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FECUNDITY COMPONENTS IN TAIWAN: APPLICATION OF A STOCHASTIC MODEL OF HUMAN REPRODUCTION

by
Anrudh Kumar Jain

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in the
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Doctoral Committee:

Professor Leslie Kish, Chairman
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Assistant Professor Thomas F. Mayer
Professor Robert G. Potter, Jr. (Brown University)

ABSTRACT

Fecundity Components in Taiwan: Application of a Stochastic Model of Human Reproduction

by Anrudh Kumar Jain

Two main objectives of this study are: (1) to develop methods to measure three fecundity components from the data collected retrospectively on a field survey in Taiwan, a developing country, and to study the variations in these estimates by important demographic and socio-economic characteristics of couples; and (2) to utilize these estimates for predicting the values of three demographic indices measuring fertility level by using Perrin and Sheps' stochastic fertility model, and to study the differences between these theoretically predicted values and the corresponding observed values. For these purposes we have utilized the data from an intensive fertility survey conducted in Taichung city of Taiwan at the end of 1962 prior to a year long family planning action program.

The three fecundity components studied intensively are: the fecundability, the level of fetal wastage, and the infecundable period following the termination of a pregnancy. The first component, fecundability, was estimated from the period between onset of marriage and the beginning of first conception by using a Pearson's type-I distribution. The estimated fecundability level was 195 per 1,000 women with a standard error of three. These estimates are based on women married for 3-8 years,

and are relatively free from 'memory' and 'truncation' biases. We found that the fecundability level increases with wife's age at marriage up to 25 years, and that fecundability is higher for women of higher socio-economic strata than those of lower strata.

The level of fetal wastage, which includes induced abortions, spontaneous abortions, and still births, comparatively free from memory bias, was found to be 173 per 1,000 completed pregnancies. It increases with the order of pregnancy and the age of the mother.

The averages and variances of temporary infecundable periods following the termination of pregnancies were estimated indirectly by subtracting the moments of the fecundable period (estimated from the observed frequency distribution of first pregnancy intervals) from the corresponding moments of completed pregnancy intervals. The estimated average infecundable period following live births was eleven months as compared to about two months following fetal deaths. The corresponding variances were about 40 and 7 respectively. The estimated variances of infecundable periods are inflated, probably, due to the inclusion of covariance terms which were assumed to be zero in the estimation procedure.

The three demographic indices predicted by applying the estimated fecundity components to the Perrin and Sheps model are: the first birth interval, the completed birth interval, and the number of live births. The theoretically predicted values of these indices are found to be different than the corresponding values calculated directly from the data. These discrepancies are explained mainly by the limitations of the model and partly by limitations of the data.

It is necessary to emphasize here that the conclusions of this study are strictly applicable to Taiwanese women living in Taichung because the estimates of fecundity components are culturally bound and do not measure biological parameters alone. Whether and in what way our conclusions are general can only be determined by comparisons with other populations varying biologically and culturally, some of which have been presented in the thesis. It will be misleading to say that these conclusions will definitely apply to all women in Taiwan, not to mention to women in other countries, though the differences in Taiwan will be smaller than across cultural boundaries.

ACKNOWLEDGEMENTS

I first became interested in the study of fecundity during the winter semester of 1965 when I took a seminar course in Population and Human Ecology taught by Professor Freedman. Courses in Mathematical Sociology from Professor Kish and Professor Mayer during the winter of 1966 developed my interest in the Perrin and Sheps stochastic fertility model. During this period I also received encouragement and assistance from Professor Potter of Brown University.

I am indebted to the Population Studies Center of the University of Michigan and to Professor Freedman, its director in 1963, for bringing me to the United States and for generous financial help in the form of fellowships and research assistantships during the period 1963-67. The Ford Foundation provides the financial support to the Population Studies Center which in turn has supported my studies.

The Taiwan Population Studies Center and the Population Studies Center of the University of Michigan have made available to me the data collected from the Taichung Intensive Survey, conducted under a grant from the Population Council. I am thankful to Dr. L. P. Chow, the Director of the Taiwan Population Studies Center, for his cooperation.

All members of my doctoral committee have helped me with their constructive criticisms and suggesticns at different stages of my thesis. Professor Kish, as the chairman of my committee, was alert all the time

and has shown a great deal of patience in guiding me to analyse the data, in checking the mathematical expressions and in making editorial changes in the draft. Professor Freedman was very helpful in guiding me to organize the subject matter and to interpret the results. Professor Potter helped me a great deal not only in Ann Arbor but also from Brown University by checking the mathematical expressions, by guiding me in analysing the data, by pointing out some obvious fallacies and by helping me in interpreting the results. Professor Mayer was especially helpful in the mathematical problems. Professor Demeny as the outside member provided a broader outlook.

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Finally, I wish to express my gratitude to my mother and other members of my family who are in India and have constantly encouraged me and provided me with the moral support needed for finishing this study.

TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS ii

LIST OF TABLES vii

LIST OF ILLUSTRATIONS xi

Chapter

I. INTRODUCTION 1

Objectives
The Model, Assumptions, and Limitations
The Plan of Presentation

II. THE DATA AND THE SAMPLE 17

Source of Data
Selection of the Sample
Response Rate
List of Variables
Estimation of the Missing Data
Computation of New Variables

III. METHODOLOGY 29

Notations
Estimation of P(AB) and P(LB)
Estimation of Moments of the Fecundable Period
Estimation of Moments of the ABNC and LBNC Periods
The Average and the Variance of Conception Delay
The Average and the Variance of First Birth Interval
The Average and the Variance of Completed Birth Intervals
The Average and the Variance of Live Births

IV. FECUNDABILITY AND ITS DEMOGRAPHIC CORRELATES 46

Introduction
Previous Research
The Model
Results

Chapter Page

The Memory Bias
The Truncation Bias
Relation of Wives Age at Marriage to Their Fecundability
Effects of the Memory Bias on the Relationship Between Wife's Age at Marriage and Fecundability
Effects of the Truncation Bias on the Relationship Between Wife's Age at Marriage and Fecundability
Interdependence Between Age at Marriage and Marriage Duration
Comparisons with Other Studies
Discussion and Summary of the Results

V. FECUNDABILITY AND ITS SOCIO-ECONOMIC CORRELATES 93

Introduction
Previous Work
The Model and the Hypothesis
The Measures of Socio-economic Status and the Methodology
Results
Effects of Differential Truncation and Memory Biases
Interdependence between Age at Marriage and Socio-economic Measures
Multiple Classification Analysis of Fecundability
Fecundability Differentials by Demographic Characteristics
Socio-economic Status and Fecundability
Summary and Discussions

VI. FETAL WASTAGE, ORDER OF PREGNANCY AND AGE OF THE MOTHER . 132

Introduction
Results
Fetal Wastage Rate and the Age of the Mother
Memory Bias and the Age Differentials in Fetal Wastage Rates
Fetal Wastage Rate and Pregnancy Order
Fetal Wastage Rate, Pregnancy Order and Age of Mother
Comparison with Other Studies
Summary

VII. RELATIONSHIPS OF PREGNANCY INTERVALS AND INFECUNDABLE PERIODS TO OUTCOME OF PRECEDING PREGNANCY, AGE OF MOTHER AND USE OF CONTRACEPTION 151

Introduction
Pregnancy Outcome and the Pregnancy Interval
Age, Pregnancy Outcome and Pregnancy Interval
Contraception and Pregnancy Interval

Chapter Page

Methodology and Biases
Results
Effect of Age of Mother
Effect of Memory Bias on the Age Differentials in Pregnancy Intervals
Effect of Contraception
Estimates of Postpartum Amenorrhea and Infecundable Periods
Summary and Conclusions

VIII. APPLICATION OF A STOCHASTIC MODEL OF HUMAN REPRODUCTION . 187

Introduction
First Birth Interval
Completed Birth Intervals
Live Births During "t" Months of Marriage
Summary and Conclusions

IX. SUMMARY AND CONCLUSIONS 209

Brief Resumé of Main Findings
Evaluation of the Present Study

BIBLIOGRAPHY 220

LIST OF TABLES

Table		Page
3.1	Comparison of Observed and Estimated Mean and Variance of Conception Delay by Wife's Age at Marriage in the Absence of Contraception	38
4.1	Hypothetical Monthly Probability of Conceiving per Cycle by Length of Fertile Period and Coital Frequency per Cycle	54
4.2	Observed and Estimated Number of Months Required for Conception in the Absence of Contraception for Taichung and the United States	61
4.3	Observed and Estimated Fecundability Rates per 1000 Women by Net Months of Marriage Duration in the Absence of Contraception for Women with at Least One Pregnancy	69
4.4	Mean Conception Delays with Variances and Number of Pregnancy Losses per 100 Reported First Conceptions by Net Months of Marriage Duration in the Absence of Contraception for Women with at Least One Pregnancy . . .	72
4.5	Mean Conception Delays, Their Variances, the Values of Chi-square, and Number of Pregnancy Losses per 100 Reported First Conceptions in the Absence of Contraception for Women with at Least One Pregnancy, by Women's age at Marriage	79
4.6	The Fecundability Rates per 1000 Women with Standard Error in the Absence of Contraception for Women with at Least One Pregnancy, by Women's Age at Marriage, for (I) All First Pregnancies, (II) Only Those First Pregnancies which Terminated in a Live Birth, and (III) All First Pregnancies Excluding Women who Took Three Years or More for First Pregnancy	83
4.7	Percentage Distributions of Women by Age at Marriage and Marriage Duration	87

Table		Page
4.8	The Fecundability Rates per 1000 Women and Their Standard Errors in the Absence of Contraception for Women with at Least One Pregnancy, by Marriage Duration and Wife's Age at Marriage	87
4.9	Comparison between (1) Number of Women Conceiving During Successive Months after Marriage Estimated on the Assumption that Type I Geometric Model Fits the Total Population and (2) Sum of Corresponding Estimated Number of Women for Each Age at Marriage Group	92
5.1	The Fecundability Rates per 1000 Women with Standard Error by Selected Measures of Socio-economic Status in the Absence of Contraception for Women with at Least One Pregnancy, for All Women and for Women Married 3-8 Years	106
5.2	The Fecundability Rates per 1000 Women by Selected Measures of Socio-economic Status by Age at Marriage in the Absence of Contraception for Women with at Least One Pregnancy	112
5.3	Multiple Classification Analysis of Fecundability Using Two Demographic Characteristics, Controlling for Measures of Socio-economic Status Separately, in the Absence of Contraception, for Women with at Least One Pregnancy	114
5.4	Multiple Classification Analysis of Fecundability for Wife's Age at Marriage Controlling for Measures of Socio-economic Status and Duration of Marriage; for Duration of Marriage Controlling for Measures of Socio-economic Status and Wife's Age at Marriage in the Absence of Contraception for Women with at Least One Pregnancy	116
5.5	Multiple Classification Analysis for Measures of Socio-economic Status Controlling for Demographic Characteristics, in the Absence of Contraception for Women with at Least One Pregnancy	118
5.6	Multiple Classification Analysis of Fecundability for Measures of Socio-economic Status in the Absence of Contraception for Women with at Least One Pregnancy .	120
5.7	Fecundability Rates per 1000 Women after Adjusting for Unreported Premarital Conceptions by Husband's Education in the Absence of Contraception for Women with at Least One Pregnancy	127

Table		Page
6.1	Fetal Wastage Rate per 1000 Completed Pregnancies by the Use of Contraception and by the Type of Fetal Wastage.	134
6.2	Fetal Wastage Rate per 1000 Reported Pregnancies by Age of Mother at Termination of Pregnancy	135
6.3	Fetal Wastage Rate per 1000 Reported Pregnancies by Age of Mother, by Use of Contraception Prior to Conception	136
6.4	Fetal Wastage Rate per 1000 Reported Pregnancies in the Absence of Contraception by Age of Mother at the Termination of Pregnancy and by Her Age at the Interview	137
6.5	Fetal Wastage Rates per 1000 Reported Pregnancies by Use of Contraception Prior to Conception by Age of Mother.	139
6.6	Comparison of Observed and Estimated Fetal Wastage Rates per 1000 Completed Pregnancies by Use of Contraception by Type of Fetal Wastage	140
6.7	Fetal Wastage Rate per 1000 Reported Pregnancies by Order of Pregnancy	142
6.8	Fetal Wastage Rate per 1000 Reported Pregnancies by Order of Pregnancy by Use of Contraception Prior to Conception	143
6.9	Fetal Wastage Rate per 1000 Reported Pregnancies in the Absence of Contraception by Age of Mother at the Interview and by the Pregnancy Order	144
6.10	Fetal Wastage Rate per 1000 Completed Pregnancies in the Absence of Contraception, by the Order of Pregnancy and the Age of Mother at Termination of Pregnancy . .	146
6.11	Fetal Wastage Rates per 1000 Completed Pregnancies in the Absence of Contraception by the Age of Mother at Termination of Pregnancy and by Type of Fetal Wastage.	148
7.1	Mean and Variance of Pregnancy Intervals by Outcome of Preceding Pregnancy and by Use of Contraception (Yes, No) During the Pregnancy Interval	159
7.2	Mean and Variance of Pregnancy Intervals by Outcome of Preceding Pregnancy and by Age of Mother in the Absence of Contraception	161

Table		Page
7.3	Mean and Variance of Pregnancy Intervals Following a Live Birth by Age of Mother at Interview and at Pregnancy in the Absence of Contraception	164
7.4	Mean and Variance of Pregnancy Intervals Following an Abortion by Age of Mother at Interview and Age at Pregnancy Interval in the Absence of Contraception	165
7.5	Estimated Mean and Variance of Pregnancy Intervals by Outcome of Pregnancy and by Age of Mother in the Absence of Contraception	168
7.6	Comparisons Between Estimated and Observed Overall Averages and Variances of Pregnancy Intervals by Outcome of Preceding Pregnancy	173
7.7	Estimated Mean and Variance of the Pregnancy Intervals by the Outcome of the Preceding Pregnancy and by the Use of Contraception (Yes,No) During the Pregnancy Interval	174
7.8	Mean Open Pregnancy Interval by Outcome of Last Pregnancy and Use of Contraception in Open Pregnancy Interval	175
7.9	Estimated Mean and Variance of Pregnancy Interval by Outcome of the Preceding Pregnancy, Use of Contraception (Yes, No) and by Age of Mother	179
7.10	Mean Lengths and Variances of Pregnancy Intervals, Fecundable Period, Anovulatory Period, Postpartum Amenorrhea and Infecundable Period by Outcome of the Preceding Pregnancy	181
8.1	Comparisons of Theoretical and Observed Averages and Variances of the First Birth Interval in the Absence of Contraception	192
8.2	Comparisons of the Theoretical and Observed Averages and Variances of Completed Birth Intervals for Taiwanese Women and for Indian Women in the Absence of Contraception	194
8.3	Estimates of Parameters Required for Predicting the Averages and the Variances of Number of Live Births in the Absence of Contraception	200
8.4	Comparison of Observed and Theoretical Average and Variance of Live Births Per Woman in t Months of Marriage in the Absence of Contraception	202

LIST OF ILLUSTRATIONS

Figure		Page
4.1	Number of Months Required for First Conception: Observed and Estimated, Taichung	62
4.2	Theoretical Probability Distributions of Fecundability for Taichung and for U.S.A.	65
4.3	Observed and Estimated Fecundability Rates by Net Duration of Marriage	70
7.1	A Schematic Representation of Different Components of Pregnancy Interval and Their Relationship with the Outcome of Pregnancy	153
7.2	Average Pregnancy Interval Following Live Births by Age of the Mother	171
7.3	Average Pregnancy Interval Following Abortions by Age of the Mother	172
8.1	Theoretical and Observed Number of Live Births by Duration of Marriage	203
8.2	Theoretical and Observed Variance of Live Births by Duration of Marriage	204

CHAPTER I

INTRODUCTION

Objectives

Fecundity, according to the United Nations[1] multilingual demographic dictionary, is the capacity of a man, a woman, or a couple to participate in reproduction. The concept of fecundity sometimes has been used to denote the physiological capability of couples to produce live births in the absence of contraception. "Pure fecundity" or "natural fecundity" is an abstract concept, and it is impossible to measure it empirically in any absolute sense. French demographers[2] have used the term "natural fecundity" to refer to what is observed in the absence of contraceptive practices in a population. This is an unfortunate use of terms, because it implies that there is some "natural" biological state being measured which has a generalizable character. The fact is, however, that the number of children born in a population on the average are affected by many factors other than contraception as indicated by

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[1] Multilingual Demographic Dictionary, United Nations Publication, number ST/SOA/Ser. A/29, English Section.

[2] For example, see L. Henry, "La fécondité naturelle: Observation-theorie-resultats," Population, XVI, No. 4 (1961), 625-36.

Davis and Blake[3] in their exhaustive inventory of so-called "intermediate variables." Many of these factors in turn are affected or can be affected by cultural factors, hence, the measurement of "natural fecundity" is an empirical question involving the comparative study of the cultural determinants of all the different biological factors affecting fertility apart from contraception. All of this is to say, then, that the general character of biological parameters connected with fertility and fecundity cannot be assumed. This must be tested by specific studies in many populations with good samples as a basis for comparison and generalization. This investigation is one of such studies.

In reality, then, the concept of fecundity is restricted by many cultural and environmental factors which vary from population to population, and thus one cannot necessarily generalize the results of one study to different populations. Some of the important cultural and biological factors affecting the operational concept of fecundity are: (1) women's age at marriage affecting the length of reproductive period, (2) the frequency and timing of coitus per menstrual cycle or simply per month affecting the monthly probability of conception known as fecundability, (3) the level of fetal wastage, and (4) the practice of breastfeeding affecting the duration of temporary infecundable period following a live birth. Besides these factors, hereditary, dietary, and general health conditions of couples also affect their physiological ability to reproduce. All of these factors may vary culturally, apart from any influence of contraception.

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[3] K. Davis and J. Blake, "Social Structure and Fertility: An Analytical Frame Work," Economic Development and Cultural Change, IV, No. 3 (April, 1956), 211-35.

Limited, like any other study, with the cultural and environmental factors, the present study is an attempt to study fecundity of couples in Taiwan--a developing country. It would be misleading to say that the results obtained in this study are definitely applicable to Taiwan as a whole not to mention other countries, because our data are taken from an intensive fertility survey[4] conducted in Taichung city--one of five major cities in Taiwan. However, it is likely that cultural variations will be smaller within Taiwan than across major cultural lines. Further, we do not assert that there may not be a general character to the findings once we have other national points of comparison (a few of which we present). We merely want to begin by emphasizing that the cultural limitations which we acknowledge for this study at this time also apply to the other work that has been done. Only the patient accumulation of a number of such culture-limited studies of the biological variables will enable us to determine as a next step just what can be generalized, with what range of error.

Fecundity, as also mentionad by Potter and Sakoda,[5] can be separated into three elements: (1) fecundability, (2) the level of fetal wastage, and (3) infecundable period following the termination of a pregnancy. The concept of fecundability was first used by the Italian demographer Gini[6] to denote the probability of conception per menstrual cycle

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[4]The Taichung Fertility Survey was conducted by Taiwan Population Studies Center in Collaboration with the Population Studies Center of the University of Michigan. For details, see Chapter II.

[5]R. G. Potter, Jr., and J. M. Sakoda, "Family and Fecundity," Population Studies, XX, 3 (March, 1967), 311-28.

[6]C. Gini, "Premières recherches sur la fécondabilité de la femme," Proceedings of the International Mathematics Congress (Toronto, 1924), pp. 889-92.

outside the gestation period and infecundable period following the termination of a pregnancy. Later on many other demographers have used this concept of fecundability. The level of fetal wastage refers to the probability that a pregnancy will terminate in a miscarriage or a still birth. The infecundable period refers to the temporary sterile period following the termination of a pregnancy during which the probability of conception is probably zero. Sometimes this period is divided into two components: the postpartum amenorrhea and the anovulatory period following the postpartum amenorrhea. These estimates of fecundity components are also affected by many factors mentioned earlier including the use of family limitation methods in the population. For example, the effect of using contraception during the fecundable period is to decrease the fecundability level, the effect of using induced abortions is to raise the level of fetal wastage, and the effect of prolonged breastfeeding is to increase the length of postpartum amenorrhea and of the infecundable period following the delivery.

The estimates of fecundity components are important to enhance our knowledge of the human reproduction process. One can use these basic parameters to estimate many demographic indices measuring the fertility level in a population. In the last few decades a number of hypothetical models relating fertility and fecundity components have been developed by different investigators. Dandekar,[7] Brass,[8]

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[7]V. M. Dandekar, "Certain Modified Forms of Binomial and Poission Distributions," Sankhya, XV (1955), 237-50..

[8]W. Brass, "The Distributions of Births in Human Populations," Population Studies, XII, No. 1 (July 1958), 51-72.

Potter,[9] Henry,[10] and Perrin and Sheps[11] are some of the investigators who have tried to develop mathematical models, and to apply them to study the fertility behavior of human populations.

The stochastic fertility model developed by Perrin and Sheps is the only analytical model, so far, in which the investigators have simultaneously considered all three components of fecundity mentioned earlier. This model has received applications in the works of Perrin and Sheps[12] and of Potter.[13] Perrin and Sheps have mainly used hypothetical values of the basic parameters of the model, whereas Potter used the data for Indian women from the Khanna study in which the users were not separated from the nonusers of contraception. The model, however, is properly applicable only to nonusers of contraception. In Western societies contraception is widely practiced for spacing and limiting purposes and thus it is difficult to get suitable data for applying this model.

The Taichung survey provides a good set of data for a large city of size 300,000. This sample provides the detailed information about the pregnancy histories of women included in the sample. In this sample about 84 per cent of the couples in the childbearing ages had never used contraception (excluding induced abortion) between marriage and the last

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[9] R. G. Potter, Jr., "Some Relationships Between Short Range and Long Range Risks of Unwanted Pregnancy," Milbank Memorial Fund Quarterly 38 (1960), 255-63; "Length of the Fertile Period," Milbank Memorial Fund Quarterly, 39 (1961), 132.

[10] L. Henry, "Fécondité et Famille, Modèles Mathematiques," Population, III (1957), 413-44; "Fécondité et Famille, Modèles Mathematiques II," Population, XVI (1961), 27-48 and 261-82.

[11] E. B. Perrin and M. C. Sheps, "Human Reproduction, A Stochastic Process," Biometrics, XX, No. 1 (March 1964), 29-45.

pregnancy prior to interview. Even for the remaining 16 per cent who had used contraception at some time, we can use that part of their pregnancy histories in which contraception was not used. Thus, the Taichung survey provided a set of pregnancy histories free from the use of contraception which can be used to estimate all three components of fecundity in the absence of contraception. These estimates can then be used to apply the Perrin and Sheps model to predict certain demographic indices, which can be compared with the corresponding observed values. Perrin and Sheps' model is used in this study to show the usefulness of the estimated fecundity components in understanding the process of human reproduction. This model is based on simplified assumptions and as such we do not expect a close agreement between the observed and estimated values. Any other existing model of this kind can also be used in the similar manner. The estimates of fecundity components in this sense are general and can be used as input data in any other model of human reproduction.

The two main objectives of this study are: (1) to measure the magnitude and differentials of fecundity components, and (2) to apply these estimates to a stochastic fertility model for measuring the

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[12] M. C. Sheps and E. B. Perrin, "Changes in Birth Rates as a Function of Contraceptive Effectiveness: Some Applications of a Stochastic Model," American Journal of Public Health, LIII (July 1963), 1031-45; "The Distribution of Birth Intervals under a Class of Stochastic Fertility Models," Population Studies, XVII, No. 3 (March 1964), 321-31; Sheps, "Pregnancy Wastage as a Factor in the Analysis of Fertility," Demography, I, No. 1 (1964), 111-18.

[13] R. G. Potter, Jr., J. B. Wyon, M. Parker, and J. E. Gordon, "A Case Study of Birth Interval Dynamics," Population Studies, XIX, No. 1 (July 1965), 81-96.

magnitude of differences between the observed and the estimated values of three demographic indices.

The Model

This is a brief version of the detailed description of the Perrin and Sheps model given in their original paper.[14]

During a given month a woman can only be found in one of four mutually exclusive states: nonpregnant fecundable state 'S_0', pregnant state 'S_1', post-partum infecundable state following a pregnancy loss 'S_2', and post-partum infecundable state following a live birth 'S_3'. A "month" here is used to denote the length of the menstrual cycle. The model is based on the following seven assumptions.

Assumptions

1. Conception is a random event.

2. A woman can get pregnant only when she is in state S_0; in other states the probability of conception is zero.

3. At the time of marriage each woman starts in the nonpregnant fecundable state S_0.

4. The outcome of any pregnancy is a random variable and is independent of the states previously visited or to be visited in future.

5. The durations of her stay in each state are random and independent variables, the distributions of which depend upon the state last visited and/or upon the state to be visited next.

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[14] Perrin and Sheps., op. cit.

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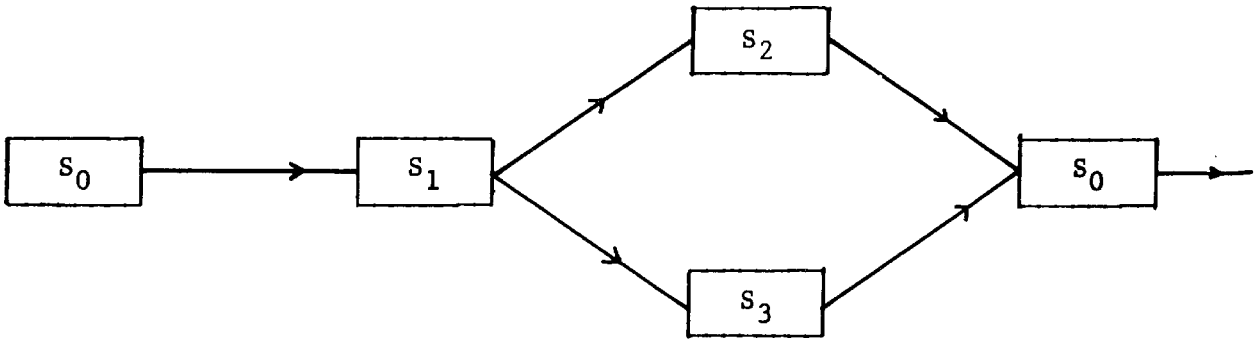
[14] Perrin and Sheps., op. cit.

6. All distributions of duration of stay in each state and all probabilities remain constant over time. For example, every time a woman visits state S_0 or S_1 or S_2 or S_3 she follows the same distribution irrespective of the number of times she has previously visited that state or any other state.

7. The length of the reproductive period is unlimited.

In state S_0 a woman is subject to a constant monthly probability of conceiving. This probability determines the distribution of the length of her stay in state S_0. After a random length of time she passes to state S_1. The duration of her stay in this state S_1 depends upon the state S_2 or S_3 to be visited next. Following the termination of each pregnancy, she becomes temporarily infecundable, the duration of which depends upon the outcome of her pregnancy. If the pregnancy terminates in a pregnancy loss, the woman passes to state S_2, and if the pregnancy terminates in a live birth, she passes to state S_3. After a random length of stay in state S_2 or S_3 she passes to state S_0 and the process begins once more. Perrin and Sheps developed the model for one woman and for its applicability to more than one woman we need to assume that women are homogeneous with respect to all parameters. Based on these assumptions the reproductive process in human females is viewed as a stochastic process.

Schematically



(The length of stay in each state and the outcome of each pregnancy are independent random variables.)

S_0 - Nonpregnant fecundable state

S_1 - Pregnant state

S_2 - Infecundable period following a pregnancy loss

S_3 - Infecundable period following a live birth.

Using rigorous probability theory, Perrin and Sheps obtained averages and variances of many indexes in terms of the basic parameters of the model. Out of these we have selected three indexes to study the differences between the observed and the estimated values from the model by using estimates of fecundity components for Taiwanese women. These indexes are: (1) First birth interval or first passage time from state S_0 to state S_3, (2) Birth interval or waiting time between two consecutive births, and (3) Births during specified periods after marriage, or the number of times a woman visits state S_3 in 't' months after marriage. Mathematical expressions for these indexes are shown in Chapter III.

Limitations of the Model

As pointed out quite clearly by Perrin and Sheps, their model does not take into account (1) the use of contraception, (2) the variations in parameters between different women, (3) changes in parameters over time, that is, influence of such demographic factors as age of women and the order of pregnancy, (4) dependence among different states, and (5) the limited reproductive period. The first limitation of the model is partly eliminated in the present study by considering only that reproductive experience of each woman during which she had not used contraception at all. Since for separating out the experience in which she did not use contraception we relied on the report of women, it is likely that small amounts of unreported contraceptive experiences are included in the present study as nonuse of contraception. As a consequence of the third limitation Perrin and Sheps restricted the childbearing period from 10-15 years in the middle of the childbearing age during which the model can be assumed to hold.

> Hence, the period for which this model can be assumed to hold for each woman must necessarily be restricted to an interval of at most from 10 to 15 years in the middle of the childbearing age.[15]

The result of other limitations can be seen by comparing the observed and expected averages and variances of the three demographic indexes.

The Plan of Presentation

In this chapter we have dealt with the specific objectives of the study and described Perrin and Sheps' model and the assumptions

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[15] Ibid., 33.

briefly. In Chapter II, we shall describe the data and the sample. This includes the source of data used in the present study, a brief description of the sample, the list of variables selected for the present study, and the estimation procedure of the missing data.

The methodology and the mathematical expressions pertaining to Perrin and Sheps' model are presented in Chapter III.

Chapters IV and V are devoted to the detailed analysis of the first fecundity component: fecundability, the monthly probability of conception in the absence of contraception, whenever women are not pregnant, and are not in infecundable period following the termination of a pregnancy. Empirically fecundability is estimated for a group of women, and the estimated fecundability represents the unweighted mean of fecundabilities of individual women in the group. For a group of women homogeneous with respect to their fecundabilities, the average fecundability can simply be estimated by the proportion of women conceiving during their first month after marriage. However, for a group of heterogeneous women the estimation procedure is more complicated. Henry[16] first suggested the use of a Pearson type-I curve to describe the distribution of fecundability among a group of heterogeneous women. Later on Henry[17] himself and Potter[18] et al. used it to estimate average fecundabilities.

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[16]L. Henry, "La fécondité naturell: observation-theorie-resultats," Population, XVI, No. 4 (1961), 625-36.

[17]L. Henry, "Mortalité intra-utérine et fécondabilité," Population, V (1964), 899-940.

[18]R. G. Potter and M. P. Parker, "Predicting the Time Required to Conceive," Population Studies, XVIII, No. 1 (July 1964), 99-116.

In Chapter IV we shall first test empirically the adequacy of the type-I curve, and then shall estimate the average fecundability for Taiwanese women. For this purpose we shall only consider the interval between marriage and the first conception, for each woman in the sample, who got pregnant after marriage. We shall exclude women who used contraception during this period and those who did not get pregnant at least once prior to the date of interview.

Since the data used in the present study were collected retrospectively and the fecundability estimates are based on the length of the first pregnancy intervals only, we suspect that the overall fecundability estimate will be affected by memory bias. Overall fecundability estimates will also be affected by a truncation bias, because the date of the interview truncated the reproductive period of women included in the sample; thus women with longer first pregnancy intervals would not be included in the analysis. These two biases are expected to be closely related with the length of marriage duration; therefore we shall study their effects on fecundability by studying the relationship between fecundability and marriage duration. In the last part of Chapter IV we shall develop and test a hypothesis relating fecundability and age at marriage.

> Hypothesis 4.1: Fecundability is entirely lacking in childhood, begins to appear at the age of 13 to 16 years (puberty), develops gradually for a period of several years (adolescence), and reaches and maintains a high plateau at maturity. It then declines in middle age, relatively rapidly after age 30, and reaches zero by the time of the last menstruation (estimated around 44 years of age).

Since we compute fecundability only from the first pregnancy interval and since most women marry by the time they are 25 years old,

from the available data we shall not be able to test the second part of the above hypothesis, i.e., the relationship between age and fecundability after 25 years of age.

In addition to the above, we shall also study the effects of the memory and truncation biases on the relationship between fecundability and age at marriage. We shall also study whether or not the relationship between fecundability and age is an artifact of the association between age at marriage and the length of marriage duration.

In Chapter V we shall develop and test a hypothesis dealing with the fecundability differentials by socio-economic status of women.

Hypothesis 5.1: Women of higher socio-economic strata have higher fecundability than those belonging to lower socio-economic strata, when their fecundability is measured from the first pregnancy intervals.

For studying the fecundability differentials by socio-economic characteristics we shall use a Pearson type-I distribution to estimate the average fecundabilities for each category of socio-economic characteristics. We shall then study whether the differentials are real or are spurious by separately controlling for marriage duration and wife's age at marriage. In the end we shall use Multiple Classification Analysis program to study the relative importance of each socio-economic characteristic by simultaneously controlling for demographic characteristics and one or more socio-economic characteristics.

Chapter VI deals with the estimation of second fecundity component--the level of fetal wastage. Total fetal wastage rate can, simply, be estimated by the ratio of pregnancies terminating in non-live births and all pregnancies. Since the pregnancy histories in this sample were

collected retrospectively we expect that the apparent level of fetal wastage will be deflated due to memory bias. In Chapter VI we shall develop a method to estimate the effect of memory bias on the level of fetal wastage. We shall then develop and test two hypotheses, dealing with the relationship between fetal wastage and the age of women and the order of pregnancy.

Hypothesis 6.1: The level of fetal wastage increases with the advancing age of the mother.

Hypothesis 6.2: The level of fetal wastage increases with the order of the pregnancy.

In addition to studying the nature of above relationships we shall also study (a) the magnitude of differences in the levels of fetal wastage and (b) how much of each relationship remains when the other is held constant.

The data to estimate directly the average and variance of infecudable periods are not available from this sample; hence in Chapter VII we shall use completed pregnancy intervals[19] to estimate the third fecundity component. This requires a detailed analysis of completed pregnancy intervals. First we shall study the variations in the averages and variances of completed pregnancy intervals by the outcome of the preceding pregnancy. We shall then develop and test a hypothesis dealing with the average length of the pregnancy interval, and the age of mother.

Hypothesis 7.1: The average length of pregnancy interval increases with the advancing age of mother, irrespective of the outcome of the preceding pregnancy.

