) As is well known the effect of age can not be estimated from a single survey. What in this section is called "effect of age" is a combination of age, cohort, and periode effect.

In fig. 3 a similar study is made concerning the relationship between education and fertility. The respondents are classified into one of seven groups by their highest completed education. These groups are:

Group 1: Primary school, lower stage
Group 2: Continuation school
Group 3: Education at second level, first stage
Group 4: Education at second level, second stage I
Group 5: Secondary general school, upper stage
Group 6: Education at second level, second stage II
Group 7: Education at third level

Fig. 3 seems to indicate that also the relationship between education and fertility is less affected by non-response than fertility itself.

To pursue this point a little further, we shall study the simultaneous relationship between fertility, age and education, and see how this analysis is affected by non-response. The technique we shall use is standardization as suggested in Pullman (1978).

Before doing the analysis we shall give a short description of the model and the estimation methods applied.

Suppose that we are interested in the relationship between fertility, y (measured as the number of live births) and explanatory variables education, x_1, and age, x_2. We also assume that, measured in a suitable way, the relationship is linear.

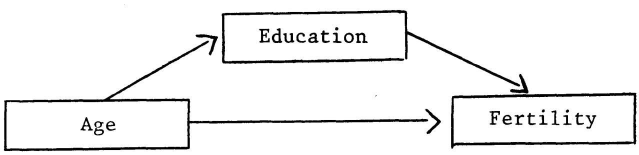
$$(4.1) \qquad y = b_1x_1 + b_2x_2 + c_0 + \text{residual}$$

Between age and education we also assume a linear relationship

$$(4.2) \qquad x_1 = b_{12}x_2 + c_1 + \text{residual.}$$

The equations (4.1) and (4.2) now define a causal chain. Under our assumptions the coefficients can all be estimated by means of ordinary least squares.

The model is usually diagrammed as follows:



In the Fertility Survey both explanatory variables are measured as ordinal variables, and are therefore transformed into dummy variables. In principle, this does not change the analysis, but the ordinary least squares estimation method is identical with a technique known as standardization. An important advantage with this technique is that calculations can be done directly on the basis of tables like the next one. Such tables (based on the whole sample) are likely to be published in the report from the survey.

In order to get an idea of what effect non-responses have on such an analysis we shall estimate the direct and indirect effects of age on fertility for data collected in the first call. The same analysis is repeated for data collected in the second call, the third call, the fourth and later calls, respectively.

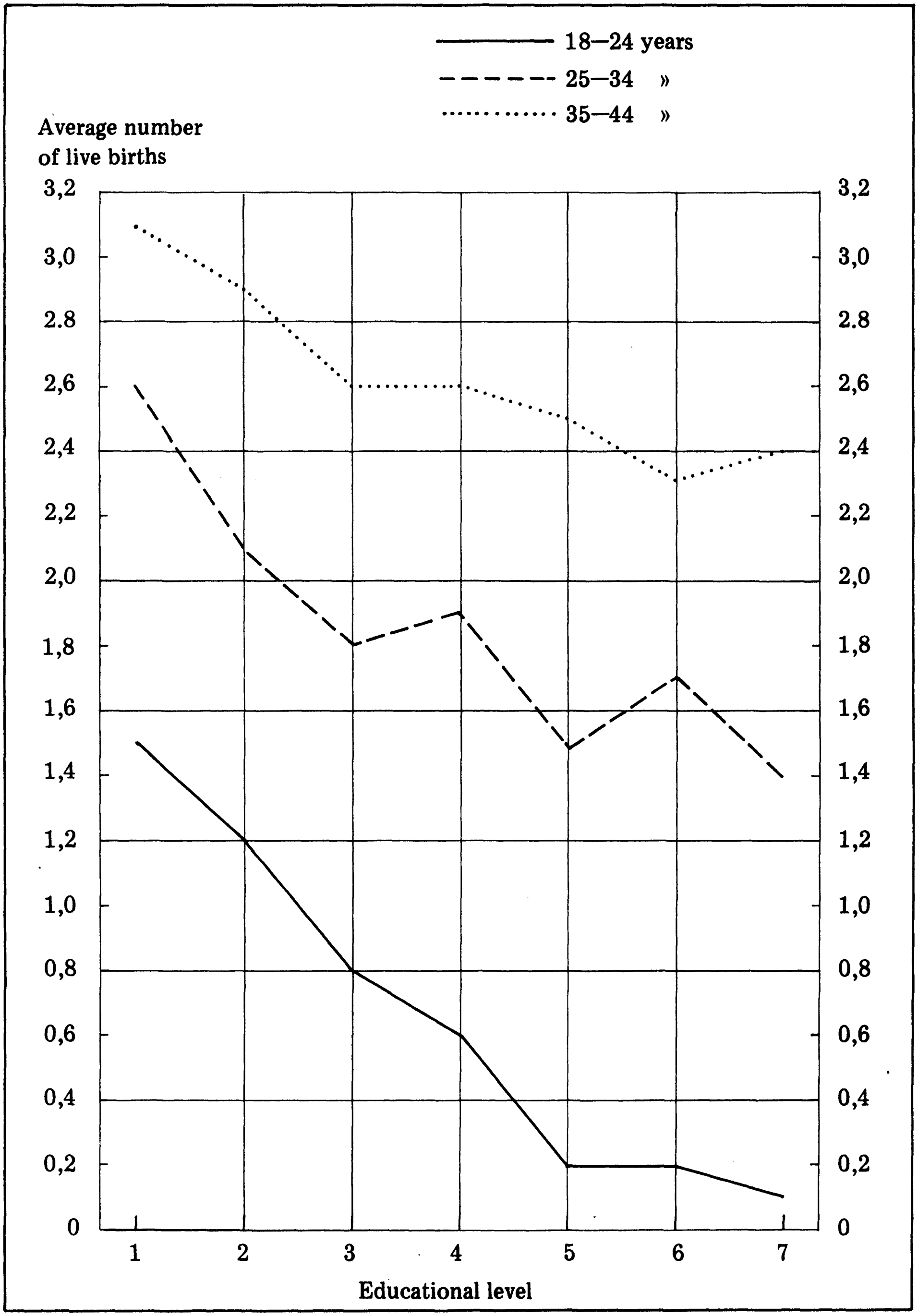
The first step is to check for interaction between age and education in their effect on the dependent variable, fertility. Fig. 4 shows graphically how fertility decreases when educational level increases, in all three age groups. Even though the lines are not exactly parallel, the interaction between age and education in their effect on fertility seems negligible, and standardization is appropriate for these data. (A formal test should be applied, but we shall omit such a test here.)

Table 11. Mean number of live births by age and education level

Age	Total	Educational level							Number of cases
		1	2	3	4	5	6	7	
Total	1.8	3.0	2.3	1.2	1.8	0.9	1.4	1.7	1 478
18 - 24 years	0.5	1.5	1.2	0.8	0.6	0.2	0.2	0.1	339
25 - 34 "	1.9	2.6	2.1	1.8	2.0	1.3	1.7	1.5	667
35 - 44 "	2.7	3.2	2.9	2.6	2.5	2.5	2.3	2.5	472
Number of cases		121	189	98	678	97	94	201	

In table 11 the mean number of live births by age and education level is presented. Only data collected at the first call are used. We shall define the total effect of a variable as the deviation of the marginal category specific mean from the overall mean.

FIGURE 4. MEAN NUMBER OF LIVE BIRTHS BY AGE AND EDUCATION LEVEL



For education we find from table 11 the following marginal means and total effects:

	Educational level						
	1	2	3	4	5	6	7
Mean number of live births	3.0	2.3	1.2	1.8	0.9	1.4	1.7
Total effect of education	1.2	0.5	-0.6	0.0	-0.9	-0.4	-0.1

In other words, a woman in education category 1 will have (on the average) 1.2 more children than the sample mean, and so on.

Similarly for age categories we find the following results:

	Age category		
	18-24	25-34	35-44
Mean number of live births	0.5	1.9	2.7
Total effect of age .	-1.3	0.1	0.9

Marginal effects of variables are in this case (as in many others) misleading. In our model the marginal effects of education are due to two effects, the net effect of education, and the sporious effect of age on education and fertility.

To estimate the net effect of education, one possibility is to control, or "hold constant" the age variable by standardization. (This technique is identical with path analysis with dummy-variables.) That is, the overall distribution of age is applied within each education group.

The standardized mean in the first educational category, for example, will be (1.5 x 339 + 2.6 x 667 + 3.2 x 472)/1 478. The standardized mean numbers of live births for all educational levels are as follows:

	Educational level						
	1	2	3	4	5	6	7
Mean number of live births standardized for age	2.5	2.1	1.8	1.8	1.4	1.5	1.5

The weighted average of the standardized means is 1.7. The deviations of the standardized means from this mean may be interpreted as the net effect of a given level of education on the mean number of live births, when age has been controlled (Pullman (1978)). The deviations are as follows:

	Educational level						
	1	2	3	4	5	6	7
Net effect of education	0.7	0.3	0.0	0.0	-0.4	-0.3	-0.3

Our aim is not to give a substantial interpretation of these net effects. (A substantial interpretation is very difficult in this case because the age-effect is a mixture of several effects.) We accept standardization to be a good technique for estimation and are primarily concerned with what effect non-response has on the results from such an analysis. In order to address this question, we shall repeat the analysis on data collected on the second call, third and fourth or later, respectively. The estimated total net effects of education are as follows:

Call		Educational level						
		1	2	3	4	5	6	7
2	Total effect of education ..	1.1	0.8	-0.9	-0.1	-0.8	-0.2	-0.2
	Net effect of education	0.6	0.5	-0.4	0.0	-0.5	0.0	-0.4
3	Total effect of education ..	1.2	0.8	-0.7	0.1	-0.9	-0.2	-0.5
	Net effect of education	0.4	0.6	0.1	0.1	-0.5	-0.1	-0.5
4	Total effect of education ..	1.0	0.8	-0.3	0.0	-0.1	-0.3	0.0
	Net effect of education	-0.1	0.5	-0.1	0.0	0.3	-0.4	-0.2

The mean number of live births varies from 1.8 to about 1.0 in the four sets of data. This, we believe, is due to the fact that women with children are more available for interview than women with few or no children. The analysis done in this section aims at answering the question whether non-response has any effect on the relationship between age, education, and fertility. The results seem to indicate that there is very little or no systematic effect of non-response on the relationships between the three variables.

5. METHODS TO REDUCE THE EFFECTS OF NON-RESPONSE

5.1. Introduction

In chapter 4 it was shown that non-response can lead to seriously biased results, and many other examples of this can be found in the literature, Zarkovich (1966).

It is generally accepted that the best way of reducing bias due to non-response is to keep response rates at maximal level through effective operational procedures. However, after the data collection is terminated, there will always remain some non-response, and it is natural to raise the question whether the bias due to non-response can be reduced by applying special estimation techniques. Many techniques have been suggested, the most well-known are:

(i) Post-stratification
(ii) The Politz-Simmon method
(iii) Bartholomew's method

In Norway we have never used the Politz-Simmon method, while the other two methods have been used on several occasions. In this chapter we shall give a few examples illustrating the use of these two methods. In chapter 6 we shall suggest a new weighting procedure, and apply this method to data from the Norwegian Fertility Survey.