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[19]The pregnancy interval here is defined as the period between the termination of a pregnancy and the beginning of the next pregnancy.

We shall then develop a method to estimate the effect of memory and truncation biases on the averages and variances of completed pregnancy intervals. The relationships between the average and variance of pregnancy intervals, the outcome of pregnancy and the age of mother shall be examined by considering the estimated moments of pregnancy intervals relatively free from two biases.

In addition to this we shall also study (a) the effect of contraception on the length of the completed pregnancy interval separately for pregnancies terminating in pregnancy losses and for thos terminating in live births, (b) the effect of contraception on the length of pregnancy intervals after controlling for age of mother, and (c) the variations in proportion of women using contraception following the termination of the pregnancy by its outcome. In the end we shall get the estimates of averages and variances of infecundable period following an abortion and following a live birth.

In Chapter VIII we shall use the estimates of fecundity components for predicting the values of three demographic indexes, mentioned earlier, by using the Perrin and Sheps stochastic model of human reproduction, also mentioned earlier. The predicted values of these three indexes shall be compared with the corresponding observed values obtained directly from the data. The comparisons of the observed and the predicted values will show the magnitude of divergencies. This will only provide an example of using these estimates of fecundity components as input data in a fertility model. The applications of estimated fecundity components are, however, not restricted to one model only; they can be applied similarly to any other mathematical or simulation fertility model.

The concluding Chapter IX summarizes the basic findings of the study and discusses their implications for future research regarding the process of human reproduction.

While we have stated the hypotheses to be investigated in a general form, we want to repeat that neither in this study nor in any other study can we assume that the biological parameters being investigated and interrelated are of such a character that they can generally be used without reservations. For example, the estimate of fecundability at which we arrive in this investigation will depend on such matters as the frequency and timing of intercourse shortly after marriage and possibly also on health conditions at that time. These are cultural matters which may affect the biological parameters and their interrelations. While we shall compare the results we get from this study with other studies so far as possible, by and large we are interested in developing parameters and studying their relationships, and using fertility models for a good sample of this one population as a beginning for comparable works in other populations from which it may be possible to say more about what is cultural and what is biological.

CHAPTER II

THE DATA AND THE SAMPLE

Source of Data

The data for this study were obtained from the results of an intensive fertility survey conducted in Taichung city, Taiwan by the Taiwan Population Studies Center, in collaboration with the Population Studies Center of the University of Michigan. Taichung is the fourth largest city of Taiwan with a population of about 300,000; it has an intensely built up urban area at the center and rural areas surrounding it.

The universe of our sample was comprised of about 36,000 married women (estimated as of August 1, 1962) in the ages 20 to 39, living with their husbands in Taichung city, including the three rural districts. The Taichung survey is based on a probability sample of 2,432 married women interviewed towards the end of 1962, just before a year long family planning action program.[1]

Interviewing "before" the action program was conducted in two parts. First, 1,367 women between the ages 20 to 39, denoted as the "original" sample, were interviewed during the period October 26 to

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[1]For the description of the design of the Family Planning Action Program refer to B. Berelson and R. Freedman, "A Study in Fertility Control," Scientific American, CCX, No. 5 (May 1964), 3-11.

December 17, 1962. This sample was supplemented with 1,065 married women between the ages 20 to 39, and with at least two living children, interviewed in January 1963. Thus, in fact only 2,432 married women were interviewed. The two samples were combined by weighting 281 married women with less than two living children in the original sample by a factor of 2, yielding an inflated sample of 2,713 cases. The weighting procedure did not introduce any bias as shown by a separate analysis.[2] Another analysis has shown "that the two samples can be merged safely for most of the variables, but that before using attitudinal variables, a check of the type made here should be carried out."[3] In this analysis, since we are not dealing with any attitudinal variable, the two samples can be merged without introducing any serious bias.

About 90 per cent of the 2,713 cases (or about 2,443) were re-interviewed during the period October to December 1963 just after the completion of the family planning action program. A loss of 270 cases occurred through death, divorce and movement out of the sample area.[4]

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[2]S. Chu, "Weighting the Taichung Fertility Survey (1962) Sample" (The Population Studies Center of the University of Michigan, 1964). (Mimeographed.)

[3]R. Freedman, "Comparability of the Original and Supplementary Samples for the Intensive Taichung Survey" (The Population Studies Center of the University of Michigan, January 1965). (Mimeographed.) In this analysis the distributions of 1,367 women in the original sample and 1,346 women (including duplicated women with 0 and 1 living child) in supplemental sample, are compared for 9 demographic, socio-economic and attitudinal variables. For seven demographic and socio-economic variables, the distributions correspond closely and the differences are within the limits expected on the basis of sampling error; for two attitudinal variables the differences are larger than expected on the basis of sampling variability alone.

[4]181 out of 270 cases had moved out of Taichung and 90 more could not be found at home even after repeated call backs, 32 cases refused, 20 were divorced, separated or had died and 7 cases could not be interviewed because of physical difficulties.

In the present analysis we shall deal only with the 2,443 women who were interviewed both "before" and "after" the action program and consider the pregnancy histories only up to the time of the first interview. The exclusion of 10 per cent of the total sample not interviewed during the second round does not bias the results according to a separate analysis.[5]

Selection of the Sample[6]

The sample is a probability sample representative of about 36,000 married women between the ages of 20 to 39 living in Taichung. The basic design for both the original and the supplemental sample followed a one-stage cluster sampling of "pseudo-lins." The pseudo-lins were formed from the existing lins[7] in such a way that they formed units of 10 to 20 households with eligible women. Out of a population of 2,389 pseudo-lins, 105 were selected with equal probability for the original sample and 104 for the supplemental sample. All eligible women

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[5]S. Chu, "Comparison of Taichung Intensive Survey Respondents Reinterviewed and Not Reinterviewed on Second Interview" (The Population Studies Center of the University of Michigan, December 1964). (Mimeographed.)

[6]"Study 4 Sample: Selection and Disposition" (Taichung Population Studies Center, May 1963). (Mimeographed.)

[7]The lins are basic administrative units of several adjacent households. From these lins the pseudo-lins were formed to get clusters of roughly equal size varying between 10 to 20 cases (households with eligible women). For this purpose, "smaller lins" with fewer than 10 cases were combined with adjacent lins in such a way that the reconstituted group of lins would have at least 10 but no more than 20 cases, and the "larger lins" with 20 or more cases were subdivided into as many parts as there were multiples of 15.

in each selected lin were interviewed, with the restriction that only one woman selected randomly be interviewed from a household with more than one eligible woman. There were only 141 households where such sub-sampling was necessary and they included 319 eligible respondents in all. A separate analysis[8] has shown that (1) the inclusion of these women makes no significant difference with respect to several demographic and socio-economic characteristics and (2) that women living in households with multiple eligible respondents are only slightly different from those living in households with only one eligible respondent. Because these differences are small and because the proportion of such women is small the incomplete inclusion of cases from the mlutiple households is unlikely to bias the distribution of the couples as a whole.

Response Rate[9]

The survey started with a list of 2,627 women from the household register (1,488 in the original and 1,139 in the supplemental sample). In all 2,432 women were interviewed (1,367 in the original and 1,065 in the supplemental sample). This yields in an overall response rate of 92.6 per cent (91.9 per cent in the original sample and 93.5 per cent in the supplemental sample). The outright refusal rate was less than one per cent (0.8 per cent).

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[8] S. Chu, "Households with Several Eligible Respondents in the Taichung Survey, No. 4: Effects of Interviewing Only One in Each Household" (The Population Studies Center of the University of Michigan, December 1963).

[9] For a sophisticated treatment of nonresponse errors in survey data, refer to: L. Kish, Survey Sampling (New York: John Wiley & Sons, 1965), chapter 13.

A canvass identified 2,300 eligible[10] women on the register, plus 215 other eligible women (123 in the original sample and 92 in the supplemental sample), who were living in selected lins, but were not listed in the household registers. These 215 women just about compensated for the 258 women who were listed in the household registers but who either had never lived in the selected lins or had moved out of the area.

To get a correct idea about the nonresponse rate, we should consider the 2,300 eligible women from the original list, out of which 2,217 were interviewed. This gives a very high response rate of 96.4 per cent. The main reason of nonresponse was the inability to locate the respondent after repeated home visits (2.3 per cent). It is possible that this group includes some of the hidden refusals. The nonresponse can introduce a serious bias in the results of the study if the nonresponse rate is high, and if there are reasons to suspect that the respondents falling in the nonresponse category have different characteristics than those in the response category. In this study the nonresponse rate (3.6 per cent) is quite low and thus is quite unlikely to bias the results of the survey.

Data

Extensive information about the various demographic and socioeconomic characteristics, attitudes towards family planning and practice

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[10]The not eligible 327 cases include those where either husband or wife had died before the survey (5), error in registration on eligibility criteria (12), respondent never lived here (54), respondent moved--not shown on register (204), women living with another eligible respondent (52).

of various family planning methods are available for each woman. In this analysis, however, only the following variables are used:

Demographic Variables

1. Wife's age at marriage in completed years.

2. Wife's age at first interview in completed single years.

3. Wife's age at first interview in four five-year age groups: 20-24, 25-29, 30-34, and 35-39 years.

4. Wife's gross and net duration of marriage in nearest months (duration between marriage and interview excluding the temporary separation of 3 months or more, if any).

5. Net length of first pregnancy interval in nearest months (duration between the marriage and the beginning of first pregnancy, excluding the temporary separation of 3 months or more, if any).

6. Net lengths of completed pregnancy intervals in nearest months (duration between the end of one pregnancy and the beginning of the following pregnancy, excluding the temporary separation of 3 months or more, if any).

7. Net length of open pregnancy interval (duration between the end of last pregnancy and the date of first interview, excluding the temporary separation of 3 months or more, if any) in nearest months.

8. Number of total pregnancies.

9. Wife's age at the beginning and the end of each pregnancy interval in completed years.

10. Number of total live births.

11. Period of temporary separation between spouses during two successive pregnancies.

12. Outcome of each pregnancy:

    a. Live birth--still alive, under age 1.
    b. Live birth--still alive, more than age 1.
    c. Live birth--died, under age 1.
    d. Live birth--died, more than age 1.
    e. Fetal death--induced abortion.
    f. Fetal death--miscarriage and still birth.

13. Whether or not premaritally pregnant.

14. Pregnancies between two surveys.

Socio-economic Characteristics

15. Wife's education by highest level of school attended.

16. Husband's education by highest level of school attended.

17. Husband's employment status.

18. Number of modern objects owned.[11]

19. Household's monthly income in New Taiwan (N.T.) dollars.[12]

20. Couple's rural background: urban, rural, or mixed.

21. Couple's ethnic background: Taiwanese, Mainlanders, or mixed.

22. Family structure.

Contraceptive Variables

23. Use of contraception between two successive pregnancies:

    a. Never used anything.
    b. Used contraception only after this interval.
    c. Contraception used all the time--accident.
    d. Contraception used less than all the time--accident.
    e. Contraception used--no accident.
    f. N.A. if used contraception in this interval but used before and/or after this interval.

Most of the variables used in this analysis are taken directly from the data processing cards on which information from two surveys are available. Some new variables, e.g., net lengths of pregnancy intervals,

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[11] The modern objects (consumer items) referred to are: bicycle, radio, radio with phonograph, motorcycle, electric iron, sewing machine, subscription to daily newspaper, private toilet, running water, electric rice-cooker, and time piece.

[12] 1 U.S. dollar = 40 New Taiwan dollars (official exchange rate).

ages at the beginning and at the end of each pregnancy interval are created from the available information on the cards. Missing lengths of pregnancy intervals are estimated from the available information. The reference date for supplemental sample is shifted from "after" survey to "before" survey. The detailed description of these procedures follows.

Estimation of the Missing Data

For 87 cases (5 in the original and 82 in the supplemental sample) the lengths of two or more pregnancy intervals are missing. In almost all cases the year of termination of each of the pregnancies involved and their outcomes are given. From this information, the missing lengths of pregnancy intervals are estimated along the following general lines.

Let us consider a case for which the lengths of n-th and (n+1)-th pregnancy intervals are missing and the year of termination and outcome of n-th pregnancy are given. The year and month of (n-1)-th and (n+1)-th pregnancies and their outcomes are also given. In this case the lengths of n-th and (n+1)-th pregnancy intervals are estimated as follows:

1. If, X = net duration between the end of (n-1)-th pregnancy and the beginning of (n+1)-th pregnancy excluding the gestation periods of n-th and (n+1)-th pregnancies.

   or, X = [year and month in which (n+1)-th pregnancy terminated] - [year and month in which (n-1)-th pregnancy terminated] - a - b.

   Where, a = 9 months, if (n+1)-th pregnancy terminated in a live birth,

   a = 3 months, otherwise.

b = 9 months, if n-th pregnancy terminated in a live birth,

b = 3 months, otherwise.

2. Y = year of termination of n-th pregnancy - year in which (n-1)-th pregnancy terminated.

3. Z = year in which (n+1)-th pregnancy terminated - year in which n-th pregnancy terminated.

4. Then, Estimated length of n-th pregnancy interval
= Period between the end of (n-1)-th pregnancy and the beginning of n-th pregnancy

$= X \cdot Y / (Y+Z)$

5. Estimated length of (n+1)-th pregnancy interval
= Period between the end of n-th pregnancy and the beginning of (n+1)-th pregnancy

$= X \cdot Z / (Y+Z)$.

6. Numerical Example

Let us suppose that for a woman the fifth and the sixth pregnancy intervals are missing and the following information is given:

The fifth pregnancy was terminated in May 1950, the sixth pregnancy was terminated in 1952 and the seventh pregnancy was terminated in July 1955. The sixth pregnancy was terminated by an abortion and the seventh pregnancy was terminated in a live birth. Then using the procedure described above, the fifth and the sixth pregnancy intervals are estimated as follows:

X = (July 1955) - (May 1950) - 9 - 3 = 50 months.

Y = 1952 - 1950 = 2

Z = 1955 - 1952 = 3

The estimated length of the fifth pregnancy interval
= 2x50/5 = 20 months.

The estimated length of the sixth pregnancy interval
= 3x50/5 = 30 months.

7. A similar procedure is applied in estimating three or more pregnancy intervals.

Shifting the Reference Date for the Supplemental Sample

For the original sample, the data on pregnancies were collected at the time of the first interview and then brought up-to-date at the time of the second interview, but for the supplemental sample they were collected at the time of the second interview only. Thus the following adjustments were needed for the supplemental sample:

1. For 802 cases with no pregnancy between the two surveys:

   12 months are subtracted from the open pregnancy interval and the gross and net duration of marriage (in months). This is done on the assumption that the difference between the two interviews on the average is 12 months.

2. For 175 cases with one pregnancy between the two surveys:

   a. Let n be the number of pregnancies to the second interview.

   b. Then number of pregnancies to first interview = n-1.

   c. The open pregnancy interval to first interview = the open pregnancy interval to second interview + length of n-th pregnancy interval + gestation period[13] for n-th pregnancy - 12 months.

   d. Net (or gross) months married to first interview = Net (or gross) months married to second interview - 12 months.

3. For 3 cases with two pregnancies between the two surveys:

   a. Let n be the number of pregnancies to second interview.

   b. Number of pregnancies to first interview = n-2.

   c. The open pregnancy interval to first interview = the open pregnancy interval to the second interview + length of the n-th and (n-1)-th pregnancy intervals - the gestation periods for n-th and (n-1)-th pregnancies.

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[13]The gestation period of any pregnancy is assumed to be 9 months if the pregnancy is terminated in a live birth and 3 months otherwise.

d. Net (or gross) months married to first interview = net (or gross) months married to second interview - 12 months.

Computation of New Variables

1. Net Lengths of Pregnancy Intervals

On the original data processing cards, the gross[14] lengths of pregnancy intervals are coded. There were 378 women (226 in the original sample and 152 in the supplemental sample) who had one or more separations of three months or more. The pregnancy intervals during which these separations occurred are also known. In order to get the net lengths of pregnancy intervals, we subtracted the lengths of separations from the corresponding gross lengths of pregnancy intervals. The months of separations are subtracted on the assumption that the probability of conceiving during this period is close to zero. The effect on the mean length of pregnancy interval of subtracting the lengths of separations is to reduce it by about 1/2 month. Thus, the net length of pregnancy interval measures the net period required for conception. In 29 pregnancy intervals, the length of separation was greater than the length of pregnancy interval, in such cases the net lengths of pregnancy intervals are coded as zero months. This might indicate some inconsistencies in reporting the dates of separations and termination of pregnancies. The magnitude of this discrepancy is quite small.

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[14] Gross length of $\overline{n}$-th pregnancy interval is obtained as follows: (month and year in which n-th pregnancy terminated) - (month and year in which (n-1)-th pregnancy terminated) - gestation period for the n-th pregnancy. In 156 cases, the gross lengths of the first pregnancy interval is less than zero because they were premaritally pregnant. In 13 cases other pregnancy intervals had gross lengths that were less than zero. In all these cases the gross lengths were coded zero month.

2. Age of Women at the Beginning and at the End of Each Pregnancy Interval

First these ages are obtained in months and then are converted into completed years, the procedure is described below:

a. Age at the beginning of the n-th pregnancy interval = Age at the end of (n-1)-th pregnancy interval + Gestation period of the n-th pregnancy.

b. Age at the end of the n-th pregnancy interval = Age at the beginning of the n-th pregnancy interval + Length of the n-th pregnancy interval.

c. For n=1, Age at the beginning of the first pregnancy interval = Age at marriage.

d. Age at marriage is given in completed years. It is converted into age in months by multiplying it by 12.

For consistency check, we compared the age at the end of the open pregnancy interval with the present age of women coded in completed single years. This comparison showed that in 475 cases the difference between the two is more than 6 months but less than a year, and in 145 cases the difference between the two is more than a year. These 145 cases are, then, checked against the original interview schedules and discrepancies are removed. The difference of one year or less is allowed because this difference could arise due to the fact that we first converted age at marriage from completed years into months, and then we converted all ages from months into completed years. This comparison shows that the coding and punching errors are small.

CHAPTER III

METHODOLOGY

Introduction

In this chapter we shall consider the mathematical expressions involved in estimating the mean and variance of (1) conception delay, (2) first birth interval, (3) completed birth interval and (4) number of live births during t months after marriage. The basic equations are taken from the work of Perrin and Sheps.[1] Necessary changes in these equations have been made because we have considered only two outcomes of a pregnancy: pregnancy loss (which includes spontaneous abortion, induced abortion and stillbirth), and live birth, instead of three considered by Perrin and Sheps in the original paper, separating miscarriages from stillbirths. The results of the model are general with respect to number of pregnancy outcomes. In another paper Sheps[2] used four different outcomes of a pregnancy for the same results as presented in the original paper.

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[1]E. B. Perrin and M. C. Sheps, "Human Reproduction: A Stochastic Process," Biometrics, XX, No. 1 (March 1964), 28-45.

[2]M. C. Sheps, "Pregnancy Wastage as a Factor in the Analysis of Fertility," Demography, I, No. 1 (1964), 111-18.

These formulae are strictly applicable only if we assume that women are homogeneous with respect to all parameters; that these parameters are independent of age and parity; and that the reproductive period is unlimited. In reality, Taiwanese women in the present sample are heterogeneous with respect to all parameters, these parameters are age and parity dependent (as shown in subsequent chapters) and the reproductive period is limited. The heterogeneous group of women can be considered as made up of different homogeneous groups and then the overall parameters for the heterogeneous group can be considered as the weighted averages of such parameters of these homogeneous subgroups. Consequently the equations presented in this chapter oversimplify the relationships for a heterogeneous population, especially those expressing variances since different covariance terms are assumed to be zero. The relationships are further complicated due to the limited length of reproductive period. Due to these limitations we do not expect that the predicted values of indices would agree closely with the observed values. Nevertheless it is useful to measure how small or great are the discrepancies between the values observed and the values estimated by a model which has the virtue of simplicity.

In the next section we have summarized the notations being used in presenting the results. The later part of the presentation is divided into four sections, each dealing with conception delay, first birth interval, completed birth interval, and number of live births respectively.

Notations

In this chapter we shall use a simplified system of the

notations similar to those of Potter et al.[3] instead of those used by Perrin and Sheps.[4]

Let p denote the monthly probability of conceiving whenever women are in state S_0.

Let P(AB) and P(LB) denote the probabilities of pregnancies ending in abortion, and live birth respectively. Here abortion includes spontaneous abortion, induced abortion, and stillbirth. It is understood that the sum of two probabilities is equal to 1.

The symbol M( ) denotes a mean, V( ) a variance, and the symbols S( ), and T( ) denote second and third moments about the origin. Letters contained in ( ) identify the type of interval and when relevant, the outcome of pregnancy to which the interval is conditional.

Other abbreviations used are given below:

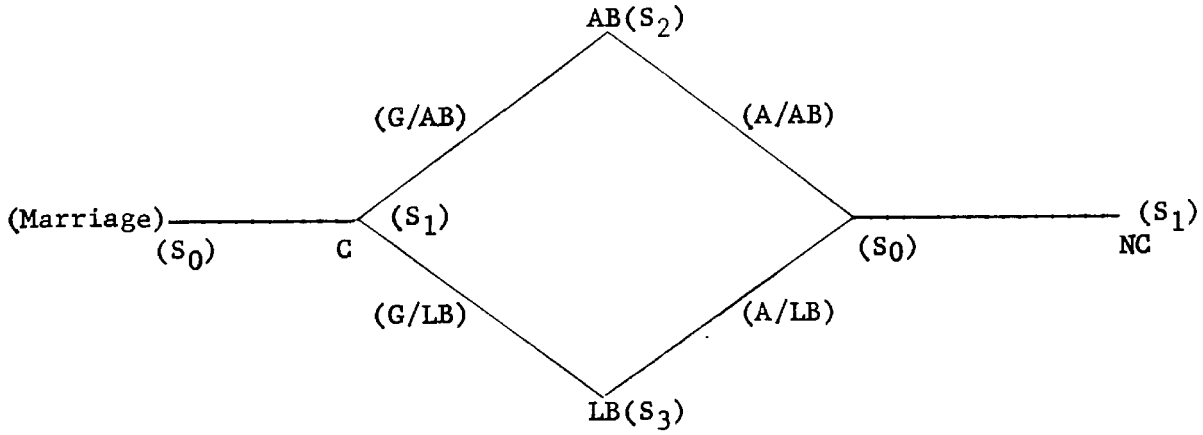
Symbol	Description
FP	Fecundable period--the duration of stay in state S_0.
G	Gestation period--the duration of pregnancy in state S_1.
AB	Abortions including spontaneous abortions, induced abortions, and stillbirths.
LB	Live births.
A	Infecundable period following the termination of a pregnancy--sum of postpartum amenorrhea and anovulatory period.
ABNC	Period between abortion and the beginning of next conception--the duration of stay in states S_2 and S_0.
LBNC	Period between live birth and the beginning of next conception--the duration of stay in states S_3 and S_0.
FBI	First birth interval--waiting time between onset of marriage and first live birth.
BI	Completed birth interval--waiting time between successive live births.
W	Time added by an abortion.

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[3]R. G. Potter, Jr., J. B. Wyon, M. Parker and J. E. Gordon, "A Case Study of Birth Interval Dynamics," Population Studies, XIX, No. 1 (July 1965), 81-96.

[4]Perrin and Sheps, op. cit.

Schematically corresponding to the states of the model:



For example,

M(FP/LB) represents the mean length of fecundable period following a live birth.

V(A/AB) represents the variance of infecundable period following an abortion.

S(BI) represents the second moment of birth interval about its origin.

In the model we assume that the distribution of fecundable period, i.e., the waiting time in state S_0 is independent of the preceding state visited, that is, the distribution of fecundable period is the same for both pregnancy outcomes. According to this assumption: M(FP) = M(FP/AB) = M(FP/LB) and similarly for V(FP), S(FP), and T(FP).

For the convenience we have also assumed the following equalities, which follow from the assumption of independence between different states of the model:

$$M(ABNC) = M(A+FP/AB) = M(A/AB) + M(FP)$$
$$V(ABNC) = V(A+FP/AB) = V(A/AB) + V(FP)$$
$$M(A+G/AB) = M(A/AB) + M(G/AB) = M(ABNC) - M(FP) + M(G/AB)$$
$$V(A+G/AB) = V(A/AB) + V(G/AB) = V(ABNC) - V(FP) + V(G/AB).$$

Analogous expressions for the other outcome live birth are also assumed.

Certain parameters receive the following assumed values, because these values cannot be estimated by the available data.

M(G/AB) = 3	M(G/LB) = 9
V(G/AB) = 1	V(G/LB) = 1
S(G/AB) = 10	S(G/LB) = 82
T(G/AB) = 36	T(G/LB) = 756

Similar values of M and V have been used by other investigators. The value of S is estimated from the expression: $S = M^2 + \hat{V}$, and for getting the values of T(G/AB) and T(G/LB), we have assumed that the third and higher order moments of the gestation period about its mean are zero; thus, $T - 3SM + 2M^3 = 0$ or $T = 3SM - 2M^3$.

From the available data we can only estimate the value of P(AB), P(LB), and the moments of FP, ABNC and LBNC. Hence all the other moments are expressed in terms of the moments of these parameters. Hence the expressions presented in this chapter are somewhat different than those presented by Perrin and Sheps.

Estimation of P(AB) and P(LB)

(PAB) is estimated from the proportion of all pregnancies terminated by abortions.

$$\text{i.e., } P(AB) = \frac{\text{[Number of pregnancies (for all women) in the sample that terminated in an abortion]}}{\text{[Total number of completed pregnancies (for all women) in the sample]}}$$

= Weighted mean of such proportions for each woman, weights being the number of pregnancies.

Its complement is the probability of a live birth: P(LB) = 1 - P(AB).

Estimation of Moments of the Fecundable Period (FP)

Moments of fecundable period (FP) are obtained from the frequency distribution of the period between marriage and the beginning of the first pregnancy. Perrin and Sheps obtained these moments by using the estimated value of fecundability "p." Justification for this replacement is given in the next section. For this purpose we have considered only those women who were married for 3 to 8 years, because these women are comparatively free of memory and truncation biases. This point is discussed in more detail in Chapter IV.

Estimation of Moments of the Periods "from Abortion to Next Conception" (ABNC) and "from Live Birth to Next Conception" (LBNC)

Moments of ABNC and LBNC are estimated from the frequency distributions of pregnancy intervals following an abortion and following a live birth respectively. Pregnancy intervals during which contraception was used are excluded in computing these moments.

Moments of Conception Delay

Conception delay is defined as the time spent by a woman in the fecundable, nonpregnant state S_0 until the first pregnancy after marriage or until the next pregnancy after entering into fecundable nonpregnant state following the termination of a pregnancy. From the present sample we do not have independent observations on nonfecundable periods associated with pregnancy outcomes; hence second and higher order pregnancy intervals cannot be used to get the observed moments of conception delay. Therefore, only first pregnancy intervals, which are

free from the nonfecundable periods associated with pregnancy outcomes, are used to get observed moments of conception delay. We excluded women who were definitely premaritally pregnant, and those who used contraception during the first pregnancy interval; also women without at least one pregnancy.

Perrin and Sheps[5] estimated the moments of conception delay for a homogeneous group of women on the following assumptions:

1. Conception is a random event.
2. The fecundability "p" of each couple in the population remains constant from month to month, and couples are homogeneous with respect to p.
3. Size of sample is adequate.

On the above assumptions, the waiting time (FP) in a fecundable nonpregnant state follows a geometric distribution. Two types of waiting time have been distinguished in the literature, depending on two different ways of counting the months of exposure: (1) the months of exposure is counted as x months if the conception occurred in x^{th} month or (2) the months of exposure is counted as x months when the delay to conception is exactly x months, i.e., the conception occurred in $(x+1)^{th}$ month. Sheps[6] denoted these two different variables as number of trials during which conception occurs and conception delays; she used the latter to estimate the mean and variance of conception delay. If the conception occurs in the x^{th} month the mean and variance of conception

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[5] Ibid., 35.

[6] Sheps, op. cit.

delay are q/p and q/p^2 (where $q = 1-p$) whereas the mean and variance of number of trials are $1/p$ and q/p^2. Average conception delay is one month shorter than the average number of trials, whereas both variables have same variance.

For estimating the mean and variance of conception delay we need to estimate the value of fecundability p. This is estimated in Chapter IV by assuming that the couples are not homogeneous with respect to the fecundability, and that among couples, p is distributed according to Pearson's Type-I distribution. We cannot use this estimate of p to estimate the moments of conception delay in a homogeneous population, which assums a constant p.

In Chapter V the fecundability p is also estimated by using the proportion of women conceiving during the first month after marriage. This inflates the value by about 50 per cent because of a coding problem, and this estimate cannot be used for the present purpose. For the purpose of estimating the moments of conception delay on the assumption of homogeneity, the fecundability p is estimated by using the following expression:

p = [(Number of women for whom the period between marriage and first conception is coded as 0 month) + 1/2 (Number of women for whom the period between marriage and first conception is coded as one month)] / (Total number of women with at least one pregnancy)

Only half of those coded one month are taken because this code refers to all women who conceived from 1/2 to 1 1/2 months after marriage.

The estimated fecundability p is 0.171 for the entire sample. The model based on homogeneity yields 4.8 and 27.8, as estimates of the

mean and variance of conception delay; this compares to 8.2 and 138.8 observed from the data on the distribution of the period between marriage and first conception, which takes account of the heterogeneity among couples. The observed values of the mean and variance of conception delay are much higher than the estimated ones. We do not need any statistical test to show the significance of these differences, and the assumption for such test are not met by the data when a student t-test is applied.

The gross underestimation of the estimated mean and variance of conception delay can be attributed mainly to the gross violation of the assumption of homogeneity. This conclusion is consistent with Sheps's remark about conception delay in a heterogeneous population.

> Since the harmonic mean of any distribution is smaller than its arithmetic mean, the mean delay in a heterogeneous population is accordingly longer than might be expected from the arithmetic mean of the distribution or the proportion conceiving in the first month.[7]

Similar comparisons between observed and estimated means and variances of conception delay are shown in Table 3.1 for each age at marriage year. If women marrying at a given age are more homogeneous than all women getting married at different ages, then we would expect observed moments for each age group to be closer to the estimated moments.

Comparisons of averages in Column 5 of Table 3.1 shows that the differences between observed and estimated averages for separate age groups are quite close on the average to the difference for total sample and that for all ages the observed averages are higher than the

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[7] Ibid.

Table 3.1.--Comparison of Observed and Estimated Mean and Variance of Conception Delay by Wife's Age at Marriage, in the Absence of Contraception[a]

Age at marriage (in completed years)	1000 p	Mean			Variance		Estimated variance per 100 observed variance	Number of women
		Observed	Estimated[b]	Difference	Observed	Estimated[c]		
12-15	130	13.4	6.6	6.8	265.5	50.2	18.9	69
16	118	11.7	7.4	4.3	150.8	62.2	41.2	110
17	109	10.4	8.2	2.2	214.6	75.4	35.1	211
18	120	9.2	7.3	1.9	97.0	60.6	62.5	292
19	158	8.7	5.3	3.4	145.6	33.4	22.9	386
20	171	7.2	4.8	2.4	99.9	27.8	27.8	373
21	162	6.4	5.1	1.3	84.3	31.1	36.9	234
22	210	6.4	3.7	2.7	127.3	17.4	13.7	186
23	240	6.0	3.2	2.8	51.2	13.4	26.2	125
24	375	5.3	1.7	3.6	102.6	4.6	4.5	72
25	274	6.4	2.6	3.8	98.2	9.4	9.6	62
26+	329	8.9	2.0	7.9	444.2	6.0	1.4	70
Total	171	8.2	4.8	3.4	138.8	27.8	20.0	2190

[a]Women who are definitely premaritally pregnant or have no pregnancy are excluded.

[b]Mean conception delay = $(1/p) - 1$.

[c]Estimated variance = $(1-p)/p^2$.

estimated ones. Note also that from ages 17 to 24 the differences are considerably smaller than the overall. Similarly the comparisons of variances in Column 8 shows that the observed variances for each age group is higher than the corresponding estimated variance. The probability[8] that this would happen due to random fluctuations is quite low, 1 in 4096. These comparisons indicate that by dividing women into different age-at-marriage groups probably a part of the heterogeneity is removed, but women in age groups are not homogeneous enough to predict the moments of conception delay from a geometric distribution. Another reason for this divergence between observed and estimated moments may be the violation of the assumption that the fecundability "p" remains constant from month to month.

Since the observed distribution of conception delay is different than the expected one based on the assumption of homogeneity, we are justified to use the observed frequency distribution of conception delay in the later parts of the analysis for estimating the moments of conception delay, instead of using the estimated value of fecundability p for this purpose as done by Perrin and Sheps. This substitution, however, does not violate the applicability of Perrin and Sheps's model, so long as we assume that the distribution of conception delay is the same for each visit to state S_0. This is quite clear from Perrin and Sheps's following remark:

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[8]The probability that for any group the observed value will be higher than the estimated value by chance is 1/2. Assuming independence among all 12 groups, the probability that for all groups the observed values will be higher than the corresponding estimated values by chance is $(1/2)^{12}$ or 1/4096.

The assumption of a constant probability of pregnancy per cycle, and the resulting geometric distribution of waiting times in the fecundable, nonpregnant state S_0, can, of course, be relaxed somewhat without destroying the Markov Renewal property of the model. In particular, the probability of conception may be allowed to vary with the time spent in the nonpregnant, fecundable state S_0, as long as the distribution is the same for each visit to S_0, without altering the results which follow except for the substitution of the appropriate moments of the new distribution.[9]

Moments of Waiting Time Between Onset of Marriage and First Live Birth Denoted as First Birth Interval (FBI)

Dividing the mean[10] first birth interval into three components, we have

$$M(FBI) = M(FP) + M(G/LB) + M(W) \tag{1}$$

where

$$M(W) = \frac{P(AB)}{P(LB)} [M(G/AB) + M(A/AB) + M(FP)]$$

$$= \frac{P(AB)}{P(LB)} [M(G/AB) + M(ABNC)] \tag{2}$$

Similarly the variance[11] of first birth interval can also be written as the sum of variances of its three components as follows:

$$V(FBI) = V(FP) + V(G/LB) + V(W) \tag{3}$$

where

$$V(W) = \frac{P(AB)}{P(LB)} [V(G/AB) + V(A/AB) + V(FP)] + \frac{P(AB)}{[P(LB)]^2} [M(G/AB) + M(A/AB) + M(FP)]^2$$

$$= \frac{P(AB)}{P(LB)} [V(G/AB) + V(ABNC)] + \frac{P(AB)}{[P(LB)]^2} [M(G/AB) + M(ABNC)]^2 \tag{4}$$

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[9] Perrin and Sheps, op. cit., 34.