5.2. Post-stratification

The technique of post-stratification was used in the household expenditure surveys. The response problem is particularly important for these surveys, because response rates in general are smaller than normally encountered. Also, it is known that response rates vary between subclasses, which are homogeneous with respect to expenditure. To evaluate the efficiency of post-stratification, the following expression for the bias due to non-response is useful, Thomsen (1973),

$$(5.1) \qquad \text{Bias} = (1/\bar{h}) \sum_{i=1}^{L} \bar{Y}'_i W_i \, (h_i - \bar{h}) + \sum_{i=1}^{L} W_i \, (1-h_i)(\bar{Y}'_i - \bar{\bar{Y}}''_i),$$

where h_i is the response rate in the i^{th} post-stratum, $\bar{h} = \sum_{i=1}^{L} W_i h_i$,

W_i is the proportion of the population in the i^{th} post-stratum, $\bar{Y}_i$, $\bar{\bar{Y}}_i$ are, respectively, the respondent and non-respondent means in the i^{th} post-stratum.

The first term in (5.1) is the component due to different response rates. It is the component that is reduced by post-stratification, and it can be estimated from the sample. It should be emphasized that (5.1) gives the bias for a given set of post-strata, and that one can shift part of the bias between the components by choice of post-strata. In practice it is important to choose the right variables for post-stratification. Also, it is important not to make too many post-strata, because the gains from using this technique decline rapidly with an increase in the number of post-strata. In addition, having too many post-strata would result in some post-strata having no respondents.

In the Household Expenditure Survey, a good variable for post-stratification was found to be "size of household". The first component in (5.1) is estimated for different choises of the number of post-strata. The results are given in table 12.

Table 12. Estimates of the component due to different response rates by the number of post-strata

	Number of post-strata			
	2	3	4	5
Estimates of the component due to different response rates	Nkr 215	Nkr 296	Nkr 326	Nkr 335

It is seen that the gains from using post-stratification decline rapidly with the number of post-strata.

The second component in (5.1) is usually not known, as $\bar{\bar{Y}}_i$ is unknown. One therefore has to make some assumptions concerning the second component to be able to evaluate the effect of post-stratification on the total bias. The first component gives the maximum reduction of the bias when post-stratification is used.

We shall now give an example in which the second component can be estimated because information concerning non-respondents is available from registers. Data are taken from the Fertility Survey, the study variable is "number of live births", while the post-stratification variables are "age" and "marital status". The sample was divided into six post-strata, three age groups, and two marital status groups. Among respondents the average number of live births per woman is 1.57, while the same average is 1.50 in the selected sample. The total bias due to non-response is 0.07.

To evaluate the efficiency of post-stratification the first term of (5.1) was estimated to be 0.05, from which follows that the estimate of the remaining bias after post-stratification is 0.02.

In this case the use of post-stratification has eliminated slightly more than 70 per cent of the non-response bias. This may not be surprising as the correlation between the post-stratification variables and the study variable is very high.

5.3. Bartholomew's method

In Bartholomew (1961) is suggested a method for reducing non-response bias, the method consists of giving different weights to results from the first and second call. The estimator is as follows:

$$\bar{y}_B = \frac{n_{11}}{n}\bar{y}_{11} + (1- \frac{n_{11}}{n})\bar{y}_{21},$$

where $\bar{y}_{11}$ and $\bar{y}_{21}$ are the sample means in the first and second call respectively, and n_{11} is the number of elements interviewed in the first call.

The method is useful when one has information indicating that the mean in the second call is closer to the mean in the non-response than the mean in the first call.

6. A PROBABILISTIC MODEL FOR NON-RESPONSE

6.1. Introduction

In this chapter we shall present a probabilistic model for non-response. This model gives rise to an estimable variance, and estimable non-response bias, and an estimable cost. The model is applied in connection with the Fertility Survey to find a new adjusting method for non-response bias. Also, the model is used to study the relationship between the mean square error and the number of call-backs, and the results are used to evaluate the allocation of resources between the initial sample and the efforts to reduce non-response by call-backs. Finally, we study the effects of non-response on measures of association between fertility and other variables.

It should be noticed that the fitting of the model to data from the Fertility Survey is tentative, and that modifications are suggested several places. This application of the model is included primarily to demonstrate the potentials of the model. Later we intend to publish the final results in an independent publication.

6.2. The model

When an interviewer makes an attempt to interview a selected household, there are three possible outcomes:

(i) The interviewer gets a response.

(ii) The interviewer gets no response and decides to call back.

(iii) The interviewer gets no response and decides to categorize the household as non-response (refusal).

In practice it is well known that it is difficult for the interviewer to distinguish between permanent and temporary refusals, but in this connection the important thing is that such a categorization is done after each visit.

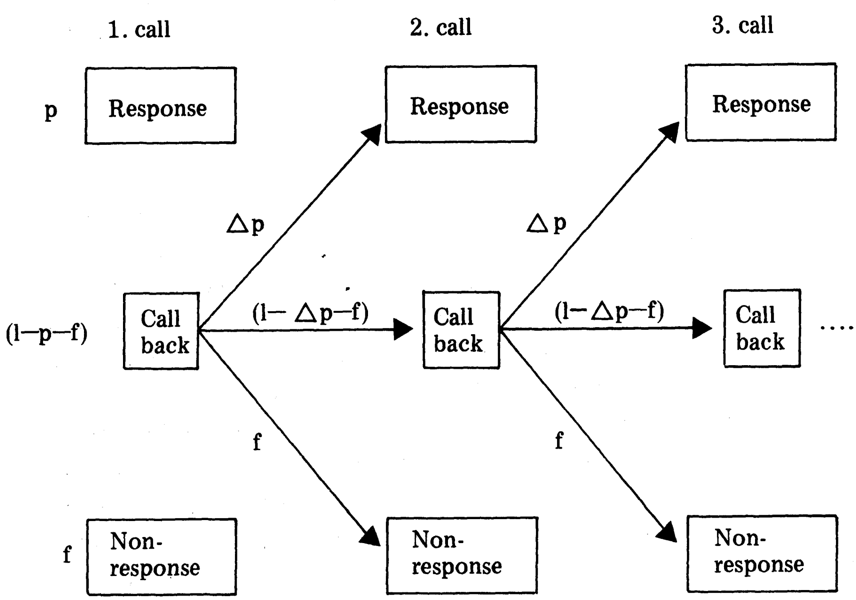
Let p denote the probability that outcome (i) occurs in the first call, and let f denote the probability that outcome (iii) occurs in the first visit. We now assume that f is constant in the successive visits, but that outcome (i) occurs with probability Δp in the second and following calls. We also expect Δ to be larger than one because the interviewers use ingenuity. They find out from neighbours or parents when the people now absent will be available. They make appointments etc. The result of this is, expectedly, that the probability of getting a response should increase after the first call.

In Figure 5 below the model is shown in a diagram.

Let C denote the outcome that the interviewer gets a response from a selected household in the c^{th} visit, then

$$P(C=1) = p$$
$$P(C=2) = (1 - p - f)\Delta p$$
$$P(C=3) = (1 - p - f)(1 - \Delta p - f)\Delta p$$
$$\vdots$$
$$P(C=c) = \begin{cases} p & \text{if } c = 1 \\ (1 - p - f)(1 - \Delta p - f)^{c-2}\Delta p & \text{if } c \geq 2 \end{cases}$$

FIGURE 5. A PROBABILISTIC MODEL FOR NON-RESPONSE



The parameters p, Δ, and f can be estimated from the sample, assuming that information concerning the number of calls for each selected household is available.

The model can be generalized by allowing p to vary between the households or persons. One possibility is to assume that p is generated by a Beta-distribution, while another is to assume that p is constant within certain subclasses in the population, but varies between them.

In what follows we shall assume that the parameters are constant within certain subclasses, called post-strata, but vary between them. This model is similar to a number of other non-response models, but also differs from them in important aspects.

The rational behind the correction method introduced in Bartholomew (1961) is that the interviewer in the second call is able to get responses from a sample representative for the non-respondents in the first call. In our model this means that the conditional probability of being a respondent in the second call, given that it was a non- respondent in the first call, is the same for all post-strata.

Our model is also similar to the probabilistic model suggested in Deming (1953). The most important difference is that the possibility to estimate the parameters in the model is ignored in Deming (1953).

The model presented in this paper is similar to the model suggested in Politz and Simmon (1949) in that it considers availability to be important when correcting for non-response bias. In Politz and Simmon (1949) the probability of finding a person at home is estimated by including questions in the questionnaire to ascertain whether a respondent was at home last night at this time, the night before last, etc., to cover the 5 nights preceding the interview. Each response is then given a weight w_i, the reciprocal of the number of nights at home over the period of 6 successive nights. In our model the probability of finding a person at home is estimated by means of information concerning the number of calls made before he/she was found at home.

A somewhat different kind of non-response model is suggested in the literature, where it is assumed that there is a linear relationship between the sample mean and the number of calls. Such relationships are often observed in practice (see table 10). In our model the linear relationship is due to the fact that people have different availability, and that availability is highly correlated with a number of variables.

We shall demonstrate below two methods of estimating the parameters in our model. First we shall use two age groups as post-strata. In this case the number of persons in each post-stratum is known, and maximum likelihood estimates can be calculated. In addition, the goodness of fit can be evaluated.

Thereafter, we shall study the more important case in which the number of persons within each post-stratum is unknown. In such cases the parameters can be estimated by means of the least squares method.

The two methods are used on the same set of data for computational convenience. In practice only one of the methods would be used on a specific survey.

6.3. Fitting the model to data from the Fertility Survey

In table 13 below, the number of women categorized as responses and non-responses in each call in the Norwegian Fertility Survey are given within two age groups. Assuming that the parameters p, f, and Δ are constant within these two age groups, p_1, f_1, Δ_1, p_2, f_2, and Δ_2 respectively, the maximum likelihood estimates are

$$\hat{f}_1 = 0.07 \qquad \hat{f}_2 = 0.08$$

$$\hat{p}_1 = 0.30 \qquad \hat{p}_2 = 0.35$$

$$\hat{\Delta}_1 = 1.56 \qquad \hat{\Delta}_2 = 1.39$$

The maximum likelihood estimates are developed in Appendix 1.