[10] Ibid., 38. Refer to equation (13).

[11] Ibid. Refer to equation (14).

First, the moments of first birth interval are computed from the frequency distribution of the observed periods between marriage and the first live birth. Then these moments are estimated by using the expressions (1) and (3). These observed and estimated moments of FBI are then compared to check the applicability of Perrin and Sheps's model.

Moments of Waiting Time between Successive Live Births or Completed Birth Intervals (BI)

Dividing the birth interval into four components, we have the following expressions for the mean[12] of completed birth intervals.

$$M(BI) = M(G/LB) + M(A/LB) + M(FP) + M(W)$$

Substituting $M(LBNC) = M(A/LB) + M(FP)$

we have $$M(BI) = M(G/LB) + M(LBNC) + M(W) \quad (5)$$

where M(W) is given by expression (2).

Similarly the variance[13] of birth intervals can be written as

$$V(BI) = V(G/LB) + V(A/LB) + V(FP) + V(W).$$

Substituting $V(LBNC) = V(A/LB) + V(FP)$,

we have $$V(BI) = V(G/LB) + V(LBNC) + V(W) \quad (6)$$

where V(W) is given by expression (4).

The second moment S(BI) of birth interval about its origin is given by the following expression:

$$S(BI) = V(BI) + [M(BI)]^2 \quad (7)$$

and the third moment[14] T(BI) of birth interval about its origin is given by the following expression:

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[12] Ibid., 37. Refer to equation (8).

[13] Ibid. Refer to equation (12).

[14] Ibid., 41. Refer to equations.

$$T(BI) = \frac{1}{P(LB)} [c + 3db + 3ae] + 6d^2a \quad (8)$$

where $a = M(BI)$ (9)

$$b = M(FP) + P(AB) \cdot S(A + G/AB) + P(LB) \cdot S(A + G/LB) \quad (10)$$

$$c = M(FP) + P(AB) \cdot T(A + G/AB) + P(LB) \cdot T(A + G/LB) \quad (11)$$

$$d = a - M(A + G/LB) \quad (12)$$

$$e = b - P(LB) \cdot S(A + G/LB) \quad (13)$$

First we shall calculate the mean and variance of birth intervals from the observed distributions of completed birth intervals. Then we shall estimate the mean and variance of birth interval by using expressions (5) and (6). These observed and estimated means and variances of birth interval shall then be compared to check the applicability of Perrin and Sheps's model. Second and third moments of birth intervals about the origin shall be estimated by using expressions (7) and (8). These estimated values shall then be used to estimate the mean and variance of live births in t months (see next section).

For estimating the third moments of birth interval we need to estimate $S(A + G/AB)$, $S(A + G/LB)$, $T(A + G/AB)$ and $T(A + G/LB)$. Expressions for estimating the other values have already been given in earlier sections. Below are given the expressions to estimate these values.

Second Moment about the Origin

We know that $S(A + G/AB) = V(A + G/AB) + [M(A + G/AB)]^2$. Substituting from expressions given in the section on notations, we have

$$S(A + G/AB) = [V(ABNC) - V(FP) + V(G/AB)] + [M(ABNC) - M(FP) + M(G/AB)]^2.$$

$$\text{Similarly, } S(A + G/LB) = [V(LBNC) - V(FP) + V(G/LB)] + [M(LBNC) - M(FP) + M(G/LB)]^2$$

Third Moment about the Origin

$$T(A + G/AB) = T(A/AB) + 3S(A/AB)\, M(G/AB) + 3M(A/AB) \cdot S(G/AB) + T(G/AB)$$

Where $M(A/AB) = M(ABNC) - M(FP)$

$$S(A/AB) = V(A/AB) + [M(A/AB)]^2$$

or $$S(A/AB) = [V(ABNC) - V(FP)] + [M(ABNC) - M(FP)]^2$$

and $$T(A/AB) = T(ABNC - FP/AB)$$

$$= T(ABNC) - 3S(ABNC) \cdot M(FP) + 3M(ABNC) \cdot S(FP) - T(FP).$$

Similarly,

$$T(A + G/LB) = T(A/LB) + 3S(A/LB)\, M(G/LB) + 3M(A/LB)\, S(G/LB) + T(G/LB)$$

where $M(A/LB) = M(LBNC) - M(FP)$

$$S(A/LB) = [V(LBNC) - V(FP)] + [M(LBNC) - M(FP)]^2$$

and $$T(A/LB) = T(LBNC) - 3S(LBNC)\, M(FP) + 3M(LBNC)\, S(FP) - T(FP)$$

Expected Number and Variance of Live Births During a Given Time t Months after Marriage

The expected number[15] of live births in t months of marriage assuming that the woman starts in the fecundable nonpregnant state, is approximately given by the following expression:

$$E[LB(t)] \simeq \frac{t}{M(BI)} + \frac{S(BI)}{2[M(BI)]^2} - \frac{M(FBI)}{M(BI)} \qquad (14)$$

The variance[16] is approximately:

$$V[LB(t)] \simeq \frac{V(BI)}{[M(BI)]^3} \cdot t + \frac{5[S(BI)]^2}{4[M(BI)]^4} - \frac{2T(BI)}{3[M(BI)]^3} - \frac{S(BI)}{2[M(BI)]^2} - \frac{M(FBI) \times S(BI)}{[M(BI)]^3} + \frac{V(FBI)}{[M(BI)]^2} + \frac{M(FBI)}{M(BI)} \qquad (15)$$

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[15] Ibid., 39. Refer to equations.

[16] Ibid. Refer to equation (16)

From the observed data we know the number of births each woman had during a given period (say t months) after marriage. By considering women married for at least t months, we shall calculate the average and the variance of live births during 6 months. For simplicity these values shall be calculated for each 12 month interval.

From the two expressions given above we shall get two linear equations as functions of duration of marriage t: one expressing the estimated average number of live births; and the other expressing the variance of live births. These expressions can be evaluated by substituting the estimated values in the right hand sides of expressions (14) and (15). The expressions for estimating the values in the right hand side of these expressions are given in earlier sections. Now substituting 12, 24, 36, ..., etc. for t in these two expressions we shall obtain the estimated average and variance of live births during 1, 2, 3, ..., etc. years after marriage.

The observed values of averages and variances shall, then, be compared with the estimated values to check the applicability of Perrin and Sheps's model. The expressions (14) and (15) will give only the approximate values of averages and variances of live birth in t months of marriage. However, as Perrin and Sheps[17] have noted, these expressions yield a good approximation to the exact moments within five years of marriage. Thus the approximate expressions shall yield different results than those obtained by using the exact expressions, only during the first five years of marriage.

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[17] Ibid., 43.

Thus the differences between the observed values and the estimated values (obtained by using the approximate expressions) will have two components: (1) difference due to using approximate expressions instead of exact expressions, and (2) difference due to the nature of the model. In testing a model we usually are interested in considering the latter component chiefly which here cannot be separated from the former component for the first five years. However, the differences between observed and estimated values after five years would reflect chiefly the magnitude of second component.

CHAPTER IV

FECUNDABILITY AND ITS DEMOGRAPHIC CORRELATES

Introduction

The present chapter deals with the first fecundity component--fecundability, which, as used by the Italian demographer Gini,[1] is the probability of conception in the absence of contraception, outside the gestation period and the infecundable period following the termination of a pregnancy. Pure fecundability or natural fecundability is an abstract concept. All measures of fecundability for real populations are more or less culturally affected by the frequency and timing of intercourse during the menstrual cycle, nutrition, health, and genetic selection. In this sense, the fecundability estimates obtained in this chapter and in the next chapter refer to Taiwanese women living in the large city of Taichung, and they cannot be generalized necessarily for any other population.

Empirically fecundability is estimated for a group of women and the estimated fecundability represent the unweighted mean of fecundabilities of individual women in the group. Fecundability estimates are required for using the fertility models such as that of Perrin and

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[1] C. Gini, "Premiéres recherches sur la fécondabilité de la femme," Proceedings of the International Mathematics Congress (Toronto, 1924), pp. 889-92.

Sheps.[2] Fecundability is one of the eleven "intermediate variables" considered by Davis and Blake[3] in their model for explaining the fertility differentials among different societies or among different groups within a society.

In this chapter we shall first study the average fecundability for all women in the sample, then we shall study the effects of two biases, the memory bias and the truncation bias, on overall fecundability by controlling for the marriage duration, and finally we shall study the relationships between the fecundability and women's age at marriage.

Previous Work

The models which have been considered to estimate fecundability can be divided into three main groups, namely, (a) hypothetical models based on "the length of fertile period" and "the frequency of coitus per menstrual cycle," (b) models based on completed family size and (c) models based on the interval between marriage and first conception. These models are considered one by one for ready reference.

Models Based on the Length of Fertile Period and the Frequency of Coitus per Menstrual Cycle

Glass and Grebenik,[4] Tietze,[5] and Potter[6] used two different

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[2]E. B. Perrin and M. C. Sheps, "Human Reproduction: A Stochastic Process," Biometrics, XX, No. 1 (March 1964), 29-45.

[3]K. Davis and J. Blake, "Social Structure and Fertility--An Analytical Frame Work," Economic Development and Cultural Change, IV, No. 3 (April 1956), 211-35.

[4]D. V. Glass and E. Grebenik, The Trends and Pattern of Fertility in Great Britain, Vol. I, London.

[5]C. Tietze, "Probability of Pregnancy Resulting from a Single Unprotected Coitus," Fertility and Sterility, XI (1960), 485.

[6]R. G. Potter, "Length of the Fertile Period," Milbank Memorial Fund Quarterly, XXXIX (1961), 132.

models to estimate theoretical values of fecundability. Basically, both models are based on the length of fertile period (F) and the frequency of coitus per menstrual cycle (n). The length of menstrual cycle, that is, the duration between the end of one menstruation period and the beginning of the next menstruation period, on an average is assumed to be 25 days. Conception cannot take place during all these 25 days; the period during which conception is possible is termed as fertile period and its length is assumed as F days. The rest (25-F) days is the sterile period during which conception is not possible.

One model assumes that at most one effective coitus occurs during any 24 hour span. If couples randomly have n coitus during the 25 days, then, according to this model, the probability that all n coitus will occur outside the fertile period F is $[\binom{25-F}{n}/\binom{25}{n}]$, and hence, the probability that at least one coitus will occur during the fertile period is $[1 - \binom{25-F}{n}/\binom{25}{n}]$. This quantity provides an indirect and rough estimate of monthly probability of conception on a further assumption that the coitus which occurs during the fertile period yields a conception. This assumption depends on many biological and environmental factors, namely, the nature of ovulation, the quality of ovum, and the quality and volume of sperm, etc. Besides these limitations this model is also limited for only integral values of F and hence has limited uses.

The second model eliminates the last limitation to the first model, but it also is subject to the remaining limitations. This model allows an equal chance of coitus to occur at any time during intermenstruation period of 25 days, and hence can also be applied to

nonintegral values of F. According to this model the probability that 1,2,3,...,n coitus will occur during sterile period of (25-F) days are $\frac{25-F}{25}$, $(\frac{25-F}{25})^2$, $(\frac{25-F}{25})^3$, ... , $(\frac{25-F}{25})^n$. Hence, the probability that out of n coitus at least one will occur during the fertile period of length F is $[1 - (\frac{25-F}{25})^n]$.

Both these models give hypothetical estimates of fecundability, and the second model is used in the present analysis simply to study the hypothetical variation in monthly probability of conception by variations in the coital frequency.

Model Based on Completed Family Size

James[7] obtained estimates of fecundability by indirect methods, making use of the total number of children born to couples over 45 in a population reputed to completely avoid contraception. He estimated the value of average fecundability for Hutterite married women aged 45 and over, by using the number of children born to them during their child-bearing period after marriage. He ends up with an interval estimate for average fecundability of 0.035 to 0.045 when the value of m is 10 months (m=pregnancy period + post partum sterility of one month); and 0.05 to 0.06 when m is given a value of 18 months. These estimates, which assume that all women are homogeneous with respect to their fecundability, are obviously very low.

Brass[8] presented two theoretical models to represent the distribution of births in human populations. He assumes that births occur

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[7]W. H. James, "Estimates of Fecundability," Population Studies, XVII, No. 1 (July 1963), 57-65.

[8]W. Brass, "The Distribution of Births in Human Population," Population Studies, XII, No. 1 (July 1958), 51-72.

at random at an expected rate E over a fixed period exposed to the risk. He further assumes that E remains constant for each mother, and that the distribution of E is continuous and is described by a Pearson type--III curve. The density of E can then be expressed by $\frac{a^k E^{k-1}}{\sqrt{(k)}} e^{-aE}$ where a and k are two constants. This model leads to a truncated negative binomial distribution of mothers of completed fertility by number of births if cessation of exposure during pregnancy is ignored. However, if cessation of exposure during pregnancy is considered, the model leads to a more complicated distribution.

Later, James,[9] using Brass's model derived an estimate of mean fecundability as $kb/N(1-b)$; where N is the number of ovulations at risk and $b = a/a+T$ if T is the period for which all mothers are exposed to the risk. Using the distribution of births among Hutterite women aged 45 and over, James estimated their average fecundability as 0.07 corresponding to a postpartum sterility period of 3.6 months, and 0.08 corresponding to a postpartum sterility period of 6.1 months. These estimates of fecundability are much too low.

Models Based on Intervals Between Marriage and First Conception

Potter[10] and his colleagues also made use of a Pearson Type III distribution in their work. In their model, one of the assumptions was that the fixed risk of accidental pregnancy per unit of exposure time varies among couples as a Pearson Type III curve. They fitted this

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[9] W. H. James, op. cit., 61.

[10] R. G. Potter, Jr., P. C. Sagi and C. F. Westoff, "Improvement of Contraception During the Course of Marriage," Population Studies, XVI, No. 2 (November 1962), 160-74.

curve to the contraceptive experience of couples between marriage and first pregnancy. The estimates of mean risks per month of exposure ranged between 0.0380 and 0.0609, and standard deviations ranged between 0.0536 and 0.1134. Potter and his colleagues used this technique for estimating "how much these couples [the couples in their sample] would have to improve their initial contraception in order to realize, by contraception alone, the calibre of family limitation claimed by respondents late in their childbearing period."[11]

Tietze[12] later used the trial and error method to fit an arbitrary three point distribution of fecundabilities to the data drawn from the Indianapolis Study. Following him, Potter[13] in his work also used the same method to fit an arbitrary triangular density of fecundabilities. Henry,[14] in his criticism of Potter's model suggested using a Pearson Type I curve to represent the distribution of fecundability among couples. Henry himself used it later.[15] Recently, Potter and Parker[16] constructed a model for predicting the time required for

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[11] Ibid., 170.

[12] C. Tietze, "Differential Fecundity and Effectiveness of Contraception," The Eugenics Review, L (January 1959), 231-34.

[13] R. G. Potter, "Length of the Observation Period as a Factor Affecting the Contraceptive Failure Rate," Milbank Memorial Fund Quarterly, XXXVIII (April 1960), 142-44.

[14] L. Henry, "La fécundité naturelle: Observation-theorie-resultats," Population, XVI, No. 4 (1961), 633.

[15] L. Henry, "Mortalité intra-utérine et fécondabilité," Population, XIX, No. 5 (October 1964), 899-940.

[16] R. G. Potter and M. P. Parker, "Predicting the Time Required to Conceive," Population Studies, XVIII, No. 1 (July 1964), 99-116. This paper gives the detailed discussion of assumptions and the mathematics involved in the model. Some of them are included in the present chapter for ready reference.

conception. In this model, following Henry's suggestion, they assumed that fecundability among couples is distributed according to a Pearson Type I curve. Basically, this model is used in the present analysis to estimate the average fecundabilities and their standard errors.

Type III curve cannot be used in the present analysis, because for using it the value of p has to be very small, and this is not the case. We cannot use the models suggested by Brass and James, because from this sample we do not have data on completed family size. Models based on the length of the fertile period and the frequency of coitus, cannot be used at present due to nonavailability of the required data. This leaves us with the Type I geometric model used by Potter and suggested by Henry. James[17] has only one objection that the fecundability of women pregnant at marriage cannot be assessed by using this type of models which are based on the first pregnancy intervals only. For this reason, we have excluded women who were definitely premaritally pregnant from our estimate of fecundability based on Type I model. A brief description of the model follows.

The Model: The model rests on the four assumptions.

1. Conception is a random event.
2. Fecundability "p" of each couple remains constant from month to month until pregnancy.
3. Fecundability among couples is distributed according to a Pearson Type I curve.
4. The number of couples is adequate.

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[17] W. H. James, op. cit.

The second assumption is not far from reality since we are dealing with first pregnancy intervals only. The variation in anovulatory cycles and coital frequency probably will not be big enough during first pregnancy interval to cause any significant difference in the monthly probability of conceiving. During any anovulatory cycle, the probability of conceiving is zero, and its presence violates the second assumption. However, first pregnancy intervals can be assumed free of anovulatory cycles because anovulatory cycles, generally occur after the termination of pregnancies. Hence the monthly probability of conceiving during first pregnancy interval can be assumed free of variations in anovulatory cycles. The effect of variation in coital frequency on monthly probability of conceiving can be indirectly estimated by using one of the models discussed earlier.[18] If the second model is used, then for women for whom the length of the fertile period is 18 hours, the monthly probability of conception varies between .115 to .306 depending on whether the coital frequency per menstrual cycle is 4 or 12. The results are shown in Table 4.1. Thus, if for any couple, the coital frequency varies as much as between 4 to 12, then the second assumption will not be valid. But it can probably be assumed that for any couple the coital frequency will not vary much from month to month during first pregnancy interval, except for unusual circumstances which can be assumed to be distributed randomly in the population.

Another source of variation in the second assumption is the temporary separation of spouses, because during the period of separation,

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[18] Models based on "length of fertile period" and "coital frequency" are discussed earlier.

Table 4.1: Hypothetical[a] Monthly Probability of Conceiving per Cycle by Length of Fertile Period and Coital Frequency per Cycle

Number of coitus per cycle (n)	Length of fertile period in hours, per cycle (F)				
	12	18	24	36	48
4	.078	.115	.151	.219	.284
5	.096	.141	.185	.266	.341
6	.114	.167	.217	.310	.394
7	.132	.192	.249	.352	.442
8	.149	.216	.279	.390	.487
9	.166	.240	.308	.427	.528
10	.183	.263	.335	.461	.566
11	.199	.285	.362	.494	.600
12	.215	.306	.387	.524	.632

[a]Monthly probability of conceiving per menstruation cycle = $[1 - (\frac{25-F}{25})^n]$ where F is the length of the fertile period per cycle and n is the number of coitus per cycle.

the monthly probability of conception reduces to zero. However, if separation occurs for a short period and does not coincide with the fertile period during the month, then it will have no effect on the monthly probability of conception. To avoid this problem, temporary separation of three months or more are excluded from the length of first pregnancy intervals.

If women using contraception discontinue its use in order to get pregnant, then it is more likely that some of them would try to increase the monthly probability by increasing their coital frequency during the fecundable period. Since in this analysis we are not dealing with women using contraception, the variation in monthly probability of conceiving

on this account would be close to zero. However, this assumption of constant monthly probability will be violated whenever an unreported miscarriage of six or eight weeks occurs before the first reported pregnancy, because in such cases the fecundability is reduced to zero for a couple of months.

For a group of women homogeneous with respect to their fecundability level p and who satisfy the assumptions 1, 2, and 4, the probabilities of conceiving during 1st, 2nd, 3rd, ..., nth months after marriage in the absence of contraception or after its discontinuation, are p, qp, q^2p, ..., $q^{n-1}p$, respectively (where $q = 1-p$). This means that the conception delay or average time taken for conception follows a geometric distribution with mean q/p and variance q/p^2. Women are not homegeneous with respect to their fecundability level and the third assumption in the model allows for the heterogeneity among women.

This assumption is generalized by Sheps[19] in her model to predict the time required for conception. She assumes that the fecundability varies between couples in the population in an unspecified way. This generalized assumption might be better for predicting the time required for conception, because it does not restrict the distribution of fecundability among couples; but it does not help much in estimating the average and variance of fecundability from a sample of women. For this purpose she only uses the observed proportion of conceptions during the first and second months and ignores the conceptions of 3rd, 4th, ..., etc. months. On the other hand, by specifying the distribution of

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[19] M. C. Sheps, "On the Time Required for Conception," Population Studies, XVIII, No. 1 (July 1964), 85-97.

fecundability as is done by assumption 3, the conceptions of all months are used in estimating the average and variance of fecundability. This is not a criticism of Sheps's model, but only a justification for specifying a distribution of fecundability among couples instead of leaving it unspecified.

The density function f(p) of fecundability p with assumption 3 added to 1,2, and 4 is $f(p) = p^a(1-p)^b / B(a,b)$; $0<p\leq 1$ and $a,b>1$ where $B(a,b) = \int_0^1 p^a(1-p)^b dp$.

The mean, mode, and variance of fecundability are given by the following expressions:

Mean $= \bar{p} = a / a+b$

Mode $= p' = (a-1) / (a+b-2)$

Variance $= V^2 = a \cdot b / (a+b)^2(a+b+1)$

In order to estimate the values of mean, mode, and variance of p, we have to estimate the values of two parameters a and b.

Under the assumptions of this model the average and variance of time required to conceive are given by the following expressions:

Mean $= M = (a+b-1) / (a-1)$

Variance $= S^2 = ab(a+b-1) / (a-1)^2 \cdot (a-2)$.

Mean is not defined unless parameter a exceeds 1 and variance is not defined unless a exceeds 2.

Proportion of women P(j) conceiving during the jth month after marriage is given by the expression:

$$P(j) = \int_0^1 p(1-p)^{j-1} f(p)dp = B(a+1,b+j-1)/B(a,b)$$

$$= \frac{a!(b+j-1)!}{(a+b+j-1)!} \times \frac{(a+b-2)!}{(a-1)!(b-1)!}$$

$$= \frac{a \cdot b \cdot (b+1) \ \ldots \ (b+j-2)}{(a+b)(a+b+1) \ \ldots \ (a+b+j-1)}, \text{ for } j = 2,3,\ldots,\text{etc.}$$

For $j = 1$, $P(1) = a/a+b$.

The number of women conceiving during jth month is $N(j) = NxP(j)$, where N is the total number of women in the sample.

For any group of women N, the standard error of $\bar{p}$, the mean fecundability, under the assumption of simple random sampling is $\frac{V}{\sqrt{N}}$. In the present analysis this will give a rough estimate of standard error of $\bar{p}$. This estimate will be subject to (1) the sampling design effect, probably a small downward bias; and (2) sampling variability in two estimated parameters a and b. If a and b for the population were known, then $\frac{V}{\sqrt{N}}$ would give a closer estimate of standard error of $\bar{p}$.

To reduce typing and reading errors the results are presented after multiplying with a constant 1,000. These estimates of average fecundability can be termed "fecundability rates" per 1,000 women. They can be interpreted as the number of women out of a group of 1,000 women who conceive in the absence of contraception during one month. Thus, they are consistent with other measures of vital statistics like fertility rates, etc., also computed on bases of 1,000.

Testing the Goodness of Fit of the Model

The testing of the model with empirical data requires three different steps. First, estimating the values of mean M, and variance S^2 by using the length of the first pregnancy interval. Second, equating the estimated values m and s^2 to M and S^2 respectively. Third, solving for two parameters a and b in terms of m and s^2. The estimated values of a and b are given below:

$$\hat{a} = 2s^2 / (s^2 - m^2 + m)$$

and,

$$\hat{b} = (\hat{a}-1)\cdot(m-1)$$

The observed data should satisfy the condition:[20] $s^2 > m(m-1)$; otherwise the estimated value of parameter a will be less than 2 for which the variance s^2 is not defined. Whenever this condition is not satisfied the type-I model cannot be fitted.

The values of $\bar{p}$, p' and V^2 can be estimated by substituting the estimated values of a and b in expressions given earlier. The expression for estimating $\bar{p}$ is given below:

$$\text{Estimated } \bar{p} = 2s^2 \,/\, [s^2(m+1) + m(m-1)^2]$$

Similar expressions for p' and V^2 can be obtained easily.

Third, computing the expected values of P(j) for j = 1,2,..., etc., then comparing them with the observed proportions of women conceiving during successive months after marriage. Chi-square test is applied to test the statistical significance of the differences between the observed and estimated number of women conceiving during each successive month after marriage.

Adjustments

For computing the mean and variance of the variable ' time required for conception ', the pregnancy intervals which are coded as

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[20] We know that variance s^2 is defined only when $\hat{a} > 2$. We also know that $\hat{a} = 2.s^2 \,/\, s^2 - m^2 + m$. Now $\hat{a}$ will be greater than 2 if and only if,

$$\frac{s^2}{(s^2 - m^2 + m)} > 1,$$

or $$s^2 > (s^2 - m^2 + m) > 0,$$

or $$0 > -m^2 + m \quad \text{and} \quad s^2 > m^2 - m$$

or $m(m-1)$ is greater than 0 and s^2 is greater than $m(m-1)$; combining the two, we have the required condition $s^2 > m(m-1) > 0$.

zero months have been assigned a value of .25 months. This is done because the coded value of zero months represents a period of 15 days or less, the midpoint of which is .25 month. Coded months j ($j > 0$) represent the number of women who conceived during $(j - 1/2)$ and $(j + 1/2)$ months, and in these cases j represents the midpoint of the interval $(j - 1/2)$ and $(j + 1/2)$.

For comparing estimated number of women conceiving during jth month with those observed during jth coded month, the latter values needed some adjustment. In order to make observed values comparable to the estimated values, the coded values have been adjusted as follows:

1. Women conceiving during first month = women for whom the length of pregnancy interval is coded as zero month + 1/2 women for whom it is coded as 1 month.
2. In general, women conceiving during the jth month ($j > 1$) = 1/2 [women for whom the length of the pregnancy interval is coded as (j-1) months + women for whom it is coded (j) months].

For the purpose of estimating the average fecundability and its variance, only the intervals between marriage and first reported conception are considered. This is done in order to eliminate the effect of variable length of postpartum sterility associated with the pregnancy outcomes on later pregnancy intervals. Furthermore, we excluded women who said that they were premaritally pregnant, or that they definitely had used contraception between marriage and the beginning of first pregnancy; and those who did not conceive even once up to the time of first interview. Out of 2443 women, 158 were premaritally pregnant, 27 had used contraception during first pregnancy interval, and 68 did

not conceive even once by the time of interview. Exclusion of these women will probably not bias the estimates of fecundability to a great extent.

Results

The results comparing the observed and estimated proportion of women during each successive month after marriage are shown in Table 4.2 and in Figure 4.1. The comparative data for the USA based on the FGIMA[21] study are also shown in Table 4.2. The value of Chi-square for deviations of observed from estimated values of the Taiwan sample is 22.11, which is not significant at the 5 per cent level of significance; it corresponds to a level of about 10 per cent with 14 degrees of freedom.[22] The value of Chi-square for FGIMA sample is 110, which is highly significant. It is quite clear from differences in Table 4.2 and in Figure 4.1 that for Taiwan the observed and estimated values are very close to each other. All the differences except one are below 1 per cent. The estimated values are higher than the observed values for 2 to 8 months; from 9 months on the observed values are higher. One of the reasons for getting as high value of Chi-square as 110 for the FGIMA sample, given by Potter and Parker is the inflated proportion of women

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[21]Here FIMA refers to Family Growth in Metropolitan America Study. For description about the sample, etc., see C. F. Westoff, R. G. Potter, P. C. Sagi, and E. G. Mishler, Family Growth in Metroplitan America (Princeton, N. J.: Princeton University Press, 1961). In the present analysis the results are quoted from a paper based on FGIMA study, R. G. Potter, M. P. Parker, "Predicting the Time Required to Conceive," Population Studies, XVIII, No. 1 (July 1964), 99-116.

[22]In a test of goodness of fit 17 classes are distinguished. Sixteen degrees of freedom are reduced to 14 because two parameters are being estimated from the sample data.

Table 4.2: Observed and Estimated[a] Number of Months Required for Conception in the Absence of Contraception for Taichung and United States

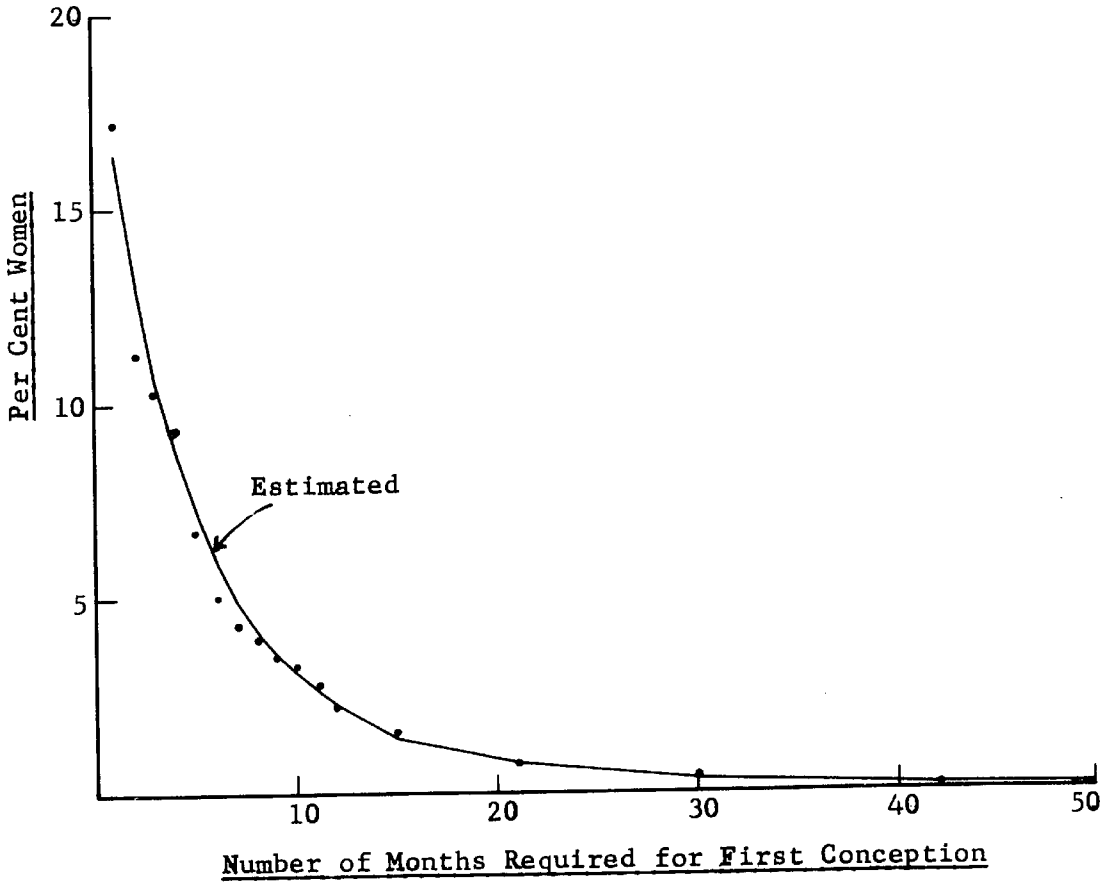
Months required to conceive	Taichung[b]			United States[c]		
	Observed	Estimated	Difference	Observed	Estimated	Difference
1	17.1%	16.3%	0.8%	28.2%	14.4%	13.8%
2	11.3	13.0	-1.7	12.4	11.8	0.6
3	10.3	10.5	-0.2	11.6	9.7	1.9
4	9.2	8.6	0.6	5.7	8.6	-2.3
5	6.6	7.1	-0.5	5.9	12.4	-6.5
6	5.0	5.9	-0.9			
7	4.2	4.9	-0.7	10.0	12.6	-2.6
8	4.0	4.1	-0.1			
9	3.5	3.5	0.0			
10	3.2	3.0	0.2	6.3	8.2	-1.9
11	2.7	2.6	0.1			
12	2.2	2.2	0.0			
13-18	9.1	8.4	0.7	9.0	14.3	-5.3
19-24	4.4	4.0	0.4			
25-36	4.4	3.4	1.0	5.7	6.3	-0.6
37-48	1.3	1.2	0.1			
49+	1.5	1.3	0.2	5.3	2.4	2.9
Total: %	100.0	100.0		100.1	100.1	
N	2190			458		
Mean	8.20			10.08		
Variance	138.82			288.46		
Chi-square	22.11			110.00		
$\hat{a}$	3.48			2.92		
$\hat{b}$	17.89			17.34		

[a]Estimated on the assumption that fecundability p among couples is distributed according to Pearson Type I-curve.

[b]Women who are definitely premaritally pregnant and/or who had no pregnancy by the time of first interview are excluded.

[c]From R. G. Potter and M. P. Parker, "Predicting the Time Required to Conceive," Population Studies, XVIII, No. 1 (July 1964), 103, Table 1.

Figure 4.1: Number of Months Required for First Conception: Observed and Estimated, Taichung



conceiving in first month; more than 50 per cent of the discrepancy was contributed by the difference for the first month. In the case of Taiwan this difference is small (less than 1 per cent) as are all others.

In the reported absence of contraception, the average interval between marriage and first conception is 8.2 months with 60 per cent of the intervals coded as 6 months or less and 79 per cent of the intervals coded as 12 months or less. The corresponding figures for the FGIMA sample are 10 months, 64 per cent and 80 per cent respectively. The difference of two months between the two averages can partially be due to the fact that in Taiwan only 2.8 per cent of women took more than three years to conceive as compared to 11 per cent in the FGIMA sample. It is quite likely that these intervals include appreciably more contraceptive exposure for the FGIMA sample than for the Taiwan sample simply because more women are using contraception in the USA than in Taiwan, which could explain the longer conception delay in the USA. This speculation is supported by the fact that when corrected for contraceptive exposure, the mean conception delay for the FGIMA sample reduced to 8.1 months,[23] which is about the same as for Taiwan.