Table 13. Observed and estimated number of respondents and non-respondents in each call

Age		Number of calls						
		1	2	3	4	5	6	7
18-29 years	Number of responses observed	662	688	306	114	35	13	9
	Number of responses estimated	655	647	297	137	63	29	13
	Number of non-responses observed	126	70	64	31	25	16	3
	Number of non-responses estimated	153	96	44	20	9	4	2
30-44 years	Number of responses observed	824	657	304	107	23	13	4
	Number of responses estimated	806	630	277	122	54	24	10
	Number of non-responses observed	114	100	61	46	20	15	4
	Number of non-responses estimated	184	105	46	20	9	4	2

From table 13 we can calculate the conditional probability that a woman is a respondent in the j^{th} call, given that she did not respond in previous calls. Similarly, we can calculate the conditional probability that a woman is categorized as a non-respondent. For the age group 18-29 years the results of such calculations are as follows:

	Number of calls					
	1	2	3	4	5	6
Observed conditional response probabilities .	0.3062	0.5007	0.4968	0.4634	0.3465	0.3165
Observed conditional non-response probabilities	0.0583	0.0509	0.1039	0.1260	0.2475	0.3902

In our model the conditional reponse probability is assumed to be constant after the first call. The observed conditional response probabilities show a clear tendency to decrease. This, we believe, is due to the fact that within the age-group 18-29 years the response probability is not constant, but varies between individuals. Therefore, in the later calls the response rates will decrease, because the interviewer will be visiting persons that are hard to find. Another reason is that the interviewer after having done several calls has a tendency to increase the probability of categorizing a household or person as a non-response instead of deciding to call back.

In our model, this could be taken care of by introducing a shift in f after the first call, and/or by allowing p to vary within the post-strata, for instance by assuming that p is generated by a Beta-distribution. We shall, however, not use such a generalization of the model here.

In spite of the simplicity of the model, the estimates seem to fit very well in with what one would expect. The fact that $\hat{p}_1$ is smaller than $\hat{p}_2$ is known from other surveys in Norway, and in other countries as well.

Many women in the first age-group live together with their parents and it seems reasonable that $\hat{\Delta}_1$ is larger than $\hat{\Delta}_2$ because the interviewer through the parents has a good chance to get contact with the interviewee in later calls. It is, in our opinion, surprising that $\hat{\Delta}_1$ and $\hat{\Delta}_2$ are as large as they are. However, this seems to be the case in other surveys as well. We shall not go further in the interpretations of the result here, as we feel that results from more surveys must be available before such interpretations can be of any value. In the future we intend to fit the same model to data from other surveys and thereby, hopefully, gain more insight into the processes generating non-response. One important question, we think, is whether f varies so little between subclasses as in this case. The results in chapter 4, however, do confirm that the refusal rate varies little between subclasses in the population.

6.4. Adjusting for non-response bias

In this section we shall demonstrate how the model presented in section 6.2 can be used when the aim is to reduce non-response bias. The variable of interest is now "number of live births", and the aim is to estimate the mean of this variable in the population. To do this the population is divided into 7 groups, or post-strata. Post-stratum i consists of women with i live births, i = 0,1,2,...,6. Post-stratum 6 includes women with 6 or more live births.

As in section 6.3 we assume that p and Δ are constant within each post-stratum, but vary between them. In addition, we assume that f is constant in the whole sample.

To estimate the mean number of live births in the population, we must estimate the number of women in each post-stratum. Several estimation methods are available, but in many cases the least squares method seems to be natural.

Assume that N women have been selected in the sample, and let N_i denote the number of women selected in post-stratum i. Then the expected number of responses in the j^{th} call in post-stratum i is $N_i P(C_i = j)$, where

$$p\{C_i = c_i\} = \begin{cases} p_i & \text{if } c_i = 1 \\ (1 - p_i - f)(1 - \Delta_i p_i - f)^{c_i - 2} \Delta_i p_i & \text{if } c_i \geq 2 \end{cases}$$

Let X_{ij} denote the observed number of responses in post-stratum i in the j^{th} call. The least squares estimates of Δ_i, p_i and f can now be found by minimizing

$$\sum_{i=0}^{6} \sum_{j=1}^{8} (N_i P(C_i = j) - X_{ij})^2,$$

under the condition that

$$\sum_{i=0}^{6} N_i = N.$$

In many cases the number of parameters can be reduced. In the present case it seems reasonable to assume that

$$p_i = i\beta + \alpha + \text{RESIDUAL},$$

where i is the number of live births. (See table 15.)

However, in order to make the calculations simple, we shall use a "quick and dirty" estimation method. The method is based on data from the three first calls, and the estimators are found as the solution to the following equations:

$$\begin{aligned} & N_i p_i = x_{i1} \\ & N_i(1-p_i-f)\ \Delta_i p_i = x_{i2} \\ (6.1)\qquad & N_i(1-p_i-f)(1-\Delta_i p_i-f)\ \Delta_i p_i = x_{i3} \qquad (i=0,1,2,\ldots,6). \\ & \Sigma\ N_i = 5047 \end{aligned}$$

The reason why we cannot use the estimator of f found in section 6.3 is that we in section 6.3 have excluded about 300 observations from the analysis. The reason for this is that these observations were collected in a second phase of selection in which specially trained interviewers were used. In this section these observations are categorized as non-response, because we have no or little information concerning the number of calls in these cases.

We find the estimates from the equations (6.1). The solution is presented in table 15 below. Table 14 shows the number of responses in each of the three first calls. The total sample size was 5 047.

Table 14. Number of responses in each call

Post-stratum	Call		
	1	2	3
Total	1.483	1.345	610
0	311	387	188
1	258	248	134
2	497	410	158
3	261	199	88
4	107	79	30
5	37	15	9
6	12	7	3

Table 15. Estimates of N_i, i, and p_i

Post-stratum	$\hat{N}_i$	$\hat{\Delta}_i$	$\hat{p}_i$	
0	1.380	1.840	0.226	
1	1.049	1.470	0.245	
2	1.433	1.489	0.347	
3	771	1.356	0.339	f=0.099
4	287	1.398	0.373	
5	96	0.783	0.383	
6	30	1.171	0.400	

From registers the number of women in each post-stratum is collected, and presented in table 16 together with $\hat{N}_i$.

Table 16. Estimated and observed number of women within each post-stratum

Post-stratum	Estimated number of women $\hat{N}_i$	Observed number of women in the selected sample N_i
Total	5.046	5.047
0	1.380	1.616
1	1.049	923
2	1.433	1.380
3	771	721
4	287	278
5	96	78
6	30	30
Not known	.	21

In the selected sample the average number of live births was 1.50. After three calls the same average in the sample was 1.67. The adjusted average, based on $\hat{N}_i$ was 1.60. In this case the bias is reduced with a little more than 40 per cent. We have reasons to believe that this reduction will increase when a better estimation method is used.

6.5. The relationship between the mean square error and the number of call-backs

In this section we shall use the model from section 6.2 to study the decline of the mean square error as a function of the number of call-backs. In particular, we shall look at the allocation of resources between the initial sample and the efforts to reduce non-response by means of call-backs.

Let X_i denote the number of live births for the i^{th} selected woman and let

$$y_i = \begin{cases} 1 \text{ if the } i^{th} \text{ selected woman is a respondent} \\ 0 \text{ else} \end{cases}$$

The respondent mean can now be written as

$$\bar{X}_s = \frac{\sum_{i=1}^{n} X_i y_i}{\sum_{i=1}^{n} y_i}$$

where n is the sample size.

We now assume that the sample is post-stratified as in section 6.4, and let

$$P\,(\text{A woman in the sample belongs to post-stratum } j \mid \text{The woman is a respondent}) = q_j; \quad j = 0,1,2,\ldots,6.$$

We then have that after the first call

$$q_j = \frac{N_j p_j}{\sum_{j=0}^{6} N_j p_j}; \quad j = 0,1,2,\ldots,6.$$

After $k(\geq 2)$ calls, we have

$$(6.2) \quad q_j = \frac{N_j p_j + \sum_{i=2}^{k} N_j (1-p_j-f)(1-\Delta_j p_j - f)^{i-2} \Delta_j p_j}{\sum_{j=0}^{6} N_j p_j + \sum_{j=0}^{6} \sum_{i=2}^{k} N_j (1-p_j-f)(1-\Delta_j p_j-f)^{i-2} \Delta_j p_j};$$

$$j = 0,1,2,\ldots,6.$$

We now have that

$$(6.3) \quad E(\bar{X}_s) = \sum_{j=1}^{5} j q_j + 6.5\, q_6,$$

and

$$(6.4) \quad \text{var}(\bar{X}_s) \approx \left[\sum_{j=0}^{5} q_j (j-E(\bar{X}_s))^2 + q_6 (6.5-E(\bar{X}_s))^2 \right] \Big/ E\left[\sum_{i=1}^{n} y_i \right],$$

where the average number of live births per woman in post-stratum 6 is assumed equal to 6.5.

Substituting N_j, p_j, Δ_j, and f with $\hat{N}_j$, $\hat{p}_j$, $\hat{\Delta}_j$, and $\hat{f}$ found in section 6.4 we find and estimate for q_j, $\hat{q}_j$, which inserted in (6.3) and (6.4) give us estimates of $E(\bar{X}_s)$ and $\text{var}(\bar{X}_s)$.

Furthermore,

$$\text{Bias } (\bar{X}_s) = E(\bar{X}_s - \bar{X}),$$

which also can be estimated as $\bar{X}$ is known is this survey.

In table 17 the estimated bias and mean square error is given as a function of the number of calls.

Table 17. Estimated bias and mean square error by the number of calls

	Number of calls									
	1	2	3	4	5	6	7	8	9	10
Bias	0.339	0.207	0.166	0.144	0.133	0.127	0.123	0.122	0.121	0.120
Mean square error	0.1162	0.0435	0.0281	0.0212	0.0182	0.0166	0.0156	0.0153	0.0151	0.0149
$\sqrt{\text{Mean square error}}$ ...	0.3408	0.2085	0.1676	0.1457	0.1347	0.1288	0.1248	0.1238	0.1228	0.1219

We shall now use the model to study how the exepcted costs increase with the number of call-backs. We shall assume that the travelling cost per visit is constant, equal to Nkr 30,-. (In many studies done elsewhere it is often assumed that the first call is less expensive than the following calls. In Norway we have no data indicating this, and we therefore assume that the travelling cost per woman is independent of whether it is the first, second or later call.)

The expected number of responses after at most j visits is

$$W = N(1 + \sum_{k=0}^{j-2} \sum_{i=0}^{6} W_i(1 - p_i - f)(1 - \Delta_i p_i - f)^k)$$

where $W_i = N_i/N$. It is seen that W is linear in N. In table 18 the total travelling costs are given for different choices of the number of call-backs. The sample size is 5 047.

Table 18. Total costs by the number of calls. Nkr

	Number of calls								
	1	2	3	4	5	6	7	8	9
Total costs, Nkr	151 410	243 120	285 510	305 460	314 970	319 590	321 870	322 980	323 520

In the Fertility Survey it was chosen to select a sample of 5 047 women, and make at most 8 calls. The total cost was Nkr 322 980. A question of interest is to see whether this allocation of resources amongst the initial sample and the recalls is reasonable. To address this question, we can look at all other possible allocations, and compare their mean square error.

The following strategies all cost Nkr 322 980:

Strategy	Initial sample size	Number of call-backs
1	10 766	0
2	6 705	1
3	5 709	2
4	5 336	3
5	5 175	4
6	5 101	5
7	5 064	6
8	5 047	7
9	5 039	8
10	5 034	9
11	5 032	10

In table 19 the mean square error is given for all strategies.