The estimated fecundability rate for Taiwanese women is 163 per 1,000 women with a standard error of 2. The estimated model value of fecundability is 128, which is less than the estimated average fecundability. The value of Pearson's[24] measure of skewness is 0.45, which shows that the distribution of fecundability among Taiwanese women is

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[23] R. G. Potter, C. F. Westoff, and P. C. Sagi, "Delays in Conception: A Discrepancy Re-examined," Eugenics Quarterly, X, No. 2 (June 1963), 53-58.

[24] Skewness = (Mean - Mode) / Standard Deviation.

positively skewed. The corresponding value for the FGIMA survey is 0.16, which shows that the distribution of fecundability among American women is also positively skewed though less than that among Taiwanese women. The two probability distributions are compared in Figure 4.2. These probabilities[25] are obtained by using a computer program to evaluate the incomplete Beta functions for given values of two parameters a and b.

The overall fecundability value 163 $\pm$ 2 is subject to two types of biases: (1) "memory" bias and (2) "truncation" bias. As a result of memory bias the overall estimate is being pulled down, but it is being pulled up due to truncation bias. We shall consider these two biases separately.

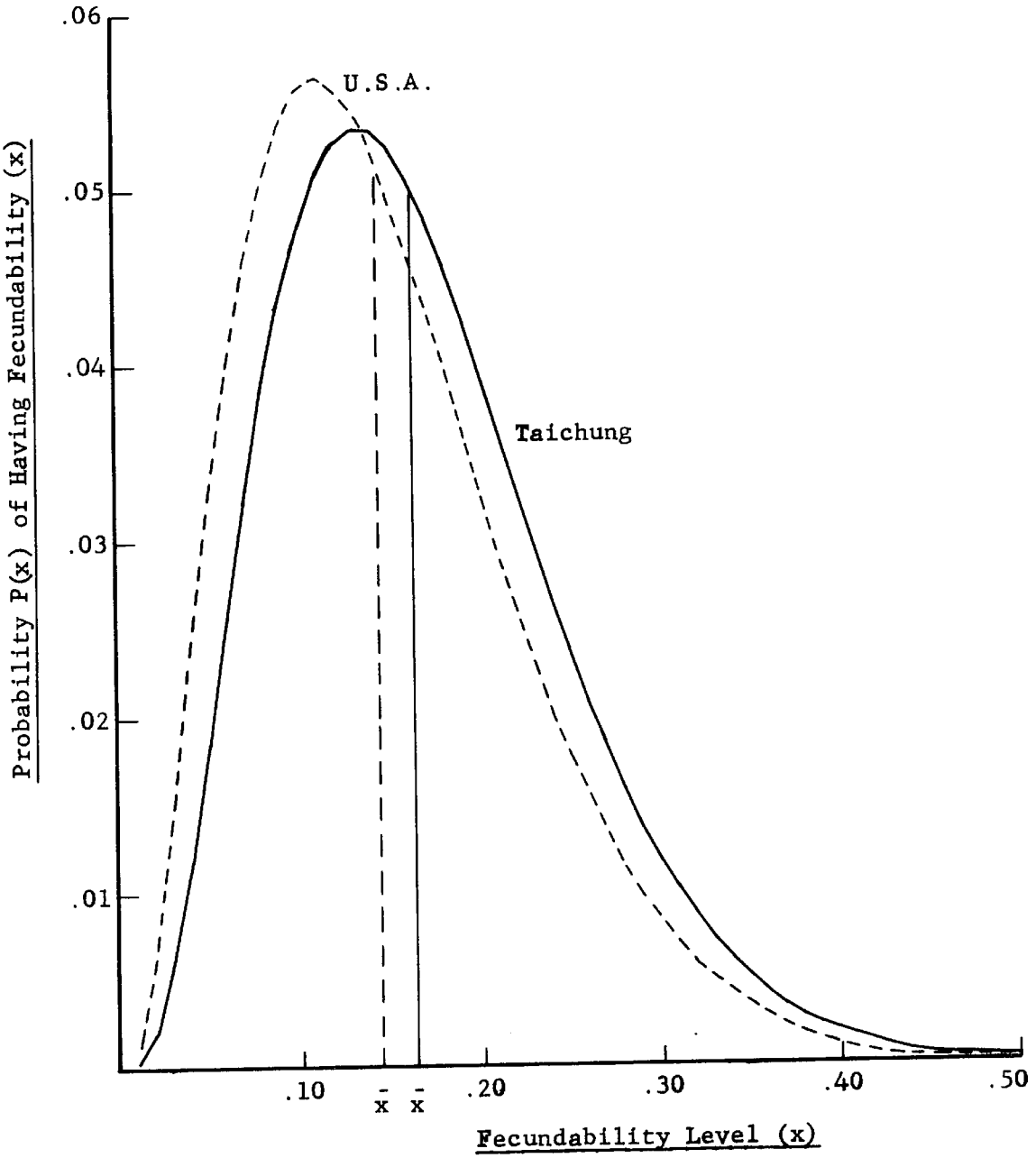
Memory Bias

The memory bias arises due to the fact that the Taichung survey is a one point survey and the information about pregnancy histories was collected at the time of interview. Recall lapses regarding retrospective demographic events are known to occur, especially when the events

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[25] Using $I(x,a,b) = \int_0^x \frac{f(p)dp}{B(a,b)} = \int_0^x p^a(1-p)^b dp \;/\; \int_0^1 p^a(1-p)^b dp$, the values of $I(x,a,b)$ are obtained for $x = .01, .02, \ldots, 1.00$, each of these values represent the proportionate area under the fecundability curve between 0 and x. By subtracting these values subsequently, we can obtain the areas between intervals 0-.01, .01-.02, etc. Given that the width .01 of these intervals is quite small, the area between the interval 0-.01 can be represented by the ordinate at $x = .005$, and the area between the interval .01-.02 by the ordinate at $x = .015$, and so on for other intervals. These ordinates are denoted by $P(x)$, which represents the proportion of women with fecundability x. $N \cdot P(x)$ gives the number of women with fecundability x, where N is the total number of women in the sample.

Figure 4.2: Theoretical Probability Distributions of Fecundabilities for Taichung and for U.S.A.



refer to loss of a child.[26] In the present analysis, since we are dealing not only with all live births but also with all pregnancy losses, it is quite reasonable to expect that some women in the sample were not able to recall all of their pregnancies. The effect of recall lapse in general shall be considered in a separate chapter. At present we shall restrict our attention to its effects on the length of first pregnancy interval which indirectly affects the overall fecundability estimate.

Two types of memory biases which can effect the fecundability estimates are: under-reporting of pregnancy losses, and mis-reporting of the occurrence time of marriage and of all first conceptions. Let us denote these two biases as type-I and type-II memory biases respectively. The effect of the type-I, considered in detail below, is to underestimate the overall fecundability. The effect of the type-II depends upon the nature of the error; if the first pregnancy interval is lengthened (or shortened) as a result of type-II memory bias, then the fecundability estimate shall be deflated (or inflated).

It can be seen from the expression for $\bar{p}$ that its estimate is a function of mean conception delay m and variance s^2. If there were some under-reporting of pregnancy losses and some women had reported their first live birth, instead of a miscarriage or abortion as their first pregnancy, then the estimated mean m would be higher than the true M and the estimated $\bar{p}$ would be lower than the true p. The under-reporting of pregnancy losses would also increase the estimated

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[26] For example see R. K. Som, "On Recall Lapses in Demographic Studies," International Population Conference (Vienna, 1959), pp. 50-61.

variance s^2, but this will have smaller effect on an estimate of $\bar{p}$, because s^2 appears both in its denominator and numerator. Thus it can be seen that under-reporting of pregnancy losses will tend to underestimate the overall fecundability value.

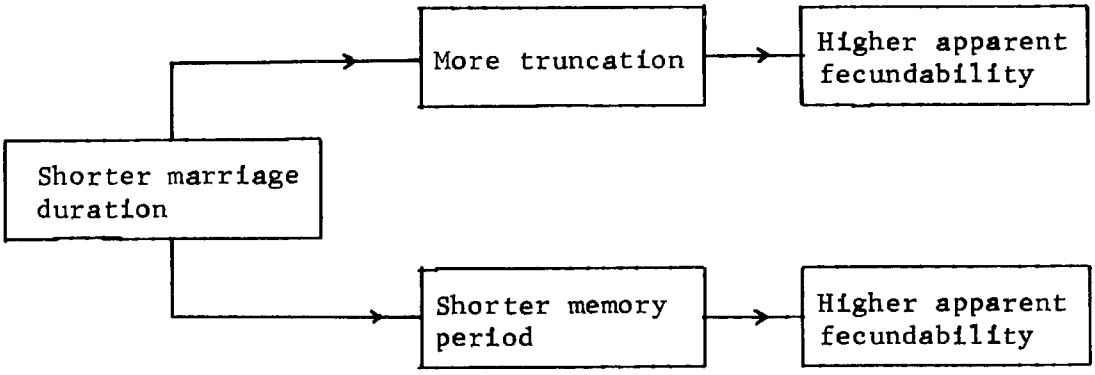
It can safely be assumed that recall lapse is a function of the period between the occurrence of an event and its reporting date, and that the likelihood of under-reporting first pregnancy loss and misreporting the occurrence time of events increases with ascending marriage duration. Therefore, we can expect that women married for a longer period will tend to have poorer recall of early conceptions and of the occurrence time of events than those married for a shorter period, and this will tend to lower the fecundability estimate for the former group more than for the latter.

Truncation Bias

The Taichung survey includes a cross section of married women at different stages in their childbearing process. All of these women did not get the same period of exposure and the date of interview truncated their childbearing experience. In estimating overall fecundability we are including women with at least one conception; hence given short marriage duration, a woman cannot be included in the analysis at all unless her first reported conception is comparatively prompt with the result that short marriage duration selects for quick conceptions, thereby inflates apparent fecundability. On the other hand, given long marriage duration, comparatively sub-fecund women will also be included in the analysis and the overestimation will be less. Thus, it can be

said that the longer the marriage duration the lower the effect of truncation on apparent fecundability.

In above paragraphs we have postulated that the two biases work in opposite directions, memory bias tends to underestimate the overall fecundability and the truncation bias tends to overestimate it. The two biases are related to the marriage duration, i.e., the shorter the marriage duration the lesser the effect of memory bias and the longer the marriage duration the lesser the effect of truncation bias. Schematically: (for shorter marriage duration)



(Comparisons are made with the fecundability estimates for longer marriage duration and not with the true fecundability values.)

To control for these two biases, it is essential to control for marriage duration. Table 4.3 and Figure 4.3 show the fecundability estimates by marriage duration (in net single years, excluding the period of separation). These estimates are obtained on the assumptions of Type-I model discussed earlier.

Marriage duration can be divided into five segments with distinct fecundability levels: 0-2 years, 3-8 years, 9-11 years, 12-16 years and 17 years or more. There is a sharp drop in fecundability as

Table 4.3: Observed[a] and Estimated[b] Fecundability Rates per 1000 Women by Net Months of Marriage Duration, in the Absence of Contraception for Women with at Least One Pregnancy[c]

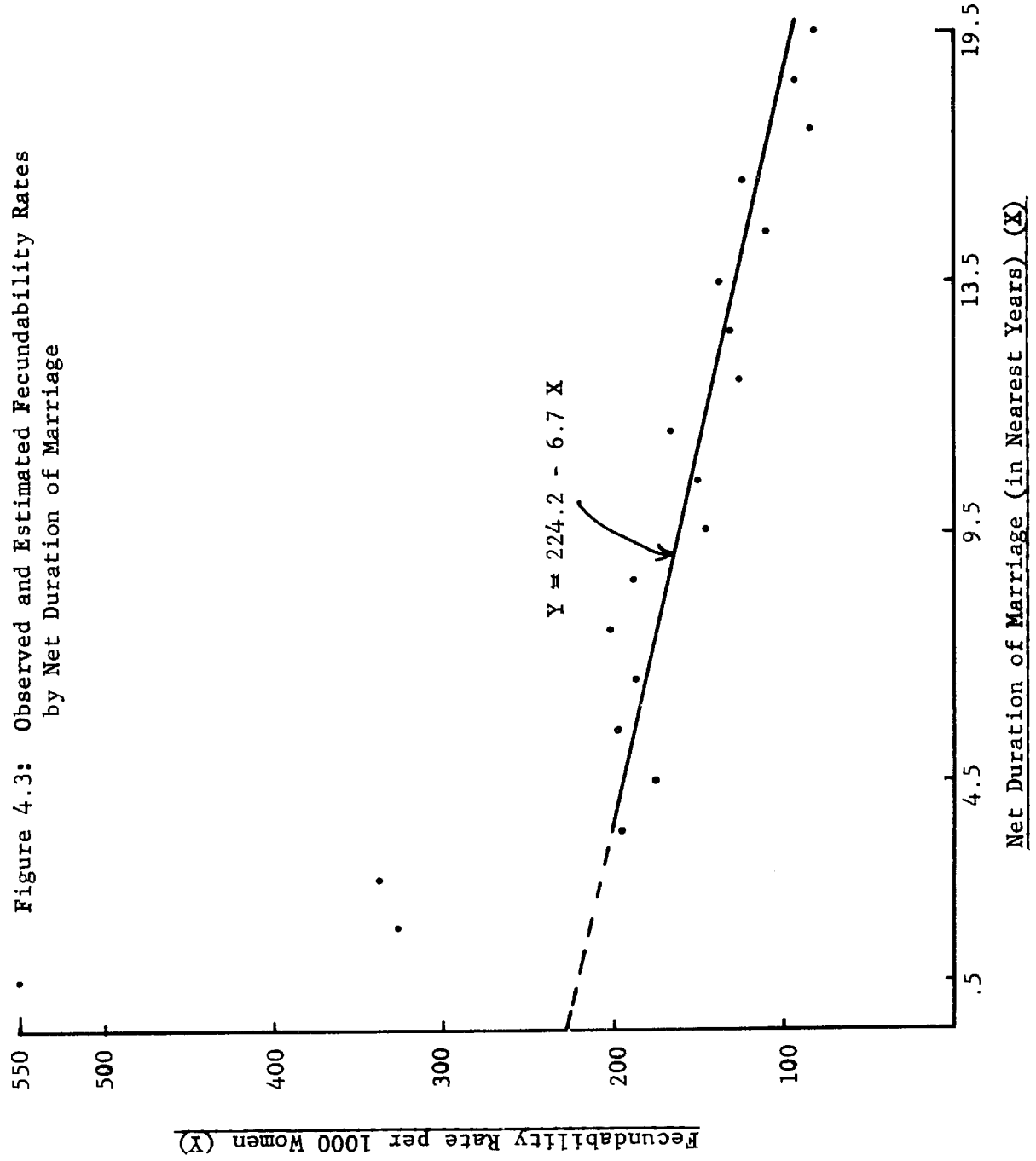
Net years married	Net months married	Fecundability rate per 1000 women			Number of women
		Observed	Estimated	Difference	
0	0-11	552	221.1	330.9	61
1	12-23	328	214.4	113.6	104
2	24-35	339	207.7	131.3	112
3	36-47	196	200.9	- 4.9	121
4	48-59	175	194.2	-19.2	119
5	60-71	197	187.5	9.5	111
6	72-83	188	180.8	7.2	118
7	84-95	202	174.1	27.9	124
8	96-107	189	167.3	21.7	129
9	108-119	150	160.6	-10.6	104
10	120-131	152	153.9	- 1.9	99
11	132-143	166	147.2	18.8	106
12	144-155	126	140.5	-14.5	126
13	156-167	131	133.7	- 2.7	123
14	168-179	138	127.0	11.0	132
15	180-191	110	120.3	-10.3	119
16	192-203	123	113.6	9.4	82
17	204-215	86	106.9	-20.9	64
18	216-227	92	100.1	- 8.1	77
19	228-239	81	93.4	-12.4	57
20+	240+	94			102

[a]Fecundability estimates based on the assumption that fecundabilities among women of different marriage durations are distributed according to a type-I distribution.

[b]Fecundability estimates based on the assumption that average fecundability declines linearly with ascending marriage duration due to constant negative effect of memory bias during marriage durations 3 to 19 years, thus, $\hat{y} = 224.3 - 6.7x$ where x is the marriage duration.

[c]Women who were definitely premaritally pregnant are excluded.

Figure 4.3: Observed and Estimated Fecundability Rates by Net Duration of Marriage



we pass from one group to the next. The first interpretation that comes to mind is as follows:

1. The sharp decline in fecundability from the first group to the second can probably be attributed to the positive effect of the truncation bias; i.e., by comparing the fecundability estimates for the first two segments, we can say that the truncation bias operates mainly during the first three years of marriage and that its effect is minor when the truncation occurs later.
2. As we pass from marriage duration of 3-8 years to 9-11 years, then to 12-16 years and 17+ years, apparent fecundability goes down substantially, namely, from about 190 to 90, i.e., by about 53 per cent. This decline can mainly be attributed to the negative effect of memory bias.

Evidence is presented below to support the above interpretation.

Truncation Effect

As a result of truncation, we can expect that as marriage duration increases, more and more sub-fecund women are included in the analysis. The estimates of mean conception delay do increase with marriage duration as shown in Table 4.4. The increase is irregular because the estimates of variances are sensitive to sampling variation and register abrupt fluctuations. To check whether the inclusion of these sub-fecund women could cause the observed decline in fecundabilities, the fecundabilities are estimated for each marriage duration group after excluding women who took three years or more for the first

Table 4.4: Mean Conception Delays with Variances and Number of Pregnancy Losses per 100 Reported First Conceptions by Net Months of Marriage Duration in the Absence of Contraception for Women with at Least One Pregnancy[a]

Net years married	Net months married	Mean conception delay	Variance	Number of pregnancy losses per 100 reported first conceptions
0	0-11	2.2	6	12
1	12-23	3.4	12	15
2	24-35	3.6	19	11
3	36-47	6.0	45	3
4	48-59	6.8	65	11
5	60-71	6.1	52	5
6	72-83	7.3	124	6
7	84-95	5.7	40	3
8	96-107	6.6	72	5
9	108-119	9.0	168	11
10	120-131	9.9	353	5
11	132-143	7.1	66	5
12	144-155	9.7	141	6
13	156-167	10.1	200	7
14	168-179	9.1	139	6
15	180-191	11.2	199	7
16	192-203	9.8	143	5
17	204-215	14.3	315	6
18	216-227	11.8	157	5
19	228-239	13.0	176	4
20+	240+	13.7	342	7
Total		8.2	139	7

[a]Women who were definitely premaritally pregnant are excluded.

conception. The results, not shown here, still show similar decline in fecundabilities with ascending marriage duration. They indicate that the effect of truncation is not serious when the truncation is as late as 36 months.

Memory Bias Effect

We have distinguished between two types of memory biases. Let us first consider the effect of type-I memory bias; under-reporting of first pregnancy losses. It can be assumed that due to improvements in health and medical facilities, etc., in Taiwan, less pregnancies were terminated in miscarriages and still-births during the 1960's than during the 1940's. Now, women married for 15-20 years would be subject to the level of pregnancy losses of the 1940's at the time of marriage and those married for 5 years or less would be subject to the level of the 1960's. Hence, in the absence of under-reporting of first pregnancy losses, we can expect a gradual increase in the index ' Number of pregnancy losses per 100 reported first conceptions' by increasing marriage duration. The absence of such a trend would reflect some under-reporting of pregnancy losses.

The index ' number of pregnancy losses per 100 reported first conceptions ', shown in Table 4.4, measures the magnitude of type-I memory bias. Here pregnancy losses include miscarriages, induced abortions and still-births. Only four pregnancies were reported to be terminated by induced abortions and thus their inclusion would not bias the magnitude of this index. The value of this index stabilizes after the third year of marriage though at a much lower level than that for

the first three years. Now, if we assume that the level of pregnancy losses in Taiwan is about 10 to 15 per 100 reported first conceptions (as shown by the values for the first three years) then, we can say that (a) after the third year of marriage duration the type-I memory bias is quite serious; about 50 per cent of pregnancy losses had not been reported; and (b) after the third year of marriage duration, the type-I memory bias increases with ascending marriage duration.

Type-II memory bias can result either in mis-reporting of the date of marriage or in mis-reporting of the date of first conception. In this sample, the bias arising due to mis-reporting of the date of the first conception cannot be serious, because occurrence date of all live births were checked[27] against the Population Register maintained by the Taiwanese government, and the discrepancies were removed. Only for 13 per cent of the women the date of first live birth could not be checked. Mis-reporting of the dates of first pregnancy losses, which constitute about 7 per cent of first reported conceptions, can be the source of error. Thus, in all, the dates of 19 per cent [(13x93/100)+7] of first reported conceptions could not be checked. On the other hand, for 55 per cent of the women the dates of marriage could not be checked. The main reason for this was the nonavailability of the dates in the Population Register. The proportion of women for whom the date of marriage could not be checked increases monotonically with ascending marriage duration. The date of first marriage could not be checked for

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[27] In this check it was found that for 83% cases the date of first live birth reported in the survey was accurate, for 2 % the survey date was earlier than the registered date, for 2% the survey date was later than the registered date, and for 13% the date of first live birth could not be checked.

29 per cent of the women married for less than three years, whereas among women married for 17 years or more the date of marriage could not be checked for 97 per cent. It can be assumed now, that among women for whom the date of marriage could not be checked, the proportion of women who reported inaccurate date of marriage increases with ascending marriage duration simply because of the increasing length of time elapsed between occurrence of marriage and its reporting date. This error in reporting the date of marriage would give rise to the observed fecundability decline by ascending marriage duration, if the reported dates of marriages were earlier than the actual dates of marriages.

Combining the two, the effect of Type-I memory bias and the effect of Type-II memory bias, we can probably say that the apparent fecundability decreases with ascending marriage duration due to the effect of memory biases.

On the assumption that fecundability decreases linearly with ascending marriage duration due to memory bias, a straight line is fitted to the observed fecundabilities for individual years between 3 to 19 years. The fecundabilities estimated from this straight line are shown in column 4 of Table 4.3 and are shown by straight line in Figure 4.3. The differences between the observed and estimated fecundabilities shown in column 5 of Table 4.3 are quite small and could have arisen due to random fluctuations.

By extending this straight line backward we can estimate the fecundabilities, probably free from truncation bias but with incomplete reporting of pregnancy losses, for the first three years of marriage duration. The difference between the observed and these estimated

fecundabilities would give the combined effect of truncation and relatively complete reporting of pregnancy losses. It can be seen that the truncation bias and the complete reporting of pregnancy losses tend to inflate the apparent fecundability by about 150 per cent (= 552-331/552) during the first year of marriage and by about 53 per cent and 63 per cent during the second and the third years respectively. These two effects cannot be separated from the available information.

Relation of Wives' Age at Marriage to Their Fecundabilities

We have already studied the variation in fecundability by marriage duration. The other demographic characteristic which is considered here for its effects on fecundability is wife's age at marriage in completed years.

Marriage is the starting point of legitimate sexual union, hence it is the beginning of childbearing period. Therefore, the age of women at the time of marriage plays an important role in determining the estimates of fecundability rates. Henry[28] has hypothesized that fecundability is nil until some age a, then increases until some age b, passes through a constant maximum from age b to age y and then decreases until an age z when it becomes nil again. After age z, the woman would be sterile.

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[28] L. Henry, "French Statistical Research in Natural Fertility," Public Health and Population Change, edited by M. C. Sheps and J. C. Ridley (University of Pittsburgh Press, 1965), p. 432.

Vincent[29] estimated the mean effective fecundability (i.e., ignoring fetal deaths) from the distributions of intervals from marriage to first births, of newly wed women aged 16 to 25 years. He found that the fecundability is lowest about 150 per 1,000 at age 16, it increases rapidly to 240 per 1,000 between ages 18 to 19 years. It increases slowly thereafter and reaches a maximum of 270 per 1,000 at the age of 25 years. Vincent's estimates are different than those obtained in the present analysis, but these estimates provide a guideline in forming the hypothesis relating fecundability and age. The difference between Vincent's effective fecundability and fecundability as used in this analysis is brought out in Henry's[30] remarks:

> These estimates concern fecundability in the strict sense, i.e., the probability of conception per menstrual cycle. Since the average length of menstrual cycles decreases from adolescence to maturity, the probability of conception per unit of time (per month, for example) will increase a little more than does the effective fecundability as estimated above [by Vincent]. The increase in gross fecundability (i.e., including conceptions terminated in miscarriages) is, on the contrary, less marked because of the decrease in intrauterine mortality as the woman passes from adolescence to maturity.

Based on both Henry's hypothesis and Vincent's estimates, the relationship between fecundability and age can be expressed as the following hypothesis 4.1.

Hypothesis 4.1: Fecundability is entirely lacking in childhood, begins to appear at the age of 13 to 16 years (puberty), develops gradually for a period of several years (adolescence), and reaches and maintains a high plateau at maturity. It then declines in middle ages, relatively rapidly after age 30, and reaches zero by the time of the last menstruation (estimated around 44 years of age).

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[29] P. Vincent, "Recherches sur la fécondité biologique," Institute national d'etudes demographiques, Travaus et Documents, Cahier no. 37, chapter VI.

[30] L. Henry, op. cit., p. 436.

By studying the variation in fecundability by age at marriage, we shall be able to test only a part of Hypothesis 4.1. We can make reasonable estimates between ages 16 and 25, but so few women marry after 25 that we shall refrain from estimating the decline in fecundability beyond it. Neither Vincent's estimates nor our estimates of fecundability tell anything about the fecundability decline after age 25. The latter part of Hypothesis 4.1 is only speculation based on the facts that (a) the length of pregnancy interval tend to increase with advancing age and (b) the coital frequency tend to decrease with advancing age. The average length of the pregnancy interval would increase either due to the increase in the average length of the fecundable period because of the decreasing fecundability with advancing age or due to increase in the average length of the post-partum amenorrhea or both. The decline in the coital frequency would also tend to decrease the average fecundability with advancing age. Thus we can expect fecundability to decline with the advancing age of the mother.

Before describing the relationship between age and fecundability, it is necessary to see whether or not the Type I geometric model still fits the sub-groups of women after controlling for their age at marriage. For this purpose the entire group of 2190 women is divided into 12 sub-groups according to their age at marriage. For each sub-group we followed the same procedure of fitting and testing the Type I model as has been described earlier for all women. The mean conception delays with their variances and the values of Chi-square are shown in Table 4.5 for each age at marriage group.

Table 4.5: Mean Conception Delays, Their Variances, the Values of Chi-square and Number of Pregnancy Losses per 100 Reported First Conceptions in the Absence of Contraception for Women with at Least One Pregnancy, by Women's Age at Marriage[a]

Age at marriage	Mean Conception delay (months)	Variance	Chi-square[b]	Degrees of freedom	Number of pregnancy losses per 100 reported first conceptions[c]	Number of women
12-15 yrs.	13.4	265	10.57	13	7	69
16	11.7	151	11.02	14	8	110
17	10.4	215	14.95	14	7	211
18	9.2	97	15.92	14	7	292
19	8.7	146	12.07	14	6	385
20	7.2	100	15.38	14	6	374
21	6.4	84	14.04	14	8	234
22	6.4	127	4.31	14	7	186
23	6.0	51	9.61	13	2	125
24	5.3	103	10.31	12	12	72
25	6.4	98	7.83	11	5	62
26 yrs. or more	8.9	444	14.50	13	16	70
Total	8.2	139	22.11	14	7	2190

[a]Women who were definitely premaritally pregnant are excluded.

[b]The grouping of months required for conception are similar to the one used for total sample shown in Table 4.2

[c]Women pregnant at the time of first interview are excluded.

All the values of Chi-square are statistically not significant at the 5 per cent level of significance: for each age at marriage group, the differences between the observed and expected numbers of women conceiving during each successive month after marriage could have arisen due to random fluctuations. Thus, it can be said that a Type I geometric model is also applicable to women in each age at marriage group, and we can take the estimated $\bar{p}$ for each age group as a reliable estimate of average fecundabilities of women belonging to that age group.

Estimates of mean conception delays show that women who get married at early ages, before their sixteenth birthday, take the longest time to conceive; the delay starts declining with increasing age at marriage, and it remains about the same for women who marry between ages 21 and 26. Women at earlier ages take longer time to conceive, probably due to lower fecundability; as their fecundability increases with age, the time taken to conceive decreases.

Estimates of fecundability rates per 1,000 women, with their variances based on the Type I model, shown in Table 4.6 for each age at marriage group, confirm part of the hypothesized relationship between the two variables. They show that the apparent fecundability is lowest, about 90 per 1,000 when women are in their early teens; it gradually increases as women move to their late teens; it remains constant at a higher level between ages 21 and 25. The apparent fecundability for women marrying at age 23 years is low and at 24 is too high as compared to nearby ages. The only plausible explanation for this fluctuation seems to be the high under-reporting of pregnancy losses we happen to find at age 23; only 2 per cent of women married at age 23 reported a

pregnancy loss at first conception as compared to about 7 per cent at other ages, and 12 per cent at age 24 (data shown in column 6 of Table 4.5). This type of relationship between age and fecundability can be expressed easily by one tail of a simple second degree parabola. A second degree parabola fitted quite well to the fecundability estimates between ages 16 and 25, but its extrapolation did not provide realistic estimates for higher ages especially after age 30.

Effect of Memory Bias on Relationship Between Age at Marriage and Fecundability

It is unlikely that women who reported a miscarriage or abortion for their first pregnancy also had another unreported miscarriage before it. There are two reasons for this assumption: (1) few women will have two or more miscarriages before a first live birth; and (2) those with 2 or more consecutive miscarriages will be more likely to remember all of them because they must have been trying to get the first birth, and once they had recalled one of the miscarriages they are likely to recall the other ones too.

On the other hand, it is more likely that women who reported a live birth for their first pregnancy have under-reported their miscarriage. Thus, if we consider women whose first pregnancy is terminated in live birth, they are also subjected to the similar type of error on account of under-reporting. This is shown by the estimated fecundability rate of 164 ± 2 for this group of women, which is about the same as for all women. Even when we control for age at marriage the estimates of fecundability rates for the two groups of women are close to one another, except for those who got married after their 24th

birthday. Results are shown in Table 4.6. These results show a pattern similar to the one shown by all women. This tends to indicate a minor effect of memory bias on the relationship between fecundability and age at marriage as long as we are interested in studying the trend. The relatively minor effect of memory bias is also shown by the results in column 6 of Table 4.5. The index measuring the magnitude of Type-I memory bias shows no variation up to age 22. It is only in the last four groups that this index fluctuates which in turn probably causes the fluctuations in apparent fecundability for these ages.

Effect of Truncation Bias on the Relationship between Fecundability and Age at Marriage

The effect of truncation bias, in general, is to inflate the fecundability estimates, and this effect is much greater for women married for shorter periods than for women married for longer periods. This happens because relatively more sub-fecund women who take a longer time (say 36 months or more) for a first conception are not included in the first group but are included in the second group. The effect of the truncation bias can be examined in two ways: (1) by controlling for marriage duration, which is done in the following section, and (2) by excluding women who took three years or more for their first conception. The estimated fecundabilities by age-at-marriage after excluding women who took three years or more for first conception are shown in column III of Table 4.6. These results indicate that fecundability increases with advancing age at marriage up to age 25 years (except for age 23). This suggests that the effect of truncation on the relationship between age at marriage and fecundability is not great. In the following

Table 4.6: The Fecundability Rates per 1000 Women with Standard Error in the Absence of Contraception for Women with at Least One Pregnancy, by Women's Age at Marriage, for (I) All First Pregnancies, (II) Only Those First Pregnancies which Terminated in a Live Birth, and (III) All First Pregnancies Excluding Women who Took Three Years or More For First Pregnancy[a]

Age at marriage in completed years	Fecundability rate per 1000 women and its standard error			Number of women		
	I	II	III	I	II	III
12-15 years	90 ± 4	96 ± 5	**	69	64	66
16	93 ± 2	94 ± 2	**	110	101	104
17	128 ± 4	138 ± 5	130 ± 2	211	196	202
18	121 ± 2	116 ± 2	123 ± 1	292	273	285
19	151 ± 4	152 ± 4	156 ± 2	385	362	371
20	180 ± 4	181 ± 5	173 ± 3	374	343	368
21	209 ± 6	218 ± 7	210 ± 5	234	211	230
22	226 ± 8	226 ± 9	230 ± 6	186	165	182
23	203 ± 7	209 ± 8	211 ± 7	125	117	123
24	276 ± 16	262 ± 18	335 ± 17	72	58	70
25	214 ± 13	209 ± 14	253 ± 15	62	57	60
26 or more	180 ± 12	254 ± 16	250 ± 13	70	54	67
All women	163 ± 2	164 ± 2	165 ± 1	2190	2001	2128

[a]Women who were definitely premaritally pregnant are excluded.

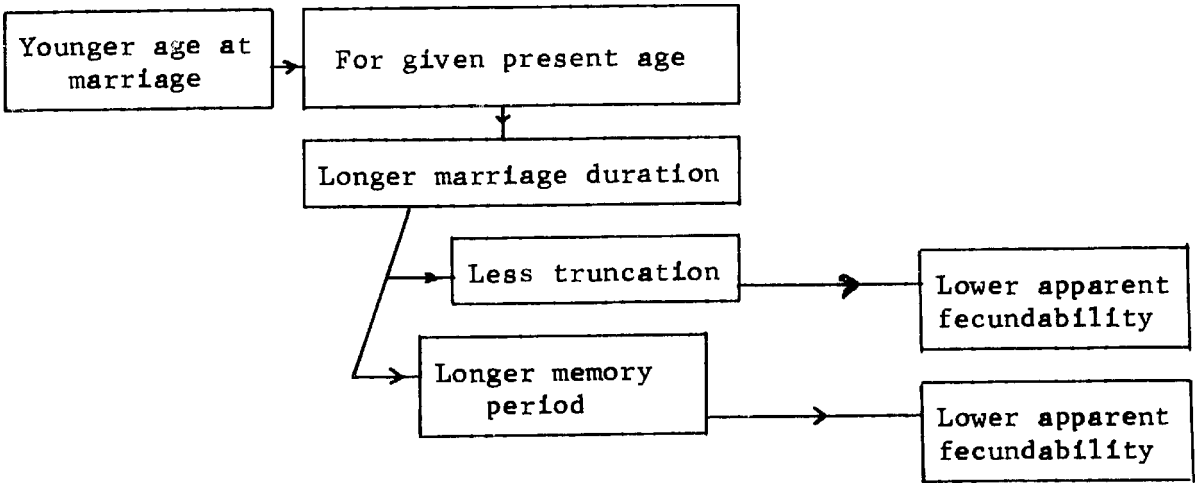
**Type-I model is not applicable.

section we shall consider the effect of memory and truncation biases simultaneously on the relationship between age at marriage and fecundability by controlling marriage duration.