Table 19.

	Strategy					
	1	2	3	4	5	6
Mean square error	0.1155	0.0433	0.0280	0.0212	0.0181	0.0166

	Strategy				
	7	8	9	10	11
Mean square error	0.0156	0.0153	0.0151	0.0149	0.0149

From table 19 it is seen that it seems reasonable to select a relatively small sample, and use a large proportion of the resources on call-backs. A similar conclusion is reached in Deming (1953).

Results in section 6.3 seem to indicate that we in our present formulation of the model overestimate the number of responses in the later calls. When the model is adjusted, we expect that the bias in table 17 still decreases, but that the decrease is smaller than the one presented in table 17. This again is expected to influence the conclusions drawn from table 19. We do, however, expect that the final results will indicate that successive recalls are more effective than an increase in the size of the sample in decreasing the mean square error.

To reach this conclusion, we have assumed that the aim is to estimate the mean number of live births in the population, and that the unweighted sample mean is used as the estimate. If the aim is to estimate relationships between some variables, or if a weighted sample mean is used, results in chapter 4 indicate that our conclusions might be different.

In the next section we shall study how the bias of some simple measures of association is affected by the number of call-backs, and by weighting.

6.6. On the effects of non-response when estimating contrasts between subclass means

As seen in section 6.4 the probability of getting a response from a woman depends on the number of live births she has had. This variable is also one of the most important depends variables in the fertility surveys, which is an important fact to have in mind when estimating relationships between fertility and other variables, because most measures of association will be affected by non-response when the probability of being in the sample is a function of the dependent variable. This seems to contradict the conclusions in section 4.4, and we shall therefore return to the problem concerning the effects of non-response when the aim is to estimate contrasts between subclass means.

In this section we shall use the results from section 6.4 to estimate the effects of non-response when the aim is to compare fertility between age groups under the assumption that p_i depends on the number of live births. As in section 4.4, we shall use the differences between the age specific means and the overall mean as measures of age effect. We now define N_{jk} as the number of women in the selected sample who have j live births, and belong to age-group k. Furthermore, let P (A woman in the sample who belongs to age-group k to have had j live births/the woman is respondent) = q_{jk}. We then have after the first call:

$$q_{jk} = \frac{N_{jk}p_j}{\sum_{j=0}^{6} N_{jk}p_j}$$

After L(≥ 2) calls, we have

$$q_{jk} = \frac{N_{jk}p_j + \sum_{i=2}^{L} N_{jk}\,(1-p_j-f)\,(1-\Delta_j p_j-f)^{i-2}\,\Delta_j p_j}{\sum_{j=0}^{6} N_{jk}p_j + \sum_{j=0}^{6}\sum_{i=2}^{L} N_{jk}\,(1-p_j-f)\,(1-\Delta_j p_j-f)^{i-2}\,\Delta_j p_j};$$

$$j = 0,1,2,\ldots,6,$$

where p_j, Δ_j, and f are defined in section 6.4.

To estimate p_j, Δ_j, f, and N_{jk}, one could again use the least squares method as in section 6.4. However, we shall use $\hat{p}_j$, $\hat{\Delta}_j$, and $\hat{f}$ as found in section 6.4, and to estimate N_{jk}, we use the simple estimator

$$\hat{N}_{jk} = \frac{X_{jk1} + X_{jk2} + X_{jk3}}{\sum_{k=1}^{3} (X_{jk1} + X_{jk2} + X_{jk3})}\,\hat{N}_j,$$

where $\hat{N}_j$ is as given in section 6.4, and $X_{jk\ell}$ denotes the number of responses observed with j live births, in age group k, in ℓ^{th} call. Again only data collected in the three first calls are used to simplify computations.

Now let $\bar{X}(k)$ denote the unweighted mean number of births in age-group k, then

$$(6.5) \qquad E(\bar{X}(k)) = \sum_{j=1}^{5} jq_{jk} + 6.5\, q_{j6}.$$

From (6.3) and (6.5) we can now estimate $E(\bar{X}(k)-\bar{X}_s)$, and from this bias $(\bar{X}(k)-\bar{X}_s)$ can be estimated as the "true" values of the population parameters are known.

In table 20 the bias of the difference between the age specific fertility and the overall fertility is presented for three age-groups after the first call, the second call, etc.

Table 20. The bias of the difference between the age-specific fertility and the overall fertility for three age-groups by the number of calls

Age-group	Number of calls						
	1	2	3	4	5	6	7
18-24 years	-.186	-.110	-.085	-.068	-.060	0.055	-.053
25-34 "	-.079	-.024	-.013	-.011	-.010	-.010	-.011
35-44 "	-.092	-.069	-.057	-.048	-.042	-.040	-.040

It is seen from table 20 that the bias of the difference between the age-specific fertility and the overall fertility is negative. It is also seen that for the age-group 18-24 years there is a rather serious bias after only one call. For the two other age-groups the bias is less serious.

To adjust for non-response bias, it is reasonable to weight each observation with the reciprocal of its inclusion probability. In table 21 the unweighted and weighted differences between the age-specific fertility and the overall fertility are presented. (Again the weights are estimated after three visits.) In registers information concerning age and number of live births is found for the selected sample, and the differences between age-specific fertility and overall fertility are calculated for the selected sample and presented in the last line of table 21.

Table 21. Differences between age-specific fertility and overall fertility

	Age-group		
	18-24	25-34	35-44
Unweighted (after three visits)	-1.212	0.096	0.910
Weighted (after three visits)	-1.158	0.104	0.942
Selected sample	-1.127	0.109	0.963

Results from table 21 seem to indicate that about 50 per cent of the non-response bias is removed by weighting.