Interdependence between Age at Marriage and Marriage Duration

We have seen that the apparent fecundability varies with both age-at-marriage and the marriage duration. We want to check now whether both the relationships are real, or if one is real and the other an artifact of the association between age at marriage and the marriage duration. The following diagram shows that given an association between age at marriage and the marriage duration, and assuming that fecundability differentials by marriage duration are real (arising due to the truncation and the memory biases), younger age-at-marriage can lead to apparent lower fecundability.

Schematically



(Here the fecundability level of women marrying younger is compared with the fecundability level of women marrying older and not with the true level.)

The reverse of the above relationship is also true, that is, the older age at marriage can lead to higher apparent fecundability. This implies that if in our sample age at marriage is correlated with marriage duration then the observed relationship between age at marriage and fecundability could be an artifact of this association, that is, the age-at-marriage differentials in fecundability could be the effect of truncation and memory biases associated with marriage duration. For further analysis we have divided age at marriage in four classes: 18 years or less, 19 to 20 years, 21 to 25 years, and 26 years or more. This grouping is done to insure the adequacy of number of cases in each cell.

Similarly, it can be shown schematically that given an association between age at marriage and marriage duration and assuming that the fecundability differentials by age at marriage are real (probably due to some physiological changes), longer (or shorter) marriage duration can lead to apparent lower (or higher) fecundability.

To measure the association between age at marriage and marriage duration, we calculated Pearson's[31] contingency coefficient which is calculated on the assumption that the two variables under consideration are independent. The value of this coefficient comes out to be 0.40 which shows an appreciable amount of association between age at marriage and marriage duration. To know the direction of this association, we calculated percentage distribution of women in each age at marriage

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[31] Pearson's contingency coefficient $C = \sqrt{x^2/N+x^2}$ where N is the total number of cases, and x^2 is the value of Chi-square calculated on the assumption that in a pxq table, the two variables under consideration are independent.

group by marriage duration groups. It is quite clear from these percentages shown in Table 4.7 that in younger age at marriage group the longer marriage durations are over-represented whereas in older age at marriage group the shorter marriage durations are over-represented. On the basis of this association alone we could suspect that the relationship between age at marriage and fecundability might be an artifact. This question is further investigated by estimating the fecundabilities after controlling for marriage duration groups within each age at marriage group. The results are shown in Table 4.8. The estimates for the last age at marriage group should be interpreted carefully, because these are based on a small number of cases.

Marginal averages show that fecundability decreases monotonically from 373 to 92 per 1,000 women with ascending marriage duration. By separating women into four age-at-marriage groups (18 years or less, 19 to 20 years, 21 to 25 years, and 26 years or more) we are roughly controlling for the effect of age at marriage. Now, since within each age-at-marriage class the apparent fecundability declines with ascending marriage duration, we can say that marriage duration differentials are not due to differences in age at marriage. These differentials, probably, are mainly due to type-I and type-II memory biases.

Marginal averages show that fecundability increases monotonically from 117 to 224 per 1,000 women with advancing age at marriage (up to age 25). We have seen earlier that the effect of truncation is minor when truncation is as late as 36 months and that after 36 months, the effect of type-I and type-II memory biases increases with ascending marriage duration. By separating women married 36 months or more into

Table 4.7: Percentage Distributions of Women by Age at Marriage and Marriage Duration[a]

Duration of marriage (in months)	Age at marriage (in completed years) Less than 18 years	19-20	21-25	26 years or more	Total
0-35	2%	14%	20%	37%	13%
36-107	23	33	41	50	33
108-143	14	14	15	11	14
144-203	31	28	23	2	26
204 or more	30	11	1	0	14
Total: %	100	100	100	100	100
N	682	759	679	70	2190

[a]Women who definitely used contraception during first pregnancy interval or had no pregnancy at first interview or were definitely premaritally pregnant are excluded

Table 4.8: The Fecundability Rates per 1000 Women and Their Standard Errors in the Absence of Contraception for Women[a] with at Least One Pregnancy by Marriage Duration and Wife's Age at Marriage

Duration of marriage (in months)	Age at marriage (in completed years) Less than 18 years	19-20	21-25	26 years or more	Total
0-35	*	291 ± 7	421 ± 15	364 ± 15	373 ± 8
36-107	159 ± 3	191 ± 5	216 ± 6	187 ± 14	195 ± 3
108-143	127 ± 4	167 ± 8	195 ± 9	*	164 ± 5
144-203	93 ± 1	130 ± 4	164 ± 7	*	126 ± 2
204 or more	91 ± 1	93 ± 2	*	*	92 ± 2
Total	117 ± 2	164 ± 3	224 ± 4	223 ± 12	163 ± 2

[a]Women who were definitely premaritally pregnant are excluded.

*Base less than 25.

four marriage duration groups (36 to 107 months, 108 to 143 months, 144 to 203 months, and 204 months or more) we are roughly controlling for the effect of memory bias. Now, since within each marriage duration class, the apparent fecundability increases with advancing age at marriage (up to age 25), we can say that the age-at-marriage differentials are real. These differentials, probably, are due to some physiological changes which increase the promptness of first conception as age at marriage increases (up to age 25).

Comparison with Other Studies

Since it has been shown that age at marriage does influence the promptness of the first conception, in any fecundability comparisons between two countries we should also consider the differences between ages at marriage. To get the true picture about the fecundability differences we should, then, compare the age specific (age at marriage) fecundabilities of two countries. However, if the ages at marriage in two countries are about the same then we can restrict our comparison to the overall fecundabilities only. In comparing the fecundability level of Taiwanese women with that of American women we have restricted our comparisons to overall fecundabilities only because (1) ages at marriage between the two countries are about the same and (2) the age specific fecundabilities for American women are not available.

The overall fecundability estimate of 163 for Taiwanese women is not much lower than the estimates for women in the United States. Henry[32] estimated from Indianapolis data, an average fecundability to

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[32]L. Henry, "Fecondité des marriage: nouvelle method de mesure" (Paris: Press University France, 1953), p. 95. Quoted in C. F. Westoff, R. G. Potter, P. C. Sagi, E. C. Mishler, Family Growth in Metropolitan America (Princeton: Princeton University Press, 1961), p. 62.

be 190. Westoff[33] and his colleagues also estimated the average fecundability at the time of marriage from the FGIMA sample. Their estimate came out to be 180, based on the proportion of women who got pregnant within the interval (-28, 28) days, marriage date being the mid-point of this interval. In our sample we do not have the data in terms of days and hence, our estimate cannot be refined on lines similar to that of Westoff et al. However, if we consider the fecundability estimate for Taiwanese women married for 3 to 8 years, then the estimate comes out to be 195 $\pm$ 3 and if we consider the fecundability estimate for Taiwanese women married for 3 to 8 years and married at the age of 19 years or more, then the estimate comes out to be 203 $\pm$ 2. These estimates are comparable to the estimates for American women.

Discussion and Summary of the Results

From the empirical analysis we conclude that the variation of the fecundability among couples can be described by a Pearson Type-I curve as far as Taiwanese couples are concerned. If we recall, Henry[34] suggested the use of type-I curve to represent the distribution of fecundabilities among couples. Later on, Henry[35] himself and Potter et al.[36] used this theoretical distribution of fecundability. The work of

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[33] C. F. Westoff et al., ibid. See Chapter IV, 45-69.

[34] L. Henry, "La fécondité naturelle: Observation-Theorie-Resultats," Population, XVI, No. 4 (1961), 633.

[35] L. Henry, "Mortalité intra-utérine et fécondabilité," Population, XIX, No. 5 (October 1964), 899-940.

[36] R. G. Potter and M. P. Parker, "Predicting the Time Required to Conceive," Population Studies, XVIII, No. 1 (July 1964), 99-116.

Potter and Parker[37] who used the type-I curve to represent the fecundability distribution among American women did not provide empirical support because the theoretical distributions and the empirical distributions showed wide divergences. As far as we know, the present analysis is the first one which provides empirical support to the theoretical assumption that the fecundability among couples is distributed according to a Pearson Type-I curve.

As a first application of the model, the fecundability estimates are obtained for each marriage duration group. The fecundability rates tend to decrease with ascending marriage duration. Two types of biases, truncation and memory, are considered to explain these differentials. The truncation bias, which tends to exclude sub-fecund women and thus tends to inflate the fecundability estimates, is mainly effective up to third year of marriage. Two types of memory biases are distinguished. Type-I memory bias, under-reporting of first pregnancy losses, is quite substantial after the third year of marriage. On the other hand, type-II memory bias, due to mis-reporting of the occurrence dates of marriage and the first conception, tends to increase with ascending marriage duration. These two memory biases probably give rise to the marriage duration differentials in fecundability after the third year of marriage duration. Some of these differentials could also have arisen due to improvements in physical health of women, socio-economic status of couples, and their living arrangements overtime. This point needs further exploration.

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[37] Ibid.

The application of this model for each sub-group of the population raises a theoretical question. If the model fits the total group of women then should it fit the sub-groups of the total population? This question can be put in another form, i.e., if this model fits reasonably well to the sub-groups of total population, then should it fit to the total population? A theoretical answer to this question needs further exploration, but the empirical evidence does not contradict the assumption. When this model is tested for each age at marriage, we find that for each age group the fit is reasonably good, in fact, it is better than for the total population, as shown by the smaller values of Chi-square in Table 4.5. The second piece of evidence is supplied by insignificant differences between (1) the number of women conceiving during each successive month after marriage, estimated on the assumption that the model fits the total population and (2) the sum of corresponding estimated number of women for each age group. The results are shown in Table 4.9. The value of Chi-square is statistically insignificant.

As a second application of the model, the estimates of fecundability are obtained for each age-at-marriage group. The apparent fecundability tends to increase with age at marriage, stabilizes between 21 to 25 years, and probably starts declining after it. These differentials are not due to differential memory or truncation biases but probably are due to some physiological changes which increase the promptness of conception. These differentials imply that in any country late marriages (say after the 25th birthday) may lead to some decline in fertility, in the absence of an increase in illegitimacy, not only by

shortening the effective reproductive period but also due to lower fecundability after marriage.

Table 4.9: Comparison between (1) Number of Women Conceiving During Successive Months after Marriage Estimated on the Assumption that Type I Geometric Model Fits to the Total Population and (2) Sum of Corresponding Estimated Number of Women for Each Age at Marriage Group

Months to conceive	Estimated number of women (1)	(2)	Difference
1	356.6	366.2	-9.6
2	285.2	286.5	-1.3
3	230.5	228.3	2.2
4	188.2	184.7	3.5
5	154.9	151.5	3.4
6	128.6	125.7	2.9
7	107.6	105.2	2.4
8	90.6	88.9	1.7
9	76.8	75.4	1.4
10	65.4	63.0	2.4
11	56.1	57.2	-1.1
12	48.3	46.9	1.4
13-18	184.1	187.3	-3.2
19-24	88.3	93.8	-5.5
25-36	74.0	75.4	-1.4
37-48	27.2	31.4	-4.2
49+	27.6	22.6	5.0
Total	2190.0	2190.0	

Chi-square = 2.83

CHAPTER V

FECUNDABILITY AND ITS SOCIO-ECONOMIC CORRELATES

Introduction

In Chapter IV we tested a model for estimating the fecundability level of Taiwanese women living in Taichung city. As a first application of the model we studied the variations in fecundability by two demographic characteristics of women. In this chapter we shall study the variations in fecundability between women of different socio-economic strata of Taiwanese society. Here the term fecundability is used to denote the monthly probability of conception in the absence of contraception. The empirical measures of the fecundability, however, not only measures the "natural" or "pure" fecundability but are also affected by the environmental factors such as the timing and the frequency of intercourse shortly after marriage.

We expect to find a positive relation between fecundability and socio-economic status of couples: that is, women of higher socio-economic strata have higher fecundability than those of lower strata. The basis and the formation of this hypothesis are dealt with in detail later on.

Previous Research

Variation in fecundability by major socio-economic groups has not yet been studied adequately. In 1940 Stix and Notestein[1] studied the variation in women's ability to conceive by the occupational class and religion for a selected group of patients of the Birth Control Clinical Research Bureau in New York city. They indirectly measured women's ability to conceive by the average period between marriage and the first pregnancy and found little variation in their ability to conceive by economic class or religion. Since then no one else has studied the variation in fecundability by socio-economic status of couples. However, three attempts have been made to study the relationship between "fecundity" and couple's socio-economic status in the United States. These studies, summarized below, indicate that in the United States there is no significant difference in the fecundity level of women of major socio-economic groups. Fecundity, in these studies, has been used to refer to the physiological capacity of couples for bearing children in the future. This concept is different from the one used in the present chapter. Here we are interested in studying the variation in "fecundability" and not "fecundity," and thus these studies do not help much in forming the hypothesis relating fecundability with socio-economic status of couples.

The first major study of this kind is the famous Indianapolis study,[2] in which couples were divided into two broad groups:

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[1]R. K. Stix and F. W. Notestein, Controlled Fertility (Baltimore, Md.: The Williams and Wilkins Co., 1940), pp. 39-40.

[2]P. K. Whelpton and C. V. Kiser (eds.), Social and Psychological

"relatively fecund" and "relatively sterile." The distinction between the two groups was based on the overall situation during the preceding 12 to 15 years of married life. The first group included couples (a) who had four or more live births and (b) who had three or fewer live births unless they knew or had "good reason"[3] to believe that they had been unable to conceive during a period of 24 months (if never pregnant) or 36 months (if pregnant one or more times). The second group included the rest of the couples in the sample. Based on this broad classification, it was found that fecundity bears no systematic relationship to such socio-economic characteristics as income, education, and standard of living.[4]

In the 1955 GAF study,[5] couples were divided according to their fecundity at the time of interview into five groups:

1. Definitely sterile included those couples who cannot conceive, i.e., couples who reported physical or medical conditions making pregnancy impossible in the future.

2. Probably sterile included those couples for whom a birth was considered improbable (rather than impossible) in the future on the medical evidence.

Factors Affecting Fertility, Milbank Memorial Fund, Vol. II (New York, 1950), p. 212.

[3]"Good reason" included the failure to conceive during specified periods of 24 months or 36 months if the couples were living together and were not trying to prevent conception.

[4]Whelpton and Kiser, op. cit., 359-416.

[5]R. Freedman, P. K. Whelpton and A. A. Campbell, Family Planning Sterility and Population Growth (New York: McGraw Hill Book Co., Inc., 1959), especially chapter 2.

3. Semifecund included those couples who had not conceived at a "normal" rate, although the wives did not know any physiological limitation to reproduction.

4. Fecundity indeterminate included those couples who could not be classified as fecund on the available information.

5. Fecund included those couples for whom there was no evidence of impaired fecundity.

Couples falling in any of the first four classes were designed as sub-fecund. Based on this classification, Freedman et al. reached to the following conclusion about the relationship between fecundity and socio-economic characteristics:

> There is no evidence of consistent differences in fecundity between most major social and economic strata of our population. Low status groups (as measured by income or education) are more likely than high status groups to be classifed as sub-fecund, but it is unlikely that this is due to basic biological differences. Instead, it probably results from the lesser use of family limitation methods early in married life by lower-status groups, which gives them greater opportunity to demonstrate sub-fecundity. Working wives are more likely than others to be sub-fecund, in part because their lower fertility permits them to work. For most other social and economic characteristics there are no apparent differences in fecundity.[6]

In a third study, Whelpton[7] and his colleagues defined fecundity as the ability to have children in the future. All couples were classified into five classes according to their fecundity: Definitely sterile, Probably sterile, Possibly sterile, Possibly fecund, and Fecund. The classification was based on two kinds of information: (1) the wife's

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[6] Ibid., p. 19.

[7] P. K Whelpton, A. A. Campbell, and J. E. Patterson, Fertility and Family Planning in the United States (Princeton, N.J.: Princeton University Press, 1966), see especially chapter 4.

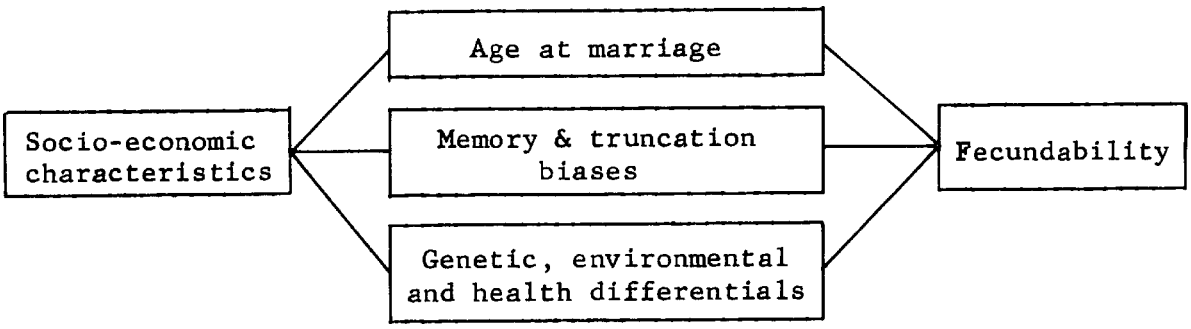
opinion of her and her husband's ability to have children in the future, frequently supplemented by the medical basis of her opinion, and (2) the wife's report of her pregnancy history and of her use of contraception. Whelpton et al. did not find any evidence for consistent differences in fecundity by education of wife.

In all three studies the main conclusion was: there are no significant differences in fecundity between major socio-economic groups in the United States. Since these investigators were more oriented towards the future growth of American families, their measure of fecundity was also oriented towards the future (i.e., after the interview period) fecundity differences among couples. Moreover, these classifications were highly dependent on the use of contraception and sterilization to the time of interview. In the present study we are interested in the fecundability differentials at the time of marriage, not in the future fecundity differentials of couples. Hence the studies quoted above do not help much informing any hypothesis about the fecundability differentials.

The Model and the Hypothesis

The model to be considered in this analysis is mainly based on two empirical observations from the Taiwan data: (1) the variation in wife's age at marriage by socio-economic characteristics of the couples; and (2) variation in the fecundability by wife's age at marriage. Together these observations suggest some variation in fecundability by major socio-economic groups. In this variation an account must be made

for differential memory and truncation biases between major socio-economic groups. We should not ignore the effect of socio-economic status on fecundability arising due to genetic, environmental and health differentials, though they cannot be measured from the available data. Schematically:



Mohapatra[8] studied the relationship between wife's age at marriage and the couple's socio-economic status. His analysis was restricted to Taiwanese women between ages 30 and 39 years and with at least two children. He found a positive association between wife's age at marriage and socio-economic status as measured by five characteristics: wife's education, husband's education, husband's employment status, ownership of modern objects and household's income. Some of his main findings are:

1. Wife's education was the most important variable in determining the age at marriage. Women with higher educational level, for obvious reasons tend to marry at a later age than women with lower educational

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[8]For details see P. S. Mohapatra, "The Effects of Age at Marriage and Birth Control Practices on Fertility Differentials in Taiwan" (unpublished Ph.D. dissertation, University of Michigan, 1966), especially chapter 4.

level. This relationship holds even when other four variables are controlled.

2. Age at marriage was higher for wives of professional men than for others.

3. Wife's age at marriage tends to increase with husband's educational level mainly due to the underlying correlation of husband's education with wife's education and husband's employment status.

4. There was small but consistent increase in wife's age at marriage with increase in the number of modern objects owned by couple. Household's income showed no consistent relationship with wife's age at marriage. These two economic characteristics showed no strong or consistent relationship with wife's age at marriage when the other three variables were controlled.

In general, Mohapatra's analysis established that women of higher socio-economic strata tend to marry at a later age than women of lower strata. It is assumed that Mohapatra's conclusions would also be applicable to the younger women in our sample as well as to those over 30 whom he analyzed.

It is expected that the memory bias affects a higher proportion of women in the lower strata than those in the upper strata; therefore the effect of memory bias would be to deflate the apparent fecundability for women in the lower strata. The effect of truncation bias, on the other hand, would be to inflate fecundability estimates for women in the upper strata, if more women in the upper strata who marry later, are married for a shorter period than those in the lower strata who marry earlier.

The effect of genetic and health differentials, and the effect of such environmental factors as the timing and the frequency of intercourse probably would be to increase the fecundability of women in the upper strata and to lower the fecundability of women in the lower strata.

The two empirical observations on age at marriage and fecundability by age, along with the expected effect of memory and truncation biases, and the genetic, health and environmental differences give rise to the following hypothesis, which will be tested in the following sections:

Hypothesis 5.1: Women of higher socio-economic strata have higher fecundability than those belonging to lower socio-economic strata, when the fecundability is measured from the period between marriage and the beginning of first conception.

If we find that the socio-economic differentials are explained by the differences in age at marriage and/or differentials in memory and truncation biases, then we can say that the apparent fecundability differentials by socio-economic status are artifacts of the associations between socio-economic status, age at marriage, memory and truncation biases. Otherwise, the differentials are real and may be caused by the genetic, health or environmental factors.

Measures of Socio-economic Status

Eight variables are selected to measure the socio-economic status of couples in Taiwan. These variables are:

1. Couple's Education--the highest formal school level achieved by husband and by wife at the time of interview.

2. Couple's Rural Background--whether or not the couple is living at farm at the time of interview, and if not whether one or both spouses have any rural background.

3. Ethnic Background--whether each spouse is from Taiwan or from mainland China.

4. Family Type--whether the couple forms a nuclear family unit or is a part of an extended family unit.

5. Household's income in new Taiwan dollars[9] and Number of Modern Objects Owned[10] by the couple measure their relative economic status.

6. Husband's Employment Status--divided into four categories according to the degree of traditional influence on husband's occupation. On one extreme are professionals like lawyers, doctors, etc., occupations with minimum traditional influence, on the other extreme are farmers. The middle two categories are formed in such a way as to show whether or not relatives have much influence on the husband's occupation.

Information about all the variables measuring socio-economic status of couples was collected at the time of the interview. Thus these variables, more or less, measure the socio-economic status of couples at the time of interview, whereas the fecundability rate, based on first pregnancy intervals, measures the fecundability level at the time of marriage. This produces a time lag between two types of measures. However, the measures of socio-economic status can be divided into two groups: background variables in which the changes after marriage are expected to be quite small, and other variables which are

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[9] 1 U.S. dollar = 40 New Taiwan dollars (official exchange rate).

[10] The modern consumer items referred to are: bicycle, radio, radio with phonograph, motorcycle, electric fan, electric iron, sewing machine, subscription to daily newspaper, private toilet, running water, electric rice cooker, and timepiece.

expected to change after marriage. The first group includes variables like couple's education, couple's rural background, ethnic background, and family type. The second group includes variables like husband's employment status, household income, and ownership of modern objects.

Methodology

The fecundability rates for different socio-economic groups of women are estimated on the assumption that the tyep-I geometric model fits women in each socio-economic group. This assumption is not tested empirically for each group. Since the fecundability estimates in this model are based on two other estimated parameters "a" and "b" in the Pearson Type-I distribution, it is not possible to do such mathematical operations as getting the weighted mean, etc., on them. This restricts the scope of the analysis.

In the beginning all the eight measures are considered separately to study the fecundability differentials, then each variable is considered along with wife's age at marriage, to study the effect of wife's age at marriage on the fecundability differentials by socio-economic status.

When socio-economic measures are considered with wife's age at marriage, two or more consecutive categories of these measures with approximately similar fecundability rates are grouped to secure adequate numbers of women with about the same fecundability level in each subgroup. These are arbitrary groupings, and no claim is made that they are the best possible.

Finally a Multiple Classification Analysis (MCA) program is used to summarize the relationship between fecundability and the socio-economic measures considered jointly. For this purpose a cruder estimate of fecundability is used. Fecundability is estimated by the proportion of women conceiving during the first month after marriage. An objection to this estimate is that the values of fecundability will be overestimated by about 50 per cent because the pregnancies during coded zero and one months represent the pregnancies of about one and a half months. This bias will be a minimum when women conceiving between one and one-half months after marriage are randomly distributed among the categories of all variables under consideration. Under this assumption, a correction factor can uniformly be applied to the estimates obtained by the MCA program. This uniform reduction should not make much difference as long as we restrict our attention to the study of fecundability differentials and not to their absolute values. The primary purpose is to rank the sub-groups instead of estimating the absolute fecundabilities of women in these sub-groups. The two measures of fecundability are moderately correlated in ranking the categories of independent variables as shown by a rank correlation coefficient of 0.64 between two measures of fecundability for categories of seven independent variables. A description of the Multiple Classification Analysis Program follows next.

The Multiple Classification Analysis technique has been used by many researchers[11] in analyzing social data. This

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[11]For example, see P. S. Mohapatra, op. cit. Also, R. Freedman and L. Coombs, "Economic Considerations in Family Growth Decisions,"

technique[12] is an extension of multiple correlation analysis, and is applicable to situations when the independent variables (known as predictors) are on a nominal scale. It makes no assumption about linearity of regression, or about ordering of sub-categories of predictors. The technique is useful in examining simultaneously the effect of each of several predictors on a dependent variable when the effect of other predictors is held constant. MCA uses "dummy variables" for each category of each predictor, i.e., it assigns a value of one or zero depending upon whether or not the case falls in the particular category. The MCA program gives the following statistical measures:

1. A measure of total variation explained by all predictors considered at one time. This measure is analogous to the multiple R^2 adjusted for the degrees of freedom.

2. Eta coefficients for each predictor, summarizing the total effect of the predictor, and analogous to the square root of the proportion of total variation explained by a variable in one way analysis of variance. These coefficients can be used for ordering the predictors according to their effects on the dependent variable.

3. Deviations of each category mean of each predictor from the overall mean, termed as "unadjusted deviations," as well as these deviations after adjusting for the effect of other predictors, termed as

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Population Studies, XX, No. 2 (November 1966), 197-222; D. S. Freedman, "The Relation of Economic Status to Fertility," American Economic Review, LIII, No. 3 (June 1963), 414-26.

[12]An extensive discussion of MCA is found in F. Andrews, J. Morgan, and J. Sonquist, Multiple Classification Analysis (Ann Arbor, Mich.: Survey Research Center, Institute for Social Research, The University of Michigan, May 1967).

"adjusted deviations." Using these deviations, it can be seen, for example, whether women with no formal education have lower fecundability than the average and whether this difference persists after taking into account the effect of other variables, such as husband's education and wife's age at marriage.

Results

Table 5.1 shows the fecundability rates per 1,000 women and its standard error, for each category of each socio-economic measure of all women in the sample, and for those who had been married for at least three years but no more than nine years. The estimated fecundabilities for all women, in general, confirm the hypothesized relationship between fecundability and socio-economic status of women: women in higher socio-economic strata in Taiwan have higher fecundability than those in lower socio-economic strata. The salient features are:

1. The apparent fecundability increases with the increase in educational level of husbands as well as of wives. The differences between the two highest categories of both variables is small, and could easily be due to random fluctuations.

2. The apparent fecundability for couples among whom at least one spouse has nonrural background is much higher than for those among whom both spouses have rural background, whether or not they lived on a farm at the time of interview.

3. The apparent fecundability is higher for Taiwanese than those from mainland China, but the fecundability of mixed couples is much higher than that of either pure type.

Table 5.1: The Fecundability Rates per 1000 Women with Standard Error, by Selected Measures of Socio-economic Status, in the Absence of Contraception for Women with at Least One Pregnancy,[a] for All Women and for Women Married 3-8 Years

Socio-economic characteristics	Fecundability rate per 1000 women: All women	Fecundability rate per 1000 women: Women married for 3-8 years	Fecundability rate for women married 3-8 years expressed in terms of fecundability rates for all women
All wives	163± 2	195± 3	120
1. Husband's education			
Less than primary graduate	148± 3	164± 5	111
Primary graduate	150± 2	184± 4	123
Junior high school	159± 5	162± 7	102
Senior high school	197± 5	218±10	111
At least some college	204± 7	349±21	171
2. Wife's education			
None	134± 2	166± 3	124
Primary nongraduate	177± 5	180± 7	102
Primary graduate	170± 3	206± 5	121
Junior high school	198± 6	213±12	108
Senior high school	191± 5	204±13	107
3. Rural background*			
Farmer now	144± 3	170± 5	118
Not farmer now			
Both H and W have RBG	153± 3	174± 5	114
Either H or W has RBG	182± 4	233± 7	128
Neither H nor W has RBG	183± 5	219± 9	120
4. Ethnic background			
Both Taiwanese	162± 2	184± 3	114
Mixture	224± 7	190±11	85
Both mainlanders	123± 4	229±15	186

Table 5.1:--(CONTINUED)

Socio-economic characteristics	Fecundability rate per 1000 women: All women	Fecundability rate per 1000 women: Women married for 3-8 years	Fecundability rate for women married 3-8 years expressed in terms of fecundability rates for all women
5. Family type			
Nuclear always	180± 4	260±10	144
Nuclear now and have lived with parents	152± 3	187± 6	123
Extended always	162± 2	177± 4	109
6. Number of modern objects			
0 or 1	140± 5	148± 8	106
2 or 3	140± 3	182± 5	130
4	151± 4	187± 7	124
5	171± 4	233± 9	136
6	185± 4	205± 7	111
7 or more	180± 4	184± 8	102
7. Household income in NT$			
Less than 1,000	157± 3	207± 6	132
1,000-1,499	145± 3	157± 5	108
1,500-1,999	173± 4	201± 6	116
2,000-2,499	187± 5	231±12	124
2,500 or more	176± 4	215±10	122
8. Husband's employment status			
Farmer	144± 3	173± 5	120
Other traditional	157± 3	200± 6	127
Other nontraditional	169± 2	185± 4	109
Professional	216±10	511±32	237

[a]Women who were definitely premaritally pregnant are excluded.
*H stands for husband.
W stands for wife.
RBG stands for Rural Background.

4. Wives living in nuclear family units have higher fecundability than those living in extended family units.

5. The apparent fecundability increases with the number of modern objects owned by the couples.

6. Wives of professional men have much higher fecundability than wives of farmers, and other two occupation groups lie between the two extremes: the apparent fecundability tends to increase with a decrease in the degree of traditional influence on husband's occupation.

7. The fecundability of wives living in households with a monthly income of 1,500 N.T.$ or more is higher than those living in households with lower income.

The fecundability differentials by socio-economic status are much too large to result from sampling variability alone. As noted earlier, these differentials could have arisen due to a combination of factors, viz., (1) differential truncation and memory biases, (2) differences in age at marriage, (3) interdependence between measures of socio-economic status. The effects of these factors on the relationship between fecundability and socio-economic status will now be considered separately.

Effect of Differential Truncation and Memory Biases

In Chapter IV it has been shown that the effect of the truncation bias is relatively minor when truncation is as late as 36 months and that the effect of memory bias increases with ascending marriage duration. Now, if women of lower strata marrying earlier have comparatively longer marriage durations than those belonging to higher strata,

then the observed relationship between socio-economic status and fecundability could be an artifact of this association between marriage duration and socio-economic status. By considering women married for 3 to 8 years, we are roughly controlling for socio-economic differentials in the two biases. Since overall fecundabilities for individual years between 3 to 8 years are about the same, it can be assumed that whether the woman is married for three years or for eight years, she probably is subjected to the same magnitude of truncation and memory biases. Thus, if socio-economic differentials in fecundability are found for women married for 3 to 8 years, then it can probably be said that these differentials are <u>not</u> due to differentials in truncation and memory biases.

The overall fecundability estimate for women married 3 to 8 years is about 20 per cent higher than the one for all women. This is interpreted to mean that for all women the two biases are not compensating and that the effect of the memory bias is higher than the effect of the truncation bias. Now if for women of any sub-group this ratio is higher (or lower) than 120, then it can be said that the relative effect of memory bias on fecundability estimate for this group is higher (or lower) than in the total group and/or the relative effect of truncation bias on fecundability estimate for this group is lower (or higher) than in the total group.

Considering the variations in fecundability by socio-economic status of couples for women married for 3 to 8 years, it can be said that most of the important socio-economic differentials in fecundability are <u>not</u> due to the differentials in truncation and memory biases. The

measures of current economic status, household income and ownership of modern objects show an irregular relationship with fecundability. However, the stable and better measured background variables, namely, couple's education, couple's rural background, and family structure show a consistently positive relationship with fecundability.

Taiwanese couples have lower fecundability than those from mainland China, which is not consistent with the trend shown by all women in the sample. This may indicate that women from mainland China are not less fecund biologically than those from Taiwan and the observed difference in fecundability is probably due to some truncation or memory bias. A part of the differences between fecundability of women from mainland China and from Taiwan may be due to the differences in their socio-economic status. This is further explored later by using the MCA program.

Effect of Interdependence between Age at Marriage and Socio-economic Measures on Fecundability Differentials

It is desirable to check whether the fecundability differentials by socio-economic measures are real or are artifacts of the association between age at marriage and the socio-economic measures. Table 5.2 shows the fecundability rates and their standard errors for each socio-economic measure by wife's age at marriage up to age 25.

By separating women into four age groups (12 to 18 years, 19 to 20 years, 21 to 25 years and 26 years or more) we are roughly controlling for the effect of age at marriage. Now if the apparent fecundability shows any relationship with socio-economic measures within each age

at marriage group, then it can probably be said that the socio-economic differentials in fecundability are not due to the differences in age at marriage. On the other hand, if the differences in fecundability by socio-economic measures disappear within each age at marriage group, then it can be said that the socio-economic differentials in fecundability are probably produced by the differences in at age marriage.

The salient features shown by the results in Table 5.2 are:

1. Fecundability of women belonging to the highest social strata is higher than those belonging to the lowest social strata; this is shown by the couple's education, couple's rural background, husband's employment status and ownership of modern objects. Since these trends are consistent within each age at marriage group, the fecundability differentials by couple's education, couple's rural background, husband's employment status and ownership of modern objects are not produced by the differences in age at marriage. The middle groups do not show any consistent pattern, which could be due to our arbitrary groupings of socio-economic measures.

2. Fecundability differentials by ethnic background are also not produced by the differences in age at marriage, because within each age at marriage group Taiwanese couples have higher fecundability than those from mainland China.

3. Fecundability differentials by family type tend to disappear after controlling for age at marriage. It is only among women who got married at ages 19 to 20 years that those living in nuclear families have higher fecundability than those living in extended family units. The differences in fecundability by family type probably are produced

Table 5.2: The Fecundability Rates per 1000 Women by Selected Measures of Socio-economic Status by Age at Marriage in the Absence of Contraception for Women with at Least One Pregnancy[a]

Measures of socio-economic status	Age at marriage: 18 years or less	19-20 years	21-25 years	All
All wives	117±2	164±3	222±4	163±2
1. Husband's education				
Primary or less	107±2	162±3	205± 5	150±2
Junior high school	116±5	148±5	250±13	159±5
Senior high school or more	161±6	179±7	244± 8	200±4
2. Wife's education				
None	93±2	137±4	226± 8	134±2
Primary	131±3	174±3	205± 6	172±2
Junior high school or more	149±5	163±7	252± 9	197±5
3. Rural background				
Farmer now	90±2	147±6	213± 3	144±3
Not farmer now:				
Both have rural background	116±3	153±4	204± 7	153±3
At least one has no rural background	131±4	187±7	239± 6	183±3
4. Ethnic background				
Both Taiwanese	113±2	164±3	232± 5	162±2
Mixture	195±9	188±3	270± 4	224±7
Both mainlanders	94±4	151±9	147±8	123±4
5. Family type				
Nuclear always	115±5	299±9	224± 8	180±4
Nuclear now; have lived with parents	107±5	157±9	223± 8	152±4
Extended always	120±2	155±4	221± 6	162±2
6. Number of modern objects owned				
0-3	94±2	148±3	212± 8	141±2
4-5	124±3	166±6	198± 7	162±3
6 or more	139±3	165±5	251± 7	183±3
7. Household income				
Less than 1,000 NT$	98±3	184±6	226± 8	157±3
1,000-1,499 NT$	109±3	149±5	194± 7	145±3
1,500 NT$ or more	124±2	185±5	226± 8	178±3
8. Husband's employment status				
Farmer	90±2	147±6	217± 9	144±3
Other traditional	111±3	156±5	224± 9	157±3
Nontraditional	129±3	176±4	222± 9	173±2

[a]Women who were definitely premaritally pregnant are excluded.

by women marrying between ages 19 to 20 years.

4. Fecundability differentials by household's monthly income probably are caused by women marrying before 19 years of age because among women marrying at the age of 19 years or more, the fecundability does not vary with household income.

In general, then, the measures of socio-economic status show a positive relationship with fecundability independent of differentials in age at marriage and of truncation and memory biases. It is possible, however, that some of these differentials are caused by the inter-dependence among different measures of socio-economic status, age at marriage, truncation and memory biases. The Multiple Classification Analysis (MCA) program is used to study the fecundability differentials by each socio-economic measure and demographic characteristic after controlling for the effect of one or more variables simultaneously. Results follow in the next section.

Multiple Classification Analysis of Fecundability; Fecundability Differentials by Demographic Characteristics

The results from the MCA tend to confirm the two relationships between fecundability and the demographic characteristics established in Chapter IV.

Wife's Age at Marriage and Fecundability

The apparent fecundability tends to increase with advancing age at marriage, as shown by the unadjusted deviations from overall fecundability in Table 5.3. Association between age at marriage and marriage duration accounts for a part of this variation as shown by some

Table 5.3: Multiple Classification Analysis of Fecundability Using Two Demographic Characteristics, Controlling for Measures of Socio-economic Status Separately, in the Absence of Contraception, for Women with at Least One Pregnancy[a]

Demographic characteristics	Deviations from overall fecundability										Number of women
	Unadjusted	Adjusted for variables[b]									
		DM/AM	HED	WED	RBG	EBG	FT	MO	HI	All SES	
Wife's age at marriage											
12-18 years	- 78	-39	- 72	- 72	- 79	- 81	- 79	- 75	- 78	- 73	682
19-20 years	- 6	- 9	1	- 3	- 2	- 1	- 2	- 5	- 5	5	759
21-25 years	68	40	58	61	65	66	64	65	66	53	679
26 years or more	165	92	129	144	162	153	157	157	170	141	70
Duration of marriage											
0-35 months	194	172	183	191	194	190	191	193	196	182	277
36-107 months	35	27	37	39	36	36	35	35	35	36	722
108-143 months	- 25	-26	- 18	- 24	- 24	- 21	- 25	- 24	- 23	- 19	309
144-203 months	- 60	-53	- 63	- 65	- 61	- 62	- 61	- 59	- 60	- 62	582
204 months or more	-122	-93	-118	-117	-123	-120	-118	-122	-123	-115	300
Overall fecundability rate	235										
Standard deviation	424										
Number of women	2190										

[a]Women who were definitely premaritally pregnant are excluded.

[b]Index of variables

AM	wife's age at marriage	EBG	couple's ethnic background
DM	duration of marriage	FT	family type
HED	husband's education	MO	ownership of modern objects
WED	wife's education	HI	household's income
RBG	couple's rural background	EBG	couple's ethnic background

reduction in deviations from overall fecundability after adjusting for the effect of marriage duration (compare Columns 1 and 2 in Table 5.3).

The association between wife's age at marriage and the measures of socio-economic status do not account for much of this variation in fecundability by wife's age at marriage, whether the effects of these socio-economic measures are considered one at a time or are considered simultaneously (as shown by the fact that there is practically no change between the unadjusted and adjusted deviations from overall fecundability by wife's age at marriage in Table 5.3). When the effect of socio-economic status is controlled along with the effect of marriage duration, only then the adjusted deviations for wife's age at marriage are reduced to half of the unadjusted deviations (Table 5.4). However, even after controlling for all measures of socio-economic status and marriage duration, the adjusted deviations, which are lower than the unadjusted deviations, show a consistent positive relationship between age at marriage and fecundability. This indicates that the fecundability differentials by wife's age at marriage are real and are not entirely caused by the differentials in truncation and memory biases associated with marriage duration or by differences in socio-economic status.

Marriage Duration and Fecundability

Apparent fecundability tends to decrease with ascending marriage duration, as shown by the unadjusted deviations from overall fecundability for marriage duration in Table 5.3. The pattern of relationship remains strong and consistent even after controlling for wife's age at marriage and seven measures of socio-economic status separately or

Table 5.4: Multiple Classification Analysis of Fecundability for Wife's Age at Marriage Controlling for Measures of Socio-economic status and Duration of Marriage; for Duration of Marriage Controlling for Measures of Socio-economic Status and Wife's Age at Marriage, in the Absence of Contraception, for Women with at Least One Pregnancy[a]

	Deviations from overall fecundability									
		Adjusted for marriage duration and variables[b]								Number
	Unadjusted	HED	WED	RBG	EBG	FT	MO	HI	All SES	of women
Wife's age at marriage										
12-18 years	- 78	-33	-31	-40	-43	-41	-36	-39	-35	682
19-20 years	6	- 2	- 6	- 5	- 4	- 5	- 8	- 8	1	759
21-25 years	68	29	31	36	39	38	36	38	27	679
26 years or more	165	55	66	88	81	87	85	94	72	70
		Adjusted for wife's age at marriage and variables[b]								
		HED	WED	RBG	EBG	FT	MO	HI	All SES	
Duration of marriage										
0-35 months	194	167	174	171	165	169	172	173	163	277
36-107 months	35	31	32	28	27	27	27	26	29	722
108-143 months	- 25	-19	-25	-24	-22	-26	-25	-24	-20	309
144-203 months	- 60	-58	-60	-55	-55	-54	-53	-53	-56	582
204 months or more	-122	-96	-95	-95	-89	-89	-96	-95	-92	300
Overall fecundability rate	235									
Standard deviation	424									
Number of women	2190									

[a]Women who were definitely premaritally pregnant are excluded.

[b]For index of variables see footnote b in Table 5.3.

simultaneously (compare unadjusted deviations with adjusted deviations from overall fecundability for marriage duration in Tables 5.3 and 5.4). This confirms that the decrease in apparent fecundability by ascending marriage duration is not due to age at marriage, the socio-economic status, or their combined effects.

Socio-economic Status and Fecundability

The unadjusted deviations from overall fecundability in Table 5.5 restate in another way the relationships already established between fecundability and measures of socio-economic status. We now consider how each of these relationships is effected by controlling for the others and for age at marriage and marriage duration simultaneously.

Husband's Education

Husband's education seems to be the most powerful predictor (among all socio-economic predictors) of fecundability. The apparent fecundability tends to increase consistently with husband's education as shown by the unadjusted deviations. Adjusting for wife's age at marriage, marriage duration, and other six measures of socio-economic status, all at one time or in various combinations, does not alter the picture. Adjusted deviations from overall fecundability, shown in Tables 5.5 and 5.6, although slightly lower in magnitude than unadjusted deviations, still show a strong and consistent positive relationship between husband's education and the fecundability.

Wife's Education

The unadjusted deviations show a positive relationship between wife's education and the fecundability. The pattern remains consistent

Table 5.5: Multiple Classification Analysis for Measures of Socio-economic Status Controlling for Demographic Characteristics, in the Absence of Contraception, for Women with at Least One Pregnancy[a]

Predictors	Deviations from overall fecundability				Number of women
		Adjusted for variables			
	Un-adjusted	Age at marriage	Marriage duration	Age at marriage and marriage duration	
1. Husband's education					
Less than primary graduate	-41	-32	-37	-34	417
Primary graduate	-43	-39	-41	-39	924
Junior high school	-11	- 6	1	2	294
Senior high school	74	60	58	53	317
At least some college	151	136	147	139	238
2. Wife's education					
None	-38	-26	-27	-24	714
Primary nongraduate	-19	-13	-39	-34	277
Primary graduate	-16	-19	-17	-19	757
Junior high school	80	73	79	76	282
Senior high school	134	105	132	118	160
3. Rural background*(RBG)					
Farmer now	-69	-67	-70	-68	415
Not farmer now:					
Both H & W have RBG	- 8	- 4	- 2	- 1	832
Either H or W has RBG	11	6	3	1	592
Neither has RBG	81	79	83	81	351
4. Ethnic background					
Both Taiwanese	-19	-18	-16	-16	1678
Mixture	105	101	48	55	244
Both mainlander	22	22	57	50	268

Table 5.5:--(CONTINUED)

Predictors	Deviations from overall fecundability				Number of women
		Adjusted for variables			
	Un-adjusted	Age at marriage	Marriage duration	Age at marriage and marriage duration	
5. Family type					
Nuclear always	66	58	51	49	441
Nuclear now, have lived with parents	-16	- 9	1	2	606
Extended always	-17	-18	-20	-20	1143
6. Number of modern objects owned					
0 or 1	-44	-30	-24	-18	178
2 or 3	-33	-27	-28	-25	525
4	-43	-43	-51	-50	339
5	19	16	13	12	338
6	45	38	37	34	478
7 or more	36	30	43	39	332
7. Household's income in NT$					
Less than 1,000	- 8	- 4	-17	-14	510
1,000-1,499	-28	-29	-26	-27	629
1,500-1,999	13	12	22	20	326
2,000-2,499	70	66	68	66	226
2,500 or more	26	29	31	31	291
Overall fecundability rate	235				
Standard deviation	426				
Number of women	2190				

[a]Women who were definitely premaritally pregnant are excluded.

*H stands for husband
W stands for wife
RBG stands for rural background

Table 5.6: Multiple Classification Analysis of Fecundability for Measures of Socio-economic Status, in the Absence of Contraception for Women with at Least One Pregnancy[a]

Predictors	Deviations from overall fecundability										Number of women
	Unadjusted	Adjusted for variables									
		1-2	1-3	1-4	1-5	1-6	1-7[b]	1-7 & AM	1-7 & DM	1-7 & AM & DM	
1. Husband's education											
Less than primary graduate	-41	-38	-29	-30	-32	-32	-38	-32	-33	-31	417
Primary graduate	-43	-38	-36	-38	-37	-39	-39	-35	-36	-34	924
Junior high school	-11	-11	-16	-16	-14	-14	-13	-10	0	1	294
Senior high school	74	68	62	59	59	62	66	54	51	47	317
At least some college	151	137	126	141	140	142	146	133	128	124	238
2. Wife's education											
None	-38	- 4	2	0	0	- 1	0	10	10	13	714
Primary nongraduate	-19	5	9	3	3	1	1	6	-16	-11	277
Primary graduate	-16	- 9	-13	-17	-17	-18	-18	-21	-17	-19	757
Junior high school	80	18	14	21	21	25	25	19	21	19	282
Senior high school or more	134	20	13	37	38	46	41	12	30	17	160
3. Rural background*(RBG)											
Farmer now	-69		-37	-36	-33	-34	-35	-39	-40	-41	415
Both H & W have RBG	- 8		-8	- 7	- 7	- 7	- 5	- 2	- 1	0	832
Either H or W has RBG	11		- 2	- 1	- 3	- 2	- 5	- 7	- 9	-10	592
Neither H nor W has RBG	81		61	60	60	59	61	64	65	66	351
4. Ethnic background											
Both Taiwanese	-19			4	8	10	10	5	7	5	1678
Mixture	105			60	42	38	39	48	0	9	244
Both mainlanders	22			-78	-91	-98	-96	-77	-45	-43	268

Table 5.6:--(CONTINUED)

Predictors	Deviations from overall fecundability										Number of women
	Unadjusted	Adjusted for variables									
		1-2	1-3	1-4	1-5	1-6	1-7[b]	1-7 & AM	1-7 & DM	1-7 & AM & DM	
5. Family type											
Nuclear always	66				34	34	34	27	27	24	441
Nuclear now, have lived with parents	-16				- 9	-10	- 9	- 3	3	4	606
Extended always	-17				- 8	- 8	- 8	- 9	-12	-12	1143
6. No. of modern objects owned											
0 or 1	-44					- 7	- 7	1	16	18	178
2 or 3	-33					4	5	6	9	9	525
4	-43					-13	-10	-14	-17	-18	339
5	19					23	26	23	17	17	338
6	45					14	13	11	5	4	478
7 or more	36					-32	-39	-34	-31	-29	332
7. Household income in NT$											
Less than 1,000	- 8						18	13	3	3	510
1,000-1,499	-28						-30	-32	-30	-29	629
1,500-1,999	13						- 9	- 8	2	1	326
2,000-2,499	70						48	52	50	51	226
2,500 or more	26						- 3	7	6	10	291
Overall fecundability rate	235										
Standard deviation	424										
Number of women	2190										

[a]Women who were definitely premaritally pregnant are excluded.

[b]In this column deviations for each measure of socio-economic status are shown after adjusting for the effect of remaining six measures. Similar interpretations apply to other columns.

*H stands for husband; W stands for wife; RBG stands for rural background.

even after controlling for wife's age at marriage and marriage duration separately or simultaneously. However, once adjusted for husband's education, fecundability varies eratically with wife's education (Column 2 in Table 5.6). This is also true when the other five measures of socio-economic status, and two demographic characteristics are added one by one to the husband's education. Wives with at least junior high school level education have slightly higher fecundability than those with lesser education, even after controlling for all other six measures of socio-economic status and two demographic characteristics. However, it appears that the relationship between fecundability and education depends much more on the husband's education than that of the wife.

Couple's Rural Background

The fecundability of couples without a farm background is much higher than that of couples living on a farm at the time of the interview. Adjusting for education reduces the magnitude of deviations, but still leaves fecundability higher for nonfarmers than for farmers. This differential remains even after controlling also for the four other measures of socio-economic status and the two demographic characteris tics.

Ethnic Background

Ethnic background has a somewhat puzzling relationship with fecundability. The unadjusted deviations show that couples from mainland China have higher fecundability than those from Taiwan, and this remains true after adjusting for wife's age at marriage and marriage duration. This pattern is not consistent with the earlier one when

fecundability was estimated by using the type-I model. However, once controlled for couple's education and rural background, the adjusted deviations show that mainlanders have lower fecundability than Taiwanese. Adjusting for three other measures of socio-economic status and two demographic characteristics in addition to education and rural background does not alter the picture. This probably shows that mainlanders in fact have lower fecundability than the Taiwanese that is obscured by the social and demographic correlates of ethnic background when only the unadjusted deviations are considered.

Family Type

Wives living in a nuclear family at the time of marriage consistently show higher fecundability than those living in extended family units, even after adjusting for the six other measures of socio-economic status and two demographic characteristics, although the magnitude of deviations reduces considerably after adjusting for couple's education, and couple's rural background along with ethnic background. Therefore, living in a nuclear family has some connection with higher fecundability apart from the higher socio-economic status of nuclear families.

Economic Variables

After taking into account the two demographic variables, the adjusted deviations in Table 5.5 show that women of high economic status (i.e., with modern objects of five or more and living in households with a monthly income of 1,500 N.T.$ or more) have higher fecundability than those of low economic status, but after controlling for the additional background variables, the adjusted deviations for economic categories in

Table 5.6 show rather small irregular variations. The only notable point is that the highest economic category (measured by ownership of modern objects only) show a distinctly lower fecundability than average after adjusting for other variables, which possibly may indicate inverted U-type relationship between the two variables when other things are equal. However, our basic conclusion remains that the two measures of contemporary economic status have no consistent connection to fecundability that is not a reflection of the background variables.

Summary and Discussion

The preceding analysis supports the hypothesized relationship between fecundability and socio-economic status. Women of higher socio-economic status have higher fecundability than those with lower status. Adjustments for demographic characteristics slightly decrease the predicting power of socio-economic measures but the adjustments for socio-economic measures do not decrease the predicting power of demographic characteristics. In particular:

1. Husband's education shows strongest relationship with fecundability, even after adjusting for wife's education and other socio-economic and demographic variables.

2. Wife's education has little relation to fecundability after adjusting for the husband's education, although wives with at least junior high school level education have slightly higher fecundability than those with less education.

3. Rural background is distinctly related to fecundability even after controlling for other socio-economic and demographic variables. Wives of farmers have lower fecundability than others.

4. Taiwanese couples have higher fecundability than those from mainland China.

5. Women always living in nuclear families have higher fecundability than those living in extended family units, even after adjusting for the effect of other variables.

6. Two measures of economic status, ownership of modern objects and household income, do not have any independent effect on fecundability, probably because of the time lag between these variables and fecundability measure.

7. Variations in fecundability by age at marriage and marriage duration are not accounted for by their joint relation to socio-economic levels. This does not contradict the interpretation given in Chapter IV, namely, (a) the positive relationship between fecundability and wife's age at marriage is due to some physiological changes which increase the promptness of first conception with advancing age at marriage to 25 years, and (b) the negative relationship between fecundability and marriage duration is due to the effects of truncation and memory biases.

8. Wife's age at marriage and marriage duration do not account for much of the variations in fecundability by socio-economic status. The differences in fecundability between highest and lowest status women are considerable even after controlling for wife's age at marriage and marriage duration. Although age at marriage and duration of marriage are both related to socio-economic status, this relationship does not explain an additional correlation between socio-economic status and fecundability.

All of this analysis indicates that socio-economic differentials in fecundability apparently are real and not the artifacts of associations between age at marriage, socio-economic status, or memory and truncation biases associated with marriage duration. It is possible that memory bias, related to socio-economic status independently of marriage duration, might give rise to a part of the apparent fecundability differentials by socio-economic status. This possibility cannot be checked from the available data.

The variation in fecundability accounted for by socio-economic status, age at marriage, or marriage duration is also a function of the quality of measures of these factors. None of these are perfect, and more refined measures might show socio-economic status as having even more prediction power. Also, in a larger sample with the possibility of more elaborate cross tabulations, age at marriage and marriage duration might explain somewhat more variation than they did in this analysis. These limitations about the sample size, the analysis technique, and the measurement errors probably exaggerate the residual error term in fecundability differentials.

What are the factors contributing to the socio-economic fecundability differences? One can speculate several possible explanations. One possibility is that women in the highest socio-economic group have more opportunities for premarital intercourses, which could inflate the fecundability estimates if (a) more premarital pregnancies in this group were reported as first month conceptions, and/or if (b) premarital intercourse <u>per se</u> changes women's physiological conditions in such a way

that after marriage these women conceive rather quickly as compared to those without any such experience.

The effect of under-reporting of premarital conceptions on fecundability is indirectly estimated in Table 5.7 under the assumption that in all status groups every alternate premarital conception is reported as first month conception. This is done only for one measure of socio-economic status--husband's education.

Table 5.7: Fecundability Rates[a] per 1000 Women after Adjusting for Unreported Premarital Conceptions, by Husband's Education, in the Absence of Contraception, for Women with at Least One Pregnancy

Husband's education	Fecund-ability rate per 1000 women (1)	Reported premarital concep-tions (2)	Adjusted fecund-ability rate per 1000 women (1)-(2) (3)	Deviations from overall adjusted fecund-ability (4)	Number of women (5)
Less than primary graduate	194	34	160	- 8	417
Primary graduate	193	67	126	-42	924
Junior high school	224	81	143	-25	294
Senior high school	309	66	243	175	317
At least some college	387	140	247	179	238
All	235	67	168		2190

[a]As obtained by MCA program.

Of women, whose husbands have at least some college education, 39 per cent conceived during the first one and one-half months after their marriage; that is, roughly 26 per cent of the women conceived

during the first month after marriage. This figure is quite close to the one reported for women in the United States (about 28 per cent in FGIMA sample). Perhaps Taiwanese couples of the highest socio-economic status behave in a similar way to those in the United States.

Columns 3 and 4 in Table 5.7 show that even after adjusting for such estimated unreported premarital conceptions, the fecundability of the highest status group is one and one-half times greater than that for the lowest group. Under the extreme assumption that all premarital conceptions in lowest group are reported as premarital conception, whereas only every alternate premarital conception in the highest group is reported as a premarital conception, the adjusted fecundability for the latter is still 247 (= 387-140) as compared to 194 for the former. This exercise suggests strongly that the observed fecundability differentials by husband's education are <u>not</u> entirely due to the under-reporting of the premarital pregnancies in the highest group.

9. A second possibility is that some of the fecundability differentials by socio-economic status arise due to very early pregnancy losses which are not noticed by women and thus are not reported at all. The proportion of such women who had an early miscarriage would be higher in the lower strata than in upper strata because of some negative association between health of women and the likelihood of an early miscarriage. This will lengthen the first pregnancy interval for lower strata women and thus will deflate their apparent fecundability.

10. There are in addition a set of other possible explanations which we are unable to test. These range from genetic factors through mixed physiological-cultural factors such as nutrition and other health

factors, and couple's attitudes towards family building and selectivity of partners governing their sexual patterns.

Higher educated husbands and wives usually come from families living in better conditions, probably are healthier and tend to select healthier partners coming from similar family backgrounds than those with less education. If couples in the higher strata are healthier this might increase their fecundability. Other social customs and environmental factors could increase the promptness of first conception. It is possible, for example, that the frequency of intercourse increases with educational level, because more educated couples live in nuclear families which provide them more freedom and privacy for sexual activities that might be lacking for couples living with their parents or married brothers under the same roof. For example, on the basis of a study done in seven villages of West Bengal India, Nag reached the following conclusion about the differences in the frequency of intercourse between couples living in "simple families" (equivalent to nuclear families) and those living in "joint families."

> The average coital frequency for simple families is consistently higher than that for joint families. It is true not only when all groups and ages are considered together, but also separately for almost every age category in each of the six (religious) groups. Although the differences in average frequencies are not large, the remarkable consistency in their trend direction leaves very little doubt about the higher coital frequency among women in simple families than those in joint families.[13]

In this Indian study for women between the ages of 15 and 29 the average coital frequency reported by couples living in simple families

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[13]Moni Nag, "Family Type and Fertility," United Nations, Vol. II, World Population Conference, Belgrade, August 30-September 10, 1965 (New York, 1967), p. 161.

was 3.2 times per week as compared to 2.3 among couples living in joint families.[14]

Higher coital frequency along with nonuse of contraception (users of contraception are excluded from the present analysis) could give rise to quicker conception among couples of higher socio-economic strata than those among lower strata who probably do not have equal opportunities (privacy) for intercourse. Due to lack of privacy and other social customs, there might also be some delay, among lower strata couples, in consummation of marriage. Any such delay would deflate the proportion of women conceiving in the first month after marriage and thus would deflate their apparent fecundability. There might also be some deliberate attempt among couples of higher strata to have their first baby rather promptly than those in the lower strata. This is possible because couples in the upper strata are economically in a better position than those in the lower strata and thus probably are ready to start their families earlier.

11. To test some of the possible explanations mentioned above for fecundability differentials by socio-economic status, detailed information is required about variables like coital frequency, attitudes about family building and social customs effecting directly or indirectly the consummation of marriage. More important is the fact that women need to be followed after marriage for complete and accurate reporting of all events, in order to get differentials free from the biases mentioned above.

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[14]Averages computed on the basis of published data in paper by Nag, ibid., pp. 160-63.

12. If after collecting all the information needed on factors like coital frequency, etc., we still find that given equal opportunities for intercourse and after allowing for truncation and memory bias and for differences in age at marriage, there are still considerable differences in fecundability between major socio-economic groups, then we would be able to say that the fecundability differentials by socio-economic status are real and might have been caused by the differences in factors like diet, health, infections, etc. This finding, if supported by further detailed analysis, have serious implications for future fertility trends and family planning programs in developing countries, because with the improvements in general health conditions we would expect that in the future the fecundability of couples will rise and so would their fertility unless drastic measures are introduced to widespread the use of contraception.

CHAPTER VI

FETAL WASTAGE, ORDER OF PREGNANCY AND AGE OF THE MOTHER

Introduction

In any retrospective study, such as the present one, it is tremendously difficult to collect complete and accurate information about pregnancy losses. The task becomes even harder if one tries to differentiate between the types of pregnancy losses such as neonatal deaths, spontaneous abortions, induced abortions and stillbirths, because for this purpose one needs to know the exact period of gestation for each pregnancy. To believe that respondents will be able to give all such details accurately would be expecting too much from them. Therefore, estimates of fetal wastage based on data collected in a retrospective survey are subject to two types of errors: (1) errors in differentiating between types of fetal wastage and (2) errors in reporting the complete number of pregnancy losses. Despite these limitations of the present data, we shall attempt (a) to estimate the level of fetal wastage in the Taichung city of Taiwan, (b) to estimate the magnitude of under-reporting of pregnancy losses, and (c) to study the variations in fetal wastage by age of mother and by the order of pregnancy.

For the purpose of this analysis, the pregnancy losses are classified into two groups: (1) pregnancies terminated by induced

abortions and (2) pregnancies terminated by spontaneous abortions or stillbirths. The distinction between the two is based on the reports of the respondents; we know nothing more about the accuracy of this distinction. We expect that some induced abortions are classified as spontaneous abortions. However, the total wastage rate (induced + spontaneous) will give a conservative estimate of the level of fetal wastage in Taichung. Here, the fetal wastage rate is defined as the number of pregnancies resulting in nonlive births per 1,000 completed pregnancies reported by the respondents.

In reviewing the existing literature we find that two findings relating the fetal wastage rate, age of mother,and the order of pregnancy appear to be consistent. These findings are expressed below as hypothesis 6.1 and 6.2.

Hypothesis 6.1: The level of fetal wastage increases with the advancing age of the mother.

Hypothesis 6.2: The level of fetal wastage increases with the order of the pregnancy.

The fetal wastage rate does not appear to have a linear relationship either with the age of the mother or with the order of pregnancies. Shapiro,[1] Potter[2] et al. and Freedman[3] et al. have shown the nonlinearity of these relationships quite clearly. In the present chapter

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[1]S. E. Shapiro, W. Jones, and P. M. Densen, "A Life Table of Pregnancy Termination and Correlates of Fetal Losses," Milbank Memorial Fund Quarterly, XL, No. 1 (January 1962), 7-45.

[2]R. G. Potter, J. B. Wyon, M. New, and J. E. Gordon, "Fetal Wastage in Eleven Punjab Villages," Human Biology, XXXVII, No. 3 (September 1965), 262-73.

[3]Ronald Freedman, L. C. Coombs, and J. Friedman, "Social Correlates of Fetal Mortality," Milbank Memorial Fund Quarterly, XLIV, No. 3 (July 1966), 327-44.

we would also study whether or not in Taichung these relationships are linear.

Results

In the Taichung sample the information was collected for about 9,980 completed pregnancies (this excludes pregnancies in progress at the time of interview). Out of these 75 per 1,000 were classified as terminated by spontaneous abortions and 45 per 1,000 by induced abortions, giving an overall fetal wastage rate of 120 per 1,000 pregnancies (see Table 6.1).

Table 6.1: Fetal Wastage Rate per 1000 Completed[a] Pregnancies by the Use of Contraception and by the Type of Fetal Wastage

Use of contraception during the interval prior to conception	Induced abortion rate per 1000 pregnancies	Spontaneous abortion rate per 1000 pregnancies	Total fetal wastage rate per 1000 pregnancies	Number of pregnancies
Yes	305	133	438	724
No	25	70	95	9256
All	45	75	120	9980

[a]Completed pregnancies are those which terminated before the date of interview. This excludes pregnancies in progress at the time of interview.

Women reported to have used contraception regularly or irregularly during 7 per cent of intervals preceding these pregnancies. For women who used contraception prior to conception the risk of fetal wastage was about five times greater than the risk in the absence of

contraception. The main reason for this difference is a twelvefold increase in the induced abortion rates after the unsuccessful use of contraception. The spontaneous abortion rate following the use of contraception is also higher than the one in its absence; this is, probably, mainly due to some classification error, it is not likely that the use of contraception would greatly change the risk of miscarriages, which mainly depends on the physiological conditions of women (see Table 6.1).

Fetal Wastage Rate and Age of the Mother

When age of the mother is measured at the termination of each pregnancy, the risk of fetal wastage increases monotonically with advancing age (results shown in Tables 6.2 and 6.3). This trend is consistent whether or not women have used contraception prior to conception. The trend is also consistent with the results obtained in other

Table 6.2: Fetal Wastage Rate per 1000 Reported Pregnancies by Age of Mother at Termination of Pregnancy

Age of mother at termination of pregnancy (in completed years)[a]	Number of pregnancies	Fetal wastage rate per 1000 reported pregnancies		
		Spontaneous abortions	Induced abortions	All
12-19 years	2118	68	3	71
20-24 years	4570	68	22	90
25-29 years	2452	82	81	163
30-34 years	772	101	171	272
35 years or more	65	169	231	400
All	9977	75	45	120

[a]The age of mother is not known for 3 cases.

Table 6.3: Fetal Wastage Rate per 1000 Reported Pregnancies by Age of Mother, by Use of Contraception Prior to Conception

Age of mother at the termination of pregnancy (in completed years)	Used contraception				Did not use contraception			
	Number of pregnancies	Fetal wastage rate per 1000 reported pregnancies			Number of pregnancies	Fetal wastage rate per 1000 reported pregnancies		
		Spontaneous abortions	Induced abortions	All		Spontaneous abortions	Induced abortions	All
12-19 years	32	125	94	219	2086	67	2	69
20-24 years	225	133	164	298	4345	65	14	79
25-29 years	290	124	328	452	2162	77	47	124
30-34 years	164	146	488	634	608	89	85	174
35 or more	13	*	*	*	52	173	173	346
All	724	133	305	438	9253	70	25	95

[a]The age of mother is not known for 3 cases.

*Base less than 25 pregnancies.

studies.[4] These differentials are probably due to a combination of (a) the association between age of the mother and pregnancy order and (b) the memory bias resulting in under-reporting of fetal deaths occurring at younger ages to older women.

Memory Bias and the Age Differentials in Wastage Rates

In order to estimate the magnitude of under-reporting and to study the age differentials in wastage rates free from memory bias, the total fetal wastage rates in the absence of contraception are presented in Table 6.4 by the age of the mother at the termination of each pregnancy and her age at the interview, i.e., at the time of reporting. It can be assumed that women aged 35 to 39 at the interview have reported comparatively all of their fetal losses occurring between ages 35 and 39.

Table 6.4: Fetal Wastage Rate per 1000 Reported Pregnancies in the Absence of Contraception by Age of Mother at the Termination of Pregnancy and by Her Age at the Interview

Age at the termination of pregnancy (in completed years)	Age at interview (present age in completed years)					Number of pregnancies
	20-24	25-29	30-34	35-39	All	
12-19 years	82	50	64	82	69	2086
20-24 years	118	85	70	74	79	4345
25-29 years		166	126	112	124	2162
30-34 years			173	175	174	608
35-39 years				346	346	52
All	99	86	89	106	95	
Number of pregnancies	710	2194	3088	3261		9253[a]

[a]The age of mother is not known for 3 cases.

[4]For example see Shapiro et al., op. cit., Potter et al., op. cit.; Freedman et al., op. cit.

Similar assumptions apply to other three age groups also. This means that the rates shown along the diagonal in Table 6.4 represent the true level of fetal wastage for each age group. It can be seen from these figures that the wastage rate increases with advancing age of the mother. It increases gradually in younger ages (below 30) and increases more rapidly at older ages (after age 30).

Assuming that the true level of wastage rate for women in the youngest age group is equivalent to the one reported by women aged 20 to 24 at the time of interview, the relationship between the wastage rate per 1,000 completed pregnancies (Y) and age of mother (X) can be represented by the following linear regression equation:

$$Y = 133 + 9.4\ (X-23.6)$$

The regression coefficient 9.4 has a standard error 0.033. According to this expression, in the absence of contraception, the fetal wastage rate, on the average, is 133 per 1,000 completed pregnancies at age 23.6 years, and it increases by about 9.4 points for every additional year in age of mother. In fact, due to nonlinearity this regression equation underestimates the fetal wastage rate for older women, and slightly overestimates the fetal wastage rate for younger women because the actual curve is concave upwards.

Similar rates are shown in Table 6.5 by age of mother, separately for induced abortions and spontaneous abortions following the use or nonuse of contraception. It can be seen, that, in general, these rates tend to confirm the relationship between the level of fetal wastage and the age of mother. The rates following the use of contraception show some irregularities, probably because they are based on small numbers of conceptions.

Table 6.5: Fetal Wastage Rates[a] per 1000 Reported Pregnancies by Use of Contraception Prior to Conception by Age of Mother

	Age of mother (in completed years)					
	Less than 20	20-24	25-29	30-34	35-38	All[b]
A. Number of pregnancies						
1. Used contraception	12	18	43	42	13	128
2. Did not use	380	330	259	110	52	1131
3. All	392	348	302	152	65	1259
B. Spontaneous Abortion Rate						
1. Used contraception	250	333	233	95	154	195
2. Did not use	76	91	100	100	173	93
3. All[b]	82	103	119	99	169	103
C. Induced abortion rate						
1. Used contraception	83	222	233	524	462	336
2. Did not use	6	27	66	73	173	40
3. All[b]	8	37	89	197	231	70
D. Total fetal wastage rate						
1. Used contraception	333	555	466	619	616	531
2. Did not use	82	118	166	173	346	133
3. All[b]	90	140	208	296	400	173

[a]Figures reported in this table are similar to the figures reported along diagonal in Table 6.4 and thus are relatively free from memory bias.

[b]Weighted average of age specific wastage rate.

The estimated wastage rates, shown in Table 6.6, are comparatively free of memory bias, because the ages at reporting coincide with the ages at termination of pregnancies; hence, the weighted averages of these age specific rates would provide an estimate of overall fetal wastage rate closer to the true level in the whole population. This difference between the estimated level of fetal wastage and the one

Table 6.6: Comparison of Observed[a] and Estimated[b] Fetal Wastage Rates per 1000 Completed Pregnancies by Use of Contraception by Type of Fetal Wastage

	Observed wastage rate per 1000 reported pregnancies	Estimate wastage rate per 1000 reported pregnancies	Estimate of under-reporting per 1000 reported pregnancies
A. Spontaneous abortion rate			
1. Following the use of contraception	133	195	-62
2. In the absence of contraception	70	93	-23
3. All	75	103	-28
B. Induced abortion rate			
1. Following the use of contraception	305	336	-31
2. In the absence of contraception	25	40	-15
3. All	45	70	-25
C. Total fetal wastage rate			
1. Following the use of contraception	438	531	-93
2. In the absence of contraception	95	133	-38
3. All	120	173	-53

[a]As reported by respondents.

[b]Weighted averages of true levels of wastage rates for each age group as shown in Table 6.5.

reported by the respondents would give the estimates of the level of under-reporting of fetal losses. Results are shown in Table 6.6.

These estimated rates would tend to underestimate the level of fetal wastage in the past, because of improvements in general health conditions of couples during the last few decades. Because of these improvements, the differences between the estimated and the reported

rates tend to exaggerate the memory bias. On the other hand, that bias is underestimated to the extent that current estimates also fail to include early abortions which are not recognized and thus are not reported by respondents.

Following the use of contraception more than 50 per cent of pregnancies are terminated by fetal wastage as compared to only 13 per cent in the absence of contraception yielding in an overall estimate of 17 per cent fetal wastage. Comparisons of these estimated percentages with the observed ones show that following the use of contraception, 9 per cent of pregnancy losses were under-reported as compared to 4 per cent in the absence of contraception resulting in an overall estimate of the level of under-reporting as 5 per cent. The level of under-reporting for induced abortions seems to be less than that for spontaneous abortions (see Table 6.6).

Fetal Wastage Rate and Pregnancy Order

Results, shown in Tables 6.7 and 6.8, tend to confirm the relationship between pregnancy order and the risk of fetal wastage observed in many other studies,[5] i.e., the risk of fetal wastage increases with the order of pregnancy. This remains consistent whether we consider induced abortion rates or spontaneous abortion rates and whether or not women used contraception prior to conception. For fifth or higher order pregnancy, more than 20 per cent of pregnancies are terminated by fetal wastage and following the use of contraception this percentage increases to more than 50 per cent.

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[5]For example see Shapiro et al., op. cit.; Potter et al., op. cit.; Freedman et al., op. cit.

A part of the association between the wastage rate and the pregnancy order could have arisen due to a combination of (a) the association between age of mother and pregnancy order and (b) the memory bias resulting in under-reporting of pregnancy losses of lower order pregnancies by older women.

Table 6.7: Fetal Wastage Rate per 1000 Reported Pregnancies by Order of Pregnancy

Order of pregnancy	Number of pregnancies	Fetal wastage rate per 1000 reported pregnancies		
		Spontaneous abortions	Induced abortions	All
1	2327	66	2	68
2	2057	70	5	75
3	1734	66	19	85
4	1368	70	48	118
5	1010	90	79	169
6	654	110	127	237
7	395	84	154	238
8	223	81	228	309
9 or more	212	118	297	415
All	9980	75	45	120

Table 6.8: Fetal Wastage Rate per 1000 Reported Pregnancies by Order of Pregnancy by Use of Contraception Prior to Conception

Order of pregnancy	Used contraception prior to conception				Did not use contraception prior to conception			
	Number of pregnancies	Fetal Wastage Rate per 1000 Reported Pregnancies			Number of pregnancies	Fetal Wastage Rate per 1000 Reported Pregnancies		
		Spontaneous abortions	Induced abortions	All		Spontaneous abortions	Induced abortions	All
1	23	87	43	130	2304	66	1	67
2	63	158	32	190	1994	67	5	72
3	105	114	134	248	1629	63	11	74
4	116	129	216	345	1252	65	32	97
5	121	174	338	512	889	79	44	123
6	98	143	388	531	556	104	81	185
7	69	87	493	580	326	83	83	166
8	60	83	550	633	163	80	110	190
9+	69	159	478	638	143	98	210	308
All	724	133	305	438	9256	70	25	95

To roughly control for the effect of memory bias on the pregnancy order differentials in wastage rates, the fetal wastage rates in the absence of contraception are presented in Table 6.9 by the pregnancy order and the age of mother at interview. The wastage rate tends to increase with the order of pregnancy within each age group. The wastage rate also tends to increase with pregnancy order when marriage duration is controlled instead of the present age (results are not shown here). This indicates that the risk of fetal wastage is higher among higher

Table 6.9: Fetal Wastage Rate per 1000 Reported Pregnancies in the Absence of Contraception by Age of Mother at the Interview and by the Pregnancy Order

Order of pregnancy	Age of mother at interview (in completed years)				
	20-24	25-29	30-34	35-39	All
1	89	67	56	66	67
2	116	55	75	69	72
3	56	85	64	80	74
4	222	128	76	95	97
5	*	167	105	125	123
6	*	293	200	159	185
7	*	*	167	157	166
8	*	*	282	157	190
9+	*	*	*	289	308
All	100	86	89	106	95
Number of pregnancies	710	2194	3088	3261	9253[a]

*Less than 25 pregnancies.

[a]The age of mother is not known for 3 cases.

order pregnancies a part of which might have been caused by the association between the order of pregnancy and the age of mother. Controlling for pregnancy order, however, decreases the effect of mother's age. In fact, mother's age shows somewhat negative effect on fetal wastage rate for each order of pregnancy. This might be due to some under-reporting of pregnancy losses at lower order of pregnancies by older women at the time of interview.

Fetal Wastage Rate, Pregnancy Order and Age of Mother

It can be assumed that the effect of memory bias will be a minimum for last pregnancies prior to interview because these are the most recent pregnancies. For these pregnancies the overall fetal wastage rate is about 166 per 1,000 reported and completed pregnancies. This is quite close to 173 estimated from all pregnancies earlier. However, if we only consider the pregnancies following the nonuse of contraception the overall wastage rate is only 113 for last pregnancies compared to 133 for all pregnancies. The difference probably is not due to memory bias but probably is due to a much higher proportion of women using contraception prior to the last pregnancies.

Table 6.10 shows the fetal wastage rates based on last pregnancies by the order of pregnancy and the age of mother at the termination of pregnancy. Due to the small number of cases only two broad age groups are considered and first to third order pregnancies are grouped together and seventh and higher order pregnancies are grouped together. Two features emerge from this table: (1) the fetal death rate increases consistently with the order of pregnancy and (2) the effect of age is

Table 6.10: Fetal Wastage Rate per 1000 Completed Pregnancies in the Absence of Contraception, by the Order of Pregnancy and the Age of Mother at Termination of Pregnancy[a]

Order of pregnancy	Age of mother at the termination of last pregnancy prior to interview						
	Less than 30 years		30 years or more		All ages		
	Number of pregnancies	Fetal wastage rate per 1000 reported pregnancies	Number of pregnancies	Fetal wastage rate per 1000 reported pregnancies	Number of pregnancies	Fetal wastage rate per 1000 reported pregnancies	Standardized fetal wastage rate per 1000 reported pregnancies
1-3	616	39	44	45	660	39	41
4	188	106	67	90	255	102	100
5	152	145	108	120	260	135	136
6	58	224	124	186	182	198	211
7 and higher	45	356	227	198	272	224	301
All	1059	90	570	156	1629	113	113

[a]Based on last pregnancies prior to interview.

[b]Fetal wastage rates standardized for the age distribution.

mainly due to its association with the order of pregnancy and its independent effect is not to increase the level of fetal wastage but to decrease it. However, when examined further we find that the negative association between age and the level of fetal wastage is due to the negative association between age and the level of induced abortions and that the level of spontaneous abortions increases with the advancing age of mother. These features are considered separately.

The fetal wastage rate increases by the order of pregnancy for all ages and for the two age groups separately. To eliminate the effect of the age distribution, the fetal wastage rates for each pregnancy order are standardized by assuming that the age distribution at each pregnancy order is equal to the overall age distribution. Results, shown in the last column of Table 6.10, confirm the relationship between the fetal wastage rate and the order of pregnancy. This indicates that the relationship between fetal wastage and the order of pregnancy is not due to its association with the age of mother.

Marginal rates show that the overall level of fetal wastage for women aged 30 and more is higher than the level for women under age 30. However, when controlled for the pregnancy order the fetal wastage rates for women aged 30 and over are lower than the rates for women under 30 at each pregnancy of fourth and higher order. The overall fetal wastage rate 106 for older women standardized for the pregnancy distribution of all women is lower than the corresponding standardized fetal wastage rate 140 for younger women. This indicates that the observed difference between fetal wastage rates by age is mainly due to the association between the age of mother and the order of pregnancy, and in fact the

independent effect of age is to decrease the fetal wastage rate with advancing age instead of increasing it. This is possible if the proportion of women using induced abortion as a birth control method is higher among younger women than among older women with the same number of pregnancies. In fact the negative association between age and the fetal wastage rate is due to the negative association between age and the induced abortion rate rather than due to the negative association between age and the spontaneous abortion rate. This is shown by the fetal wastage rates standardized for the pregnancy distribution of all women shown in Table 6.11 by age of women separately for induced and spontaneous abortions. The independent effect of age on the level of spontaneous abortions is positive and not negative as shown by total fetal wastage rates.

Table 6.11: Fetal Wastage Rates per 1000 Completed Pregnancies, in the Absence of Contraception by the Age of Mother at Termination of Pregnancy and by Type of Fetal Wastage[a]

Fetal wastage rates per 1000 completed pregnancies	Observed		Standardized for pregnancy distribution of all women		
	Women under age 30 years	Women aged 30 years and more	Women under age 30 years	Women aged 30 years and more	All ages
Induced abortions	54	98	93	54	69
Spontaneous abortions	36	58	47	52	44
All pregnancy losses	90	156	140	106	113

[a]Based on last pregnancies prior to interview.

Comparison with Other Studies

The level of fetal wastage usually excluding induced abortions in Western countries is estimated somewhere between 100 and 200 per 1,000 recognized pregnancies. It is believed now to be closer to 200 than to 100. In two large surveys in the United States the Indianapolis study and the national GAF study (1955), the fetal wastage level was estimated close to 130 per 1,000 recognized pregnancies.[6] In both of these surveys the information about pregnancy losses were collected retrospectively and these estimates were also subjected to the memory bias.

In 11 villages in India, Potter et al. have estimated that 136 out of 1,000 pregnancies are terminated by fetal wastage if the data were collected through monthly household visits, whereas the level of wastage rate based on retrospective data was less than a fifth of that determined prospectively.[7]

In the above estimates of wastage rates for the United States and India, no distinction was made between induced abortions and spontaneous abortions, and the rates referred to all pregnancies following the use or nonuse of contraception. Comparing to these rates the overall reported wastage rate of 120 is not grossly under-estimated. The wastage rate 173 adjusted for memory bias for Taichung is quite

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[6]R. Freedman, P. K. Whelpton and A. A. Campbell, Family Planning, Sterility and Population Growth (New York: McGraw Hill Book Co., Inc., 1959), pp. 31-35; P. K. Whelpton and C. V. Kiser (eds.), Social and Psychological Factors Affecting Fertility, Milbank Memorial Fund, (New York, 1950), Vol. 2, p. 312.

[7]Potter et al., op. cit., p. 264.

close to the 200 mark believed to be true in Western countries. Even if we consider only pregnancies in the absence of contraception, the adjusted rate 133 is not far below the one reported for India in a prospective study. However, if we exclude induced abortions, then the adjusted wastage rate for Taichung is 103 which is far below the levels reported for the United States and for India.

Summary

1. The overall fetal wastage rate reported by respondents in Taichung is 120 per 1,000 recognized and completed pregnancies.

2. The estimated level of under-reporting of fetal wastage in this survey is 53 per 1,000 recognized pregnancies yielding an overall wastage rate of 173 per 1,000 recognized and completed pregnancies.

3. The use of contraception prior to conception increases the risk of fetal wastage mainly by increasing the level of induced abortions. The estimated wastage rate for pregnancies followed by the use and non-use of contraception are 531 and 133 respectively.

4. The risk of fetal wastage increases with the order of pregnancy even after controlling for the age of mother. On the other hand, the risk of fetal wastage for a given order of pregnancy is lower for older women as compared to the one for younger women. The observed positive effect of age on fetal wastage is due to its association with the order of pregnancy and the independent effect of age is to lower the fetal wastage rate instead of increasing it. However, if we exclude induced abortions, then the independent effect of the age of mother on the level of fetal wastage is also positive.

CHAPTER VII

RELATIONSHIPS OF PREGNANCY INTERVALS AND INFECUNDABLE PERIODS TO OUTCOME OF PRECEDING PREGNANCY, AGE OF MOTHER AND USE OF CONTRACEPTION

Introduction

In this chapter an attempt is made to get indirect estimates of the moments of the total infecundable period (postpartum amenorrhea + anovulatory period) associated with the termination of a pregnancy. This chapter will also deal with the variations in the length of the pregnancy interval by outcome of pregnancy, use of contraception and age of mother. In the present analysis the pregnancy interval is defined as the period between the end of one pregnancy and the beginning of the next pregnancy. Thus the pregnancy interval excludes the period of gestation. The pregnancy interval is assumed to be made up of three independent and additive components: (1) Postpartum amenorrhea, (2) Anovulatory period, and (3) Fecundable period. The length of postpartum amenorrhea could be estimated directly when the data are available by the period between the termination of a pregnancy and the beginning of first menstruation following the termination of the pregnancy. This period is followed by one or two anovulatory cycles. During these two periods, the probability of conception is probably close to zero and hence the two together are termed as the "infecundable period." The

data to estimate the length of the infecundable period directly are not available from the present survey and therefore we will use the length of pregnancy intervals to get indirect estimates of the infecundable period.

During the fecundable period a woman is exposed to the risk of conception with a given constant monthly probability. The moments of the fecundable period are obtained from the distribution of first pregnancy intervals. In this chapter we shall estimate the moments of pregnancy intervals from their observed frequency distributions. Knowing the estimated moments of the fecundable period and the pregnancy interval, we can estimate the moments of the infecundable period. The estimates obtained in this chapter are not general but are culturally bounded. For example, the expected length and variance of the infecundable period will depend upon the practice of breastfeeding in this population, which varies from one population to another.

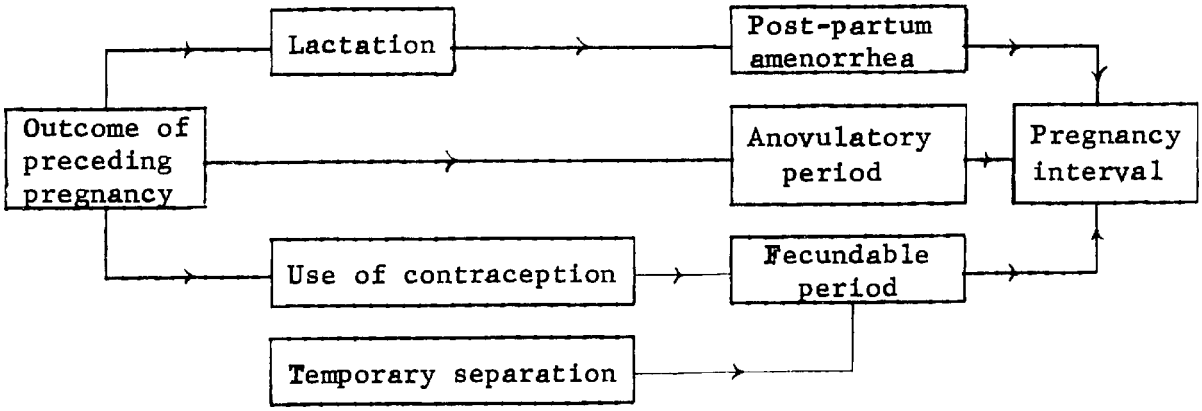
Two factors which can result in lengthening the pregnancy intervals are: temporary separation between spouses and use of contraception for spacing or limiting the childbearing. Both of these factors can increase the length of pregnancy interval only if they overlap with the fecundable period. The average effect of temporary separation in this sample is about half a month per pregnancy interval, and we have subtracted the exact amount of separation from the duration of corresponding pregnancy intervals. The effect of contraceptive use on pregnancy intervals will be studied briefly in this analysis. The use of contraception may depend upon the outcome of the preceding pregnancy which we

shall consider in this chapter. We shall omit the possible effects of demographic factors like number of living children and motivational factors.

Pregnancy Outcome and the Pregnancy Interval

It is expected that the length of a pregnancy interval or the time required for conception, varies with the outcome of the preceding pregnancy. The basis of this expectation is shown in the following Figure 7.1 and is discussed in the following paragraphs.

Figure 7.1: A Schematic Representation of Different Components of Pregnancy Interval and Their Relationship with the Outcome of Pregnancy



(It is assumed that the length of the fecundable period would be independent of the pregnancy outcome, if women did not use contraception after the termination of pregnancy.)

Previous research in this field suggest that the length of post-partum amenorrhea is closely associated with lactation which in turn depends upon the practice of breastfeeding in a society. For example, in the Khanna Study conducted in 11 villages in India, Potter et al. reached the following conclusion about the relationship between post-partum amenorrhea, lactation and outcome of pregnancy:

> When an infant survived one month or more, lactation usually lasted well over a year and the median length of postpartum amenorrhea was 11 months. Whereas if the child was stillborn or died in the first month of life, the mother did not lactate and the median length of postpartum amenorrhea stayed in the vicinity of two months.[1]

It can be assumed, then, that the length of postpartum amenorrhea varies with lactation which in turn is affected by the outcome of the preceding pregnancy. However, there is no clear evidence that lactation does or does not affect the length of anovulatory cycles and of the fecundable period. The length of the anovulatory period for mothers in the United States, on an average, has been assumed to be two months if the preceding pregnancy is terminated by a live birth as compared to zero months if the preceding pregnancy is terminated by an abortion.[2] Following the experience of women in the United States, it is assumed that in Taiwan the length of the anovulatory period does vary with the outcome of the preceding pregnancy. On the other hand, it is assumed that in the absence of contraception, the length of the fecundable period does not vary with the outcome of the preceding pregnancy. Since two of the components of pregnancy interval comprising the total infecundable period are assumed to vary with the outcome of the preceding pregnancy and the third component, the fecundable period, is assumed

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[1] R. G. Potter, Jr., M. L. New, J. B. Wyon and J. E. Gordon, "Applications of Field Studies to Research on the Physiology of Human Reproduction: Lactation and Its Effects upon Birth Intervals in Eleven Punjab Villages, India" in M. C. Sheps and J. C. Ridley (eds.), Public Health and Population Change (University of Pittsburgh Press, 1965), p. 394.

[2] R. G. Potter, Jr., "Birth Intervals: Structure and Change," Population Studies, XVII (November 1963), 156-58.

to be independent of pregnancy outcome, any variation in the length of pregnancy interval by the pregnancy outcome would indicate the variation in the infecundable period by outcome of the preceding pregnancy.

Age, Pregnancy Outcome and Pregnancy Interval

As in all demographic analysis, the age of the women plays an important role in the present analysis also. The basic structure of the relationship between pregnancy outcome and different components of the pregnancy interval remains the same except that the lengths of these components are expected to change as the process moves in time or as women get older. Using data from the Khanna study, Potter[3] et al. have shown that as mothers pass from their early twenties to their late thirties and early forties (1) menstruating intervals lengthened substantially and (2) the length of post-partum amenorrhea associated with lactation increased substantially. The increase in menstruating intervals or the fecundable period with advancing age is usually attributed to decline in fecundability. Whether the lengthening of postpartum amenorrhea with age is culturally bounded due to the increase in duration of breastfeeding as women get older or the length of postpartum amenorrhea also increases with age, in the absence of any increase in the length of breastfeeding or in the absence of breastfeeding, is not known. Nor is it known whether or not the anovulatory period increases with age. For this analysis, it is assumed that both components of the infecundable period, namely, postpartum amenorrhea and anovulatory period, increase with the age of the mother. Since both components, the fecundable and nonfecundable periods, of pregnancy interval are

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[3]Potter et al., op. cit., p. 395.

expected to increase with the age of the mother irrespective of the outcome of the preceding pregnancy, we can expect the following relationship between the length of pregnancy interval and the age of the mother.

Hypothesis 7.1: The length of pregnancy interval increases with the advancing age of mother, irrespective of the outcome of the preceding pregnancy.

Contraception and Pregnancy Interval

Contraception in any pregnancy interval would be effective only if its use coincides with the fecundable period. The use of contraception during a fecundable period decreases the probability of conception, hence increases the length of the fecundable period and the length of pregnancy interval. On the other hand, if women use contraception during the infecundable period, then its length would not change because the probability of conception whenever women are in the infecundable state is already zero. This would be true irrespective of the outcome of the preceding pregnancy. Thus, the length of the pregnancy interval will increase if contraception is being used following the termination of a pregnancy, irrespective of its outcome.

Methodology and Biases

Assuming that the three components of pregnancy interval are mutually exclusive, additive and uncorrelated, we can express the average and the variance of pregnancy intervals in terms of the corresponding moments of its components as follows:

$$M(PI) = M(FP) + M(AP) + M(PPA)$$

$$V(PI) = V(FP) + V(AP) + V(PPA)$$

Where M() stands for a mean, V() for a variance, FP for fecundable

period, and AP for anovulatory period and PPA for postpartum amenorrhea. The sum of AP and PPA is denoted by A in expressions shown in Chapter III which denotes the infecundable period following the termination of a pregnancy.

From the above two expressions we can estimate the averages and variances of the postpartum amenorrhea and the infecundable period.

In order to get the moments of pregnancy intervals, the "first pregnancy intervals" and the "open pregnancy intervals" are excluded from the analysis. The first pregnancy intervals are excluded because they are not affected by the outcome of any pregnancy and therefore have only one component--the fecundable period. These intervals are used to estimate the moments of the fecundable period. The open pregnancy intervals are excluded because at the time of interview women were still exposed to the risk of conception and in fact some women got pregnant after the interview. Exclusion of open pregnancy intervals will somewhat bias the results because the time of interview has truncated reproductive histories before their natural end and therefore a short pregnancy interval has a better chance of inclusion in the analysis as a complete interval than a long interval. The selection becomes more intense as the time of termination of a pregnancy approaches the interview date. The consequence is a variable negative bias operating at all ages.

A second bias will be introduced due to under-reporting of "abortions."[4] It has been shown in Chapter VI that women do

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[4]In this analysis the term "abortion" includes induced abortions as well as miscarriages. Whenever a distinction between the two is necessary, the proper term is used.

under-report their abortions, especially older women under-report the abortions of their younger ages. The length of pregnancy intervals will be affected if any abortion following the termination of a pregnancy is not reported. The magnitude of this bias will depend upon the time elapsed between the occurrence of the event and its reporting.

Results

The averages and the variances of pregnancy intervals by outcome of the preceding pregnancy and use of contraception are shown in Table 7.1. In the absence of contraception women, on an average, took about 16 months to conceive. The average length of pregnancy interval is greatly affected by the outcome of the preceding pregnancy. Women took about 17 months to conceive, if the preceding pregnancy is terminated by a live birth and the infant survived for at least one year. Whether the infant died or lived after surviving for one year appears to make little difference since in both cases the averages and the variances are about the same. On the other hand, if the infant died within one year after its birth, the average length of the following interval was shortened by about six months.

When the preceding pregnancy ended in an abortion, intended or not, the length of the succeeding interval was considerably shorter than for a live birth that survived for one year. It was also slightly shorter than in the case of a live birth resulting in an infant death. In the absence of contraception, women took about the same time to conceive (about ten months) whether the previous pregnancy was terminated by an induced abortion or by a miscarriage.

Table 7.1: Mean and Variance of Pregnancy Intervals by Outcome of Preceding Pregnancy and by Use of Contraception (Yes, No) During the Pregnancy Interval

Outcome of preceding pregnancy	Number of pregnancy intervals			Mean			Variance		
	Use of contraception								
	Yes	No	All	Yes	No	All	Yes	No	All
All pregnancies	751	7288	8039	17.86	16.31	16.45	206.49	116.26	124.87
All live births	532	6629	7161	20.29	16.92	17.17	209.56	101.99	110.73
All abortions	219	659	878	11.96	10.14	10.59	150.63	218.25	201.81
Live birth--alive more than age one[a]	514	5955	6469	20.43	17.28	17.53	211.96	97.45	107.24
Live birth--died after age one	5	281	286	*	17.04	17.03	*	92.69	93.30
Live birth--died under age one	13	393	406	*	11.40	11.55	*	145.64	145.54
Spontaneous abortions	84	568	652	9.51	10.15	10.07	138.90	220.71	209.98
Induced abortions	135	91	226	13.48	10.05	12.10	152.92	205.19	175.98

[a]Includes 26 cases in which the infant was alive and was less than one year.

*Based on small number of intervals.

Effect of Age of Mother

The averages and the variances of pregnancy intervals in the absence of contraception by outcome of preceding pregnancy and by age of mother are shown in Table 7.2. Age of mother is measured at two separate times: at the beginning and at the end of the pregnancy intervals. To measure the effect of age on the length of pregnancy intervals it is best to consider first the pregnancy intervals that start during ages less than 20 and from 20 to 24, and then to shift the attention to pregnancy intervals that end during the ages 25 to 29, 30 to 34 and 35 to 39. This is done for the following reason: When age is measured at the beginning of the pregnancy interval then among age group 25 to 29 only those intervals will be included which ended before women reached age 29, and among age groups 30 to 34 and 35 to 39 only those intervals will be included which ended before women reached ages 34 and 39, respectively. Thus only shorter completed intervals will be included in the analysis which will give rise to negative bias for these age groups. On the other hand, if the age is measured at the end of the pregnancy intervals, then younger age groups are subject to a similar negative bias. Thus for women who were 39 years old at interview, among intervals that started at age 37 years, only those will be included in the analysis which were completed within two years. Other completed intervals which took more than two years will not be included, and therefore the moments of pregnancy intervals at ages 35 to 39 will be deflated. A similar argument holds for other age groups.

Table 7.2: Mean and Variance of Pregnancy Intervals by Outcome of Preceding Pregnancy and by Age of Mother in the Absence of Contraception

Outcome of preceding pregnancy	Age of mother	Age measured at the beginning of pregnancy interval			Age measured at the end of pregnancy interval		
		Number	Mean	Variance	Number	Mean	Variance
Live birth[a]	Less than 20	874	16.87	167.69	377	13.04	53.39
	20-24	3178	16.31	91.30	2734	15.07	65.91
	25-29	1961	17.60	91.20	2470	17.92	109.54
	30-34	568	18.08	96.05	904	20.40	161.79
	35 and more	48	16.08	72.72	144	23.01	184.79
	All: Observed	6629	16.92	101.99	6629	16.92	101.99
	Estimated[c]	7570	17.52	118.34			
Abortion[b]	Less than 20	95	12.92	451.10	64	6.20	29.15
	20-24	263	9.90	234.59	248	7.80	66.90
	25-29	200	9.72	157.74	220	11.30	240.91
	30-34	87	8.93	76.46	106	13.84	522.55
	35 and more	14	9.14	65.67	21	18.76	598.09
	All: Observed	659	10.14	218.25	659	10.14	218.25
	Estimated[c]	705	11.16	321.03			

[a]Includes all live births irrespective of whether or not the infant was alive and irrespective of the duration for which the infant was alive.

[b]Includes all pregnancy losses, i.e., induced abortions as well as miscarriages.

[c]Weighted moments of age specific moments when for first two age groups the age is measured at the beginning of pregnancy intervals and for last three age groups the age is measured at the end of pregnancy intervals.

Following a "live birth,"[5] the average length of pregnancy interval, in the absence of contraception, is slightly higher for the youngest age group than for age group 20 to 24, presumably due to lower fecundability at ages below 16 years. The average pregnancy interval increases gradually from 16 months to 23 months between ages 20 to 24 and 35 to 39. Presumably, the increase in the average pregnancy interval following a live birth by advancing age of the mother is due to increase in the postpartum amenorrhea and also due to an increase in the fecundable period as a result of declining fecundability. These two factors cannot be separated from the available data.

Exclusion of births ending in infant deaths does not alter the picture. This is so mainly due to two reasons: (1) the average pregnancy intervals following an infant death do not change with age, and (2) the number of such intervals is very small (about 6 per cent of live births); hence their relative contribution to the overall averages is quite small.

The relationship between average pregnancy intervals following an abortion and age of mother follows the same pattern as shown by averages following a live birth. The average length of pregnancy interval following an abortion, in the absence of contraception, is higher for the youngest age group than for the age group 20 to 24 years. It increases gradually from ten months to eleven months between ages 20 to 24 and 25 to 29 and then increases more rapidly to 19 months during ages 30 years and more.

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[5]In further analysis the term "live birth" includes all live births irrespective of the duration for which the infant survived.

We can get the overall moments of pregnancy intervals which probably will be relatively free from the truncation bias if we compute the weighted moments of the age-specific moments of pregnancy intervals, when ages are measured at the beginning of pregnancy intervals for age groups less than 20 and 20 to 24, and it is measured at the end of pregnancy intervals for age groups 25 to 29, 30 to 34 and 35 to 39. Comparison of these estimates with overall observed ones will give the effect of truncation bias. The results shown in Table 7.2 confirm the expectations, i.e., the estimated moments for both pregnancy outcomes are higher than the observed ones. The difference between the two measures the degree to which the observed overall moments are deflated due to truncation bias. This method of estimating overall moments are deflated by "Method I" in further discussions.

Effect of Memory Bias on the Age Differentials in Pregnancy Intervals

The results presented in Table 7.2 do not measure the total effect of advancing age on pregnancy intervals, because the moments for younger ages at the pregnancy are inflated on account of under-reporting of abortions by older women at interview. In Chapter VI it has been shown that older women do under-report the abortions of their early twenties, and consequently their pregnancy intervals are lengthened. To study the effect of this under-reporting on the moments of pregnancy intervals, these moments are presented in Tables 7.3 and 7.4 by the age of women at interview and their ages at the beginning and at the end of pregnancy intervals.

Table 7.3: Mean and Variance of Pregnancy Intervals Following a Live Birth[a] by Age of Mother at Interview and at Pregnancy in the Absence of Contraception

Age of mother at pregnancy intervals	Age measured at the beginning of pregnancy intervals: Age at interview (in completed years)				Age measured at the end of pregnancy intervals: Age at interview (in completed years)			
	20-24	25-29	30-34	35-39	20-24	25-29	30-34	35-39
	Number of pregnancy intervals							
Less than 20	165	219	263	227	91	90	108	88
20-24	196	1029	1078	875	270	887	877	700
25-29		254	837	870		523	1023	924
30-34			125	443			295	607
35 or more				48				144
All	361	1502	2303	2463	361	1502	2303	2463
	Mean Pregnancy Intervals							
Less than 20	13.24	15.02	17.34	20.77	11.44	12.99	12.62	15.26
20-24	12.03	14.66	16.82	18.60	12.97	13.69	15.49	17.11
25-29		13.64	17.15	19.19		16.22	17.89	18.93
30-34			14.31	19.15			18.93	21.12
35 or more				16.08				23.01
All	12.58	14.54	16.86	19.06	12.58	14.54	16.86	19.06
	Variance of Pregnancy Intervals							
Less than 20	56.05	71.10	170.47	312.43	47.05	45.99	46.28	70.22
20-24	43.03	59.18	84.76	135.34	49.52	52.53	63.12	84.43
25-29		43.03	84.54	104.52		65.96	105.64	135.05
30-34			43.60	105.83			132.08	175.35
35 or more				72.72				184.79
All	49.21	58.29	92.52	134.53	49.21	58.29	92.52	134.53

[a]Includes all live births.

Table 7.4: Mean and Variance of Pregnancy Intervals Following an Abortion[a] by Age of Mother at Interview and Age at Pregnancy Interval in the Absence of Contraception

Age of mother at pregnancy interval	Age measured at the beginning of pregnancy intervals: Age at interview (in completed years)				Age measured at the end of pregnancy intervals: Age at interview (in completed years)			
	20-24	25-29	30-34	35-39	20-24	25-29	30-34	35-39
				Number				
Less than 20	26	18	27	24	22	9	18	15
20-24	33	84	77	69	37	80	75	56
25-29		40	82	78		53	87	80
30-34			21	66			27	79
35 or more				14				21
All	59	142	207	251	59	142	207	251
				Mean				
Less than 20	5.69	10.39	9.37	26.63	5.32	4.78	4.89	9.93
20-24	5.48	8.58	7.82	15.93	5.73	7.19	7.96	9.84
25-29		7.20	7.66	13.19		10.91	7.93	15.24
30-34			6.57	9.68			9.11	15.46
35 or more				9.14				18.76
All	5.58	8.42	7.83	14.08	5.58	8.42	7.83	14.08
				Variance				
Less than 20	15.58	104.60	116.55	1342.77	16.42	17.69	12.22	61.92
20-24	23.95	82.56	80.23	648.77	22.48	47.29	66.39	120.79
25-29		27.09	77.66	292.21		103.32	77.46	487.20
30-34			26.26	90.71			156.10	641.02
35 or more				65.67				598.09
All	19.94	69.64	77.88	439.77	19.94	69.64	77.88	439.77

[a]Includes induced abortions, spontaneous abortions and stillbirths.

The effect of under-reporting abortions following live births on average pregnancy intervals can be seen from the increase in averages by present age groups at all ages when age is measured either at the beginning or at the end of pregnancy intervals (see Table 7.3). The effect is not so pronounced on the intervals following an abortion (see Table 7.4), because the probability of under-reporting an abortion following a reported abortion is probably less than the probability of under-reporting an abortion following a reported live birth. Even if we consider averages along the diagonal, we see that the averages increase with advancing age of women. It can be said, then, that the average length of pregnancy interval increase with advancing age of women. The problem now is to get the estimates of averages and variances which are relatively free of memory bias as well as free of truncation bias. The strategy follows:

1. For the age group less than 20 years at pregnancy, the intervals reported by women aged 20 to 24 at interview probably are relatively free from memory bias as compared to the intervals reported by women aged 25 to 29, because the time elapsed between the occurrence of the events and their reporting is shorter for the former group than for the latter. Hence the estimates based on the intervals reported by women aged 20 to 24 at interview would provide estimates closer to the true value for the youngest age group. These estimates will still be subject to some truncation bias which is believed to be quite low.

2. For the age group 20 to 24 years at pregnancy, the intervals reported by women aged 20 to 24 at interview will have some negative bias due to truncation and the intervals reported by women aged 25 to 29

would be inflated due to some memory bias. Assuming that the two biases are compensating, the weighted average of the two will give a closer estimate of moments for age group 20 to 24 at pregnancy than the one based on intervals reported by all women aged 20 to 39.

3. With similar reasoning the results for age groups 25 to 29, 30 to 34, and 35 to 39 at pregnancy are presented for women aged 25 to 34, 30 to 39, and 35 to 39 at interview respectively.

4. To remove the effect of truncation bias simultaneously, the ages are measured at the beginning of the pregnancy intervals for age groups less than 20 and 20 to 24 at pregnancy, and ages are measured at the end of pregnancy intervals for age groups 25 to 29, 30 to 34, and 35 to 39.

The averages and variances of pregnancy intervals based on the above assumptions, in the absence of contraception, by outcome of the preceding pregnancy and by age of mother are shown in Table 7.5.

The average length of the pregnancy interval following a live-birth increases from 13 months to 14 months between ages less than 20 years and 20 to 24 years, and then increases monotonically to 23 months until age 35 to 39 years. The relationship between the average length pregnancy interval (Y) and age of mother (X) can be expressed by the following linear regression equation:

$$Y = 17.11 + 0.59\ (X-27.04)$$

The regression coefficient 0.59 has a standard error 0.036. According to this expression, in the absence of contraception, women on an average take little over 17 months for conceiving after a live birth at age 27, and the time taken for conception increases by one month for every two additional years in age of mother.

Table 7.5: Estimated Mean and Variance of Pregnancy Intervals by Outcome of Pregnancy and by Age of Mother in the Absence of Contraception

Outcome of preceding pregnancy	Age of mother	Number N	Mean M	Variance V	95% confidence interval for mean[c] Lower limit	Upper limit
Live birth[a]	Less than 20[d]	165	13.24	56.05	12.08	14.40
	20-24[e]	1225	14.23	57.49	13.80	14.66
	25-29[f]	1546	17.32	92.79	15.81	18.83
	30-34[g]	902	20.40	162.09	19.58	21.22
	35-39[h]	144	23.01	184.79	20.78	25.24
	All[i]	3982	17.11	106.21	16.80	17.42
Abortion[b]	Less than 20[d]	26	5.69	15.58	4.18	7.20
	20-24[e]	117	7.71	67.64	6.22	9.20
	25-29[f]	140	9.06	88.04	7.51	10.61
	30-34[g]	106	13.84	522.55	9.49	18.19
	35-39[h]	21	18.76	598.09	8.31	29.21
	All[i]	410	10.19	224.38	8.74	11.64

[a]Includes all live births.

[b]Includes all pregnancy losses.

[c]95% confidence interval for mean (M) = $M \pm 1.96\sqrt{V/N}$

[d]Age is measured at the beginning of the pregnancy intervals and the moments are based on women 20-24 years old at interview.

[e]Age is measured at the beginning of the pregnancy intervals and the moments are based on women 20-29 years old at interview.

[f]Age is measured at the end of the pregnancy intervals and the moments are based on women 25-34 years at interview.

[g]Age is measured at the end of the pregnancy intervals and the moments are based on women 30-39 years at interview.

[h]Age is measured at the end of the pregnancy intervals and the moments are based on women 35-39 years at interview.

[i]Weighted averages of age specific values.

On the other hand, the average length of a pregnancy interval following an abortion, in the absence of contraception, increases gradually from six months to nine months between ages less than 20 and 25 to 29 years and then increases more rapidly to 19 months during ages 30 years and over. The relationship between the average length of pregnancy interval following an abortion (Y) and age of mother (X) can be expressed by the following linear regression equation:

$$Y = 10.19 + 0.62\ (X-27.24)$$

The regression coefficient 0.62 has a standard error 0.150. According to this expression, the average time taken for conception after an abortion, in the absence of contraception, is a little over ten months at age 27 and increases by about one month for every two additional years.

The substantial increase in the average pregnancy interval following an abortion between ages 25 to 29 and 35 to 39, probably, reflects some hidden use of contraception following abortions. This increase cannot be explained by the increase in <u>postabortum amenorrhea</u>. It is expected that postpartum amenorrhea increases more rapidly with advancing age than does the postabortum amenorrhea. If we assume that in the absence of contraception the increase in the fecundable period with advancing age following a live birth is the same as that following an abortion, then we would expect a more rapid increase in the average pregnancy interval following a live birth than the increase in the average pregnancy interval following an abortion. The results show the contrary, which could be explained only by a more rapid increase in the fecundable period following an abortion as compared to the one following

a live birth. This is quite possible if some women who used contraception following an abortion did not report that they had used contraception. The hidden use of contraception probably also explains a slightly higher regression coefficient following an abortion as compared to the one following a live birth.

In getting the estimates of standard error of regression coefficients, we have assumed that the relationship between average pregnancy interval and the age of mother is linear. No statistical test is applied to test the assumption of linearity because many of the assumptions for such a test are not met by the data. These standard errors give a rough idea about the range of regression coefficients. As can be seen from Figures 7.2 and 7.3 the relationships seem to be rather curvilinear and not strictly linear.

In getting the above regression equations we have ignored the fact that variances of pregnancy intervals also increase with advancing age. The effect of different variances and different numbers of pregnancy intervals is shown by computing 95 per cent confidence ranges for average pregnancy intervals for each age group. The 95 per cent confidence intervals simply means that if we draw 100 different samples and follow similar procedure to estimate average pregnancy intervals, then in 5 out of 100 cases on the bases of random chances alone, the true average pregnancy interval is expected to fall outside this range. The lower and upper limits of this range for each age group and for two outcomes of pregnancy are shown in the last two columns of Table 7.5 and are shown by broken lines in Figures 7.2 and 7.3. The width of the confidence interval following a live birth shows no consistent

Figure 7.2: Average Pregnancy Interval Following Live Births by Age of the Mother

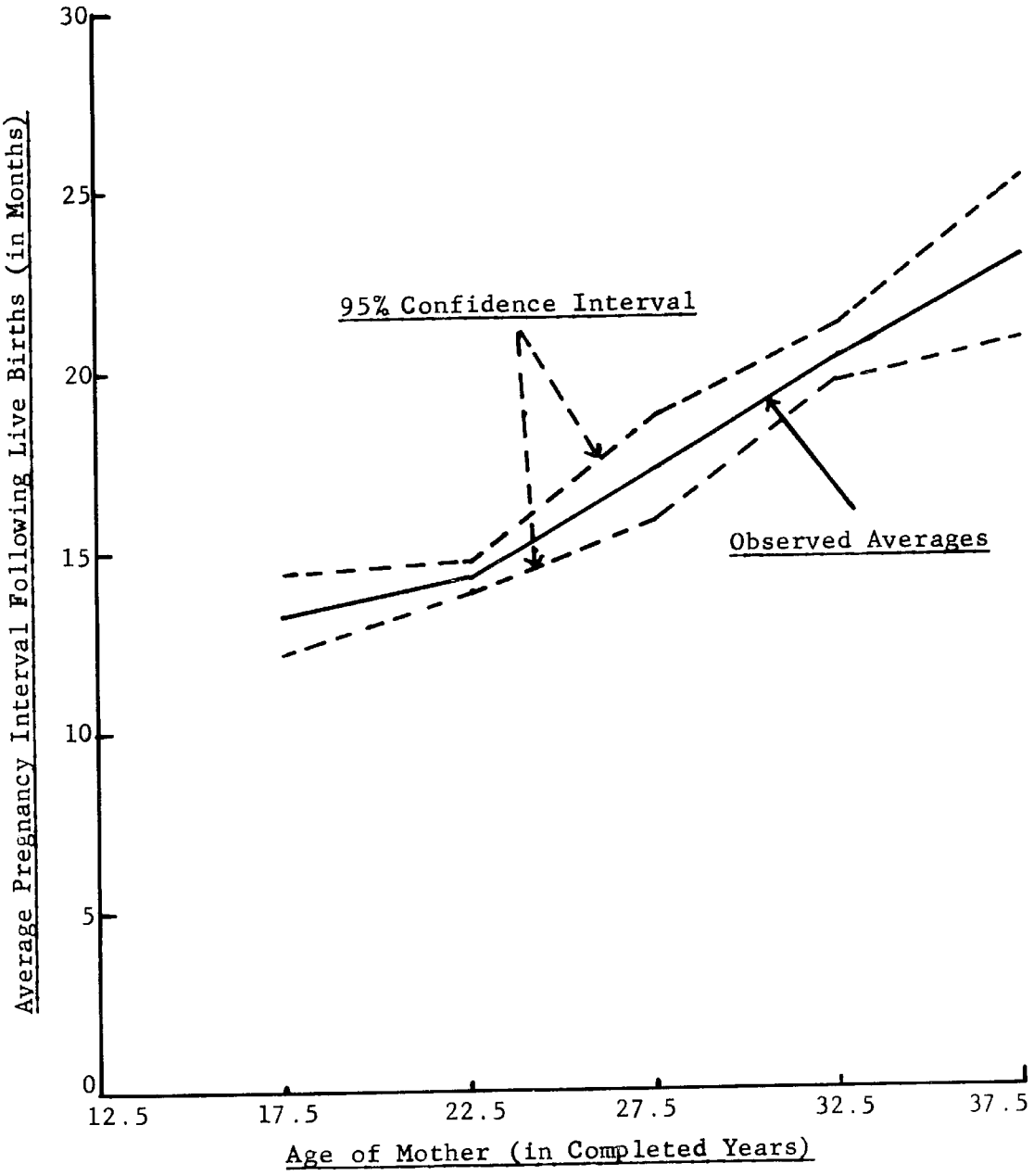
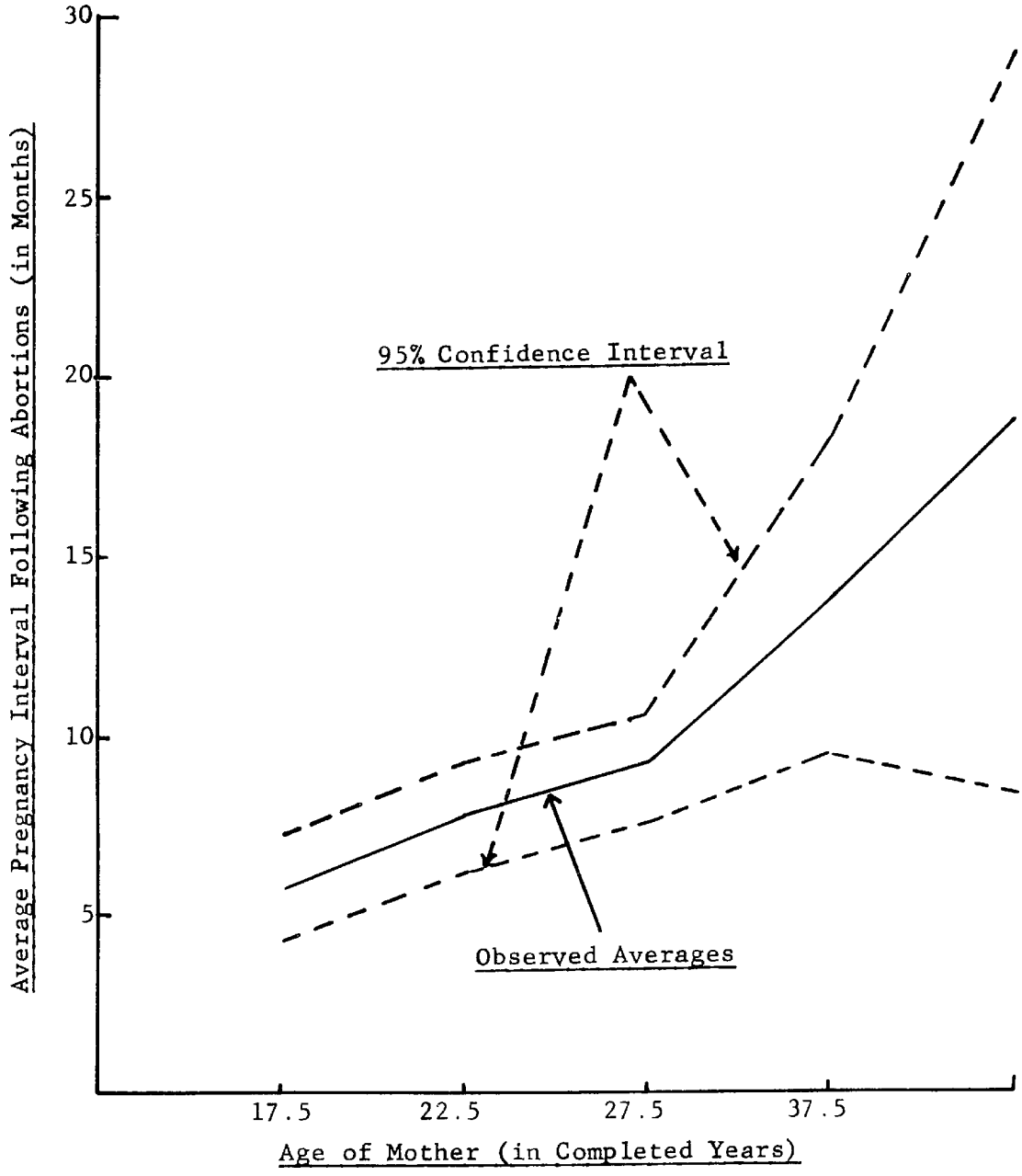


Figure 7.3: Average Pregnancy Interval Following Abortions by Age of The Mother



relationship with age (Figure 7.2) but Figure 7.3 clearly indicates that the width of the confidence interval increases rapidly with advancing age of mother.

Assuming that the age specific moments shown in Table 7.5 are comparatively free from memory bias as well as truncation bias and hence are closer to the true values, the weighted moments will also yield the estimates closer to true values of overall moments. Comparison of these overall estimates with the observed ones and with the ones estimated earlier by using Method-I will respectively show the combined effect of two biases and the effect of memory bias alone on the overall moments. Similarly, the comparison between observed moments and moments estimated by Method-I will show the effect of truncation bias alone. These comparisons are shown in Table 7.6. It can be seen from these

Table 7.6: Comparisons Between Estimated and Observed Overall Averages and Variances of Pregnancy Intervals by Outcome of Preceding Pregnancy

Item	Outcome of preceding pregnancy			
	Live birth[a]		Abortion[b]	
	Mean	Variance	Mean	Variance
1. Observed pregnancy interval[c]	16.92	101.99	10.14	218.25
2. Estimated-I pregnancy interval[c]	17.52	118.34	10.16	321.03
3. Estimated-II pregnancy interval[d]	17.11	106.21	10.19	224.38
4. Truncation effect	0.60	16.35	0.02	102.78
5. Memory effect	-0.41	-12.13	-0.03	-96.65
6. Net effect	0.19	4.22	-0.01	6.13

[a]Includes all live births.

[b]Includes induced abortions, spontaneous abortions and still-births.

[c]Source: Table 7.4.

[d]Source: Table 7.5.

comparisons that in this sample (a) the effect of truncation bias is to deflate the moments of pregnancy intervals, (b) the effect of memory bias is to inflate the moments of pregnancy intervals, and (c) the combined effect of the two biases is negligible.

Hereafter we shall show the estimated averages and variances of pregnancy intervals based on the method described earlier in this section. That is, the averages and variances shown in Tables 7.7 and 7.9 are also comparatively free from memory and truncation biases.

Effect of Contraception

Table 7.7 shows the averages and variances of pregnancy intervals, relatively free from memory and truncation biases, by the outcome of the preceding pregnancy with and without the use of contraception.

Table 7.7: Estimated[a] Mean and Variance of the Pregnancy Intervals by the Outcome of the Preceding Pregnancy and by the Use of Contraception (Yes/No) During the Pregnancy Interval

Outcome of preceding pregnance	Number of pregnancy intervals		Mean		Variance	
	Use of contraception					
	Yes	No	Yes	No	Yes	No
All pregnancies	656	4392	18.29	16.46	203.31	121.03
All live births	460	3982	20.64	17.11	281.98	106.21
All abortions	196	410	12.76	10.19	121.71	224.38
Live births[b]	452	3801	20.72	17.35	222.05	106.26
Infant deaths	8	181	*	11.95	*	78.85
Spontaneous abortions	70	337	9.76	10.15	158.77	224.69
Induced abortions	126	73	14.43	10.37	174.34	226.21

[a]Estimated according to the procedure applied in getting the results of Table 7.5.

[b]Includes live births alive at interview and those who died after attaining age one year.

*Base less than 25 intervals.

In Taiwan the mean effect of using contraception in any pregnancy interval is to increase its length by about 2 to 4 months, probably subject to wide variation. This slight mean increase does not fully measure the effect of contraception in the present sample, however, since in Taiwan contraception is being mainly used for ending the family growth rather than for child spacing. The main effect of contraception appears in the open pregnancy interval.

Table 7.8 shows the average length of the open pregnancy interval by the use of contraception outcome of the last pregnancy, with and without the use of contraception. The overall effect of using contraception in open pregnancy interval is to increase its length by about 12 months and of using sterilization is to increase the length of open pregnancy interval by about 33 months as compared to only two to four months in completed pregnancy intervals.

The effect of using contraception is not uniform when the outcome of the preceding pregnancy is controlled. The average length of

Table 7.8: Mean Open Pregnancy Interval by Outcome of Last Pregnancy and Use of Contraception in Open Pregnancy Interval

Outcome of pregnancy	Use of contraception				Number of women
	Sterilized	Used	Did not use	Total	
Live birth	50.2	36.5	18.8	25.6	1569
Infant death	*	*	22.3	23.6	48
Induced abortion	45.9	21.7	11.6	25.0	225
Spontaneous abortion	*	*	31.8	37.4	96
All	51.6	31.4	19.2	26.1	
Number of women	227	488	1223		1938

*Base is less than 25.

pregnancy interval increased by about four months if women used contraception following an induced abortion (14.43 vs. 10.37) as compared to no increase following a miscarriage (9.76 vs. 10.15). This suggests that women were comparatively more successful in delaying the next pregnancy after induced abortion than after miscarriage. The reason might be partly motivational on their part. In general, induced abortions are used as one of the means to control fertility. Thus one would expect that women using induced abortion at a given pregnancy order would also try to avoid the next pregnancy by subsequently using a more effective contraceptive. It is not necessarily true, of course, that women start using contraception only after induced abortion. In some cases they might have been using contraception to avoid the pregnancy that was aborted intentionally when it occurred. On the other hand, miscarriages are not voluntary. We can expect, then, that a higher proportion of women would be using contraception in pregnancy intervals preceded by an induced abortion than in those preceded by a miscarriage. And we can also expect that they would use contraception more effectively in the pregnancy intervals following an induced abortion than in those following a miscarriage. In Taiwan, women used contraception in about 60 per cent of the pregnancy intervals preceded by an induced abortion, as compared to 13 per cent of those preceded by a miscarriage, 3 per cent of those following a live birth ending in an infant death and 8 per cent of those preceded by a live birth surviving for at least one year. (These percentages are based on numbers shown in Table 7.1.)

The fact that women used contraception in 13 per cent of pregnancy intervals preceded by a miscarriage as against 8 per cent of those

intervals following a live birth, may be a measure of some intentional or unintentional misrepresentation of whether the abortion was intended or unintended. On the other hand, the experience of a miscarriage may have increased the motivation for contraception for health reasons or to avoid repetition of an unhappy experience.

Similarly, the fact that women used contraception in 3 per cent of pregnancy intervals preceded by an infant death as compared to 8 per cent in those following a live birth, may be a measure of some intentional efforts of having another baby after an infant death, i.e., replacing the one who died in infancy.

It can be said then, that a higher proportion of women adopted voluntary means to avoid the pregnancy following an induced abortion and that they were comparatively more successful at least in delaying the next pregnancy, if not in avoiding it completely.

It is generally said that women take more time to conceive after an induced abortion than after a miscarriage. This is supported by the averages for all pregnancy intervals irrespective of the use of contraception (12.76 vs. 10.19). But when we consider the pregnancy intervals during which contraception was used and those during which it was not used, then the reason for this difference becomes clear. The reason, as suggested by the results of this analysis, seems to be the more frequent and probably more effective use of contraception following the induced abortion rather than physiological factors.

It has been shown that if women use contraception following the termination of a pregnancy, the average lengths of pregnancy intervals are higher than those in the reported absence of contraception

irrespective of the outcome of the preceding pregnancy. It is possible that this slight increase in the averages is an artifact of the association between use of contraception and the age of mother at which contraception was being used. Let us assume that a majority of women start using contraception in their late thirties, and we already know that average pregnancy interval increases with advancing age of mother even in the absence of contraception; therefore, we can expect an increase in overall average pregnancy interval during which contraception was used just because a majority of women used contraception at older ages.

This proposition is tested by comparing averages in the absence of contraception with those with contraception by age of mother separately for pregnancies terminated in a live birth and for those terminated by abortions. The results are shown in Table 7.9. This comparison of averages for pregnancy intervals following a live birth shows that for each age group separately, the average length of pregnancy intervals when contraception is used is higher than the one in the absence of contraception. In fact, the difference between the two, increases with advancing age, which indicates that the effectiveness of contraception in delaying the next pregnancy increases with the advancing age of mother. This does not confirm the speculation about the artifact. In fact, if women use contraception following a live birth, the average lengths of pregnancy intervals are higher than those in the absence of contraception irrespective of their age.

On the other hand, the comparisons of averages for pregnancy intervals following an abortion show that only for age groups 20 to 24 and 25 to 29, the average length of pregnancy intervals when

Table 7.9: Estimated[a] Mean and Variance of Pregnancy Interval by Outcome of the Preceding Pregnancy, Use of Contraception, (Yes, No) and by Age of Mother

Outcome of preceding pregnancy	Age of mother[b]	N		Mean		Variance	
		Yes	No	Yes	No	Yes	No
Live birth[c]	Less than 20	10	165	*	13.24	*	56.05
	20-24	96	1225	15.45	14.23	111.96	57.49
	25-29	178	1546	19.04	17.32	130.01	92.79
	30-35	152	902	24.38	20.40	326.25	162.09
	35-39	24	144	28.33	23.01	367.46	184.79
	All	460	3982	20.64	17.11	281.98	106.21
Abortion[d]	Less than 20	2	26	*	5.69	*	15.58
	20-24	30	117	10.10	7.71	141.61	67.64
	25-29	61	140	10.95	9.06	151.16	88.04
	30-35	81	106	13.68	13.84	74.53	522.55
	35-39	22	21	19.00	18.76	148.00	598.09
	All	196	410	12.76	10.19	121.71	224.38

[a]Estimated according to the procedure applied in getting results of Table 7.5.

[b]For explanations see footnotes to Table 7.5.

[c]Includes all live births.

[d]Includes spontaneous abortions, induced abortions and stillbirths.

*Small number of pregnancy intervals.

contraception is used is higher than the one in the absence of contraception; for older age groups the two averages are about the same. This confirms the speculation about the hidden use of contraception following an abortion at older ages; the effect of contraception shown by higher overall ages does not seem to be an artifact of the association between age of mother and the use of contraception. As a result of this hidden use of contraception following abortions the estimates of average and variance of pregnancy intervals are inflated. The extent of this cannot be assessed exactly but it is expected that it is small because we suspect hidden use at older ages only and their relative contribution to overall average and variance is quite small due to the small number of such pregnancy intervals.

Estimates of Postpartum Amenorrhea and Infecundable Period

In Table 7.10 we show the estimates of postpartum amenorrhea and total infecundable periods associated with different pregnancy outcomes. The estimates for the fecundable period are based on the distribution of first pregnancy intervals for women married 3 to 8 years. In getting these estimates women who were definitely premaritally pregnant and/or have no pregnancy prior to the date of interview are excluded. It has been shown in Chapter IV that the first pregnancy intervals for women married 3-8 years are comparatively free from memory and truncation biases. The estimates of postpartum amenorrhea and the infecundable periods are based on the following assumptions:

1. The distribution of the fecundable period has the same moments irrespective of the outcome of the preceding pregnancy.

Table 7.10: Mean Lengths and Variances of Pregnancy Intervals, Fecundable Period, Anovulatory Period, Postpartum Amenorrhea and Infecundable Period by Outcome of the Preceding Pregnancy

Type of interval	Outcome of preceding pregnancy							
	Abortion		Live birth		Infant death		All live birth	
	Average	Variance	Average	Variance	Average	Variance	Average	Variance
Pregnancy interval[a]	10.19*	224.38*	17.35	106.26	11.95	78.85	17.11	106.21
Fecundable period[b]	6.43	66.55	6.43	66.55	6.43	66.55	6.43	66.55
Anovulatory period[c]	0.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Postpartum amenorrhea[d]	3.76**	157.83**	8.92	39.71	3.52	12.30	8.68	39.66
Total infecundable period[e]	3.76**	157.83**	10.92	39.71	5.52	12.30	10.68	39.66

[a]Source: Table 7.7.

[b]Computed from the distribution of first pregnancy intervals for women married 3-8 years.

[c]Assumed.

[d]Computed = (a) - (b) - (c)

[e]Computed = (a) - (b)

*The corrected estimates of average and variance of pregnancy intervals for women under 30 are 8.19 and 73.96 respectively.

**The corrected estimate of average and variance of postabortum amenorrhea and of infecundable period are equal and are 1.76 and 7.41 respectively. These estimates are obtained by using the estimated average and variance of pregnancy intervals following abortions for women under 30.

2. The average and variance of anovulatory periods following a live birth are two and zero respectively. Both the average and the variance of anovulatory period following an abortion are zero.

3. The three components of the pregnancy interval are mutually exclusive, additive, and uncorrelated.

The following features emerge from the results shown in Table 7.10:

1. Following an abortion the moments of postabortum amenorrhea and the infecundable period are equal, the average being about 4 and variance being 158. These values seem to be rather high because there is no lactation period associated with abortion. Usually, both the average and variance associated with abortion are assumed to be one in other investigations.[6] It is possible that our estimates are inflated due to the hidden use of contraception.

2. The estimate of average postpartum amenorrhea associated with a live birth when the infant died before attaining one year of age is about 3.5 and its variance is 12. The corresponding figures for the infecundable period are 5.5 and 12 respectively. The estimate of the average postpartum amenorrhea associated with an infant death seems to be reasonable since the lactation period can be assumed to be short in view of the fact that most of the infant deaths occur in early childhood.

It is also quite possible that due to high motivational factors on the part of couples to replace the lost child immediately, the average length of the fecundable period following an infant death is

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[6]For example, see Potter, op. cit.

less than the estimated one. If the couple is highly motivated to replace the lost child, the average length of the fecundable period can be shortened indirectly by maximizing the probability of conception by substantially increasing the coital frequency and by adjusting its timing. Hence, the estimates of averages might be deflated. However, it does not seem very likely because these estimates are already higher than those obtained in other studies. For example, from the Khanna Study for Indian women Potter[7] et al. estimated the median length of postpartum amenorrhea as two months when the child died in the first month of life.

3. The estimate of average postpartum amenorrhea when the infant survived at least for one year is about nine and its variance about 40. The corresponding figures for the infecundable period are 11 and 40 respectively. The difference of about five months between the estimated postpartum amenorrhea associated with an infant death and that associated with a live birth surviving for at least one year can probably be attributed to prolonged lactation in the latter case.

The estimated average postpartum amenorrhea for Taiwanese women is lower than for Indian women. Based on hospital data in Bombay city, Baxi[8] estimated 11.9 months as the average length of postpartum amenorrhea. According to the figures quoted by Tietze,[9] the mean

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[7]Potter et al., op. cit.

[8]P. G. Baxi, "A Natural History of Child Bearing in the Hospital Class of Women in Bombay," Journal of Obstetrics and Gynecology of India VIII (September 1957), 26-51, quoted in C. Tietze, "The Effects of Breastfeeding on the Rate of Conception," Proceedings of the International Conference, New York, 1961, Vol. II, pp. 129-36.

[9]Ibid.

duration of postpartum amenorrhea among villagers in Ramanagaram, Mysore state was of the order of 10 to 11 months and of the order of 13 to 14 months in rural districts of Bombay and Hyderabad. From the Khanna study in Punjab villages in India, Potter[10] et al. estimated the average length of postpartum amenorrhea as 10.78 and variance as 54.68. The difference between the estimates of average postpartum amenorrhea for Taiwanese and Indian women could probably be attributed to the prolonged breastfeeding among Indian women which tend to lengthen postpartum amenorrhea for them.

4. The estimated variance (224) of pregnancy interval following an abortion V(ABNC), the variance (158) of the infecundable period associated with an abortion V(A/AB) and the variance (158) of postabortum amenorrhea V(PPA/AB) are very high as compared to the corresponding estimated variances following a live birth. Since the average postabortum amenorrhea is quite short we would also expect its variance to be small certainly to be smaller than the variance of postpartum amenorrhea. If so, we would expect V(A/AB) to be smaller than V(A/LB) and V(ABNC) to be smaller than V(LBNC) because V(FP/LB) is assumed to be equal to V(FP/AB). But the estimated values show quite the opposite. A plausible explanation seems to be that the moments of the fecundable period following an abortion probably are not equal to the corresponding moments following a live birth. There may be an increase in the fecundable period due to some association between the fecundability and the outcome of the preceding pregnancy. This may be due to some hidden use

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[10]Potter et al., op. cit.

of contraception, or due to temporary abstinence, during some pregnancy intervals following abortions.

Let us re-examine Table 7.5 which shows the estimates of means and variances of pregnancy intervals by the outcome of the preceding pregnancy and the age of mother. It is quite clear that the overall variances of ABNC intervals appear high due to abnormally high variances for two older age groups. A more reasonable estimate of overall average and variance of ABNC intervals can be obtained if we consider only women under age 30. These estimates would be underestimated because the moments of ABNC intervals at older ages would be higher than the overall moments; we are excluding them from our estimates of overall moments.

If we consider only women under age 30, the estimated mean and variance of pregnancy intervals following abortions comes out to be 8.19 and 73.96 respectively. The corresponding estimates for mean and variance of postabortum amenorrhea and of the infecundable period are equal and are about 2 and 7 respectively.

Summary and Conclusions

1. In the absence of contraception, women on an average took about 17 months to conceive following a live birth as compared to only 10 months following an abortion. Whether or not the abortion was intentional, the average time taken for conception was the same. If the child died in infancy then women took only 12 months for the following conception.

2. As women get older the average time taken for conception increases following the live birth as well as abortion.

3. The use of contraception increases the average length of completed pregnancy intervals by about two to four months depending upon the outcome of the preceding pregnancy. The major effect of contraception appears in the open pregnancy interval, because a majority of women in Taiwan use contraception for stopping the family growth completely rather than for spacing purposes. The slight increase in the average pregnancy interval during which contraception was used is not an artifact of the association between use of contraception and the age of mother at which contraception was being used. In fact, if women use contraception in their late thirties, then they are more successful in delaying their next pregnancy as compared to their experience before age 30.

4. The chances that women will use contraception following an induced abortion are considerably higher than those following a miscarriage or a live birth. The average time taken for conception when the contraception is being used following an induced abortion is higher than that following a miscarriage; this seems to provide a plausible explanation for the fact that in Taiwan women take a longer period to conceive after an induced abortion than after a miscarriage.

5. The average infecundable period following a live birth is about 11 months as compared to two months following an abortion. The corresponding variances are 40 and 7 respectively. These estimates of average and variance of the infecundable period following abortions are based on pregnancy intervals for women under 30. The estimated variances are probably inflated due to the inclusion of positive covariance terms which are assumed to be zero for the estimation purposes.

CHAPTER VIII

APPLICATION OF A STOCHASTIC MODEL OF HUMAN REPRODUCTION

Introduction

In this chapter we shall use the values of the fecundity components estimated in earlier chapters for estimating the averages and the variances of three demographic indices by applying Perrin and Sheps's[1] stochastic model of human reproduction discussed in Chapter I. These estimated values will be compared with the observed values obtained directly from the Taichung sample. The three indices selected for this purpose are: (1) first birth interval, (2) completed birth intervals, and (3) number of live births during "t" months of marriage. The magnitudes of divergencies between the observed and the estimated values of these three indices will not only reflect the limitations of the model but also the deficiencies of the data. One can always substitute some hypothetical values for the parameters of the model, and by giving them different values, can study the changes in the predicted values under hypothetical conditions; but this kind of exercise tells relatively little about what happens in a real situation. In this chapter we are concerned about what happens to the predicted values when the

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[1]E. B. Perrin and M. C. Sheps, "Human Reproduction: A Stochastic Process," Biometrics, XX, No