Similarly, the non-response effect on the relationship between education and fertility can be studied. In table 22 the unweighted and weighted differences between the education specific fertility and the overall fertility are presented.

Table 22. Differences between education specific fertility and overall fertility

	Education group						
	1	2	3	4	5	6	7
Unweighted (after three visits)	1.203	0.673	-0.727	0.000	-0.874	-0.297	-0.234
Weighted (after three visits)	1.234	0.701	-0.702	0.003	-0.853	-0.290	-0.231

In table 22 is seen that the difference between the weighted and unweighted estimate is positive, indicating that the difference between age-specific fertility and overall fertility is positive.

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Appendix 1

MAXIMUM-LIKELIHOOD ESTIMATION OF p, f, AND Δ

Let N denote the number of elements in the selected sample, N_i denotes the number of elements responding in the i^{th} call, and F_i denotes the number of elements categorized as non-respondents in the i^{th} call. We then have that

$$P(N_1 = n_1 \cap F_1 = f_1) = \frac{N}{n_1!\, f_1!\, (N-n_1-f_1)!} p^{n_1} f^{f_1} (1-p-f)^{(N-n_1-f_1)}.$$

If $i \geq 2$ we have that

$$P(N_i = n_i \cap F_i = f_i \mid \bigcap_{j=1}^{i-1} N_j = n_j, \bigcap_{j=1}^{i-1} F_j = f_1) =$$

$$\text{(A.1.)} \quad k_i (\Delta p)^{n_i} f^{f_i} (1-\Delta p-f)^{N-\sum_{j=1}^{i} n_j - \sum_{j=1}^{i} f_j},$$

where k_i is a constant independent of p, f, and Δ. Assume that at most j calls have been made, then

$$P(\bigcap_{i=1}^{j} (N_i = n_i \cap F_i = f_i)) =$$

$$= P(N_j = n_j \cap F_j = f_j \mid \bigcap_{i=1}^{j-1} (N_i = n_i \cap F_i = f_i)) \cdot$$

$$\cdot P(N_{j-1} = n_{j-1} \cap F_{j-1} = f_{j-1} \mid \bigcap_{i=1}^{j-2} (N_i = n_i \cap F_i = f_i)) \cdot$$

$$\cdots\cdots\cdots\cdots\cdots\cdots$$

$$\cdots\cdots\cdots\cdots\cdots\cdots$$

$$\text{(A.2.)} \quad \cdot P(N_2 = n_2 \cap F_2 = f_2 \mid N_1 = n_1 \cap F_1 = f_1)\, P(N_1 = n_1 \cap F_1 = f_1).$$

From (A.1) and (A.2) follows that

$$P\left(\bigcap_{i=1}^{j} (N_i = n_i \cap F_i = f_i)\right) =$$

$$= \prod_{i=1}^{j} k_i (\Delta p)^{\sum_{i=2}^{j} n_i} f^{\sum_{i=1}^{j} f_i} (1-\Delta p-f)^{(j-1)N - (j-1)(n_1+f_1) - \sum_{i=2}^{j} (j-i+1)(n_i+f_i)}$$

$$\cdot \, p^{n_1}(1-p-f)^{N-n_1-f_1} =$$

$$= \prod_{i=1}^{j} k_i (\Delta p)^a f^b (1-\Delta p-f)^c p^{n_1}(1-p-f)^{N-n_1-f_1} = \prod_{i=1}^{j} k_i \, h(p,f,\Delta),$$

where $a = \sum_{i=2}^{j} n_i$, $b = \sum_{i=1}^{j} f_i$, and

$$c = (j-1)\, N-(j-1)(n_1+f_1) - \sum_{i=2}^{j} (j-i+1)(n_i+f_i).$$

Furthermore,

$$\ln h(p,f,\Delta) = a\ln p + a\ln\Delta + b\ln f + c\ln(1-\Delta p-f) + n_1 \ln p + (N-n_1-f_1)\ln(1-p-f)$$

After derivation with respect to p, Δ, and f the following equations must be fulfilled to maximize $h(p,f,\Delta)$.

$$\text{(A.3.)} \quad \frac{\partial \ln h}{\partial p} = \frac{a}{p} - \frac{\Delta c}{1-\Delta p-f} + \frac{n_1}{p} - \frac{N-n_1-f_1}{1-p-f} = 0$$

$$\text{(A.4.)} \quad \frac{\partial \ln h}{\partial \Delta} = \frac{a}{\Delta} - \frac{cp}{1-\Delta p-f} = 0$$

$$\text{(A.5.)} \quad \frac{\partial \ln h}{\partial f} = \frac{b}{f} - \frac{c}{1-\Delta p-f} - \frac{N-n_1-f_1}{1-p-f} = 0$$

The maximum-likelihood estimators are now found from (A.3) - (A.5) to be

$$\hat{f} = \frac{b}{N - F_1 + a+b+c} = \frac{\sum_{i=1}^{f} F_i}{j\,N - \sum_{i=1}^{j} (j-1)(F_i+N_i)} ,$$

$$\hat{p} = \frac{N_1(1-\hat{f})}{N-F_1} ,$$

and

$$\hat{\Delta} = \frac{a(1-\hat{f})}{\hat{p}(a+c)} .$$

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Publikasjonen utgis i kommisjon hos
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og er til salgs hos alle bokhandlere
Pris kr 11,00

Omslag trykt hos Grøndahl & Søn Trykkeri, Oslo

ISBN 82-537-1107-7
ISSN 0085-431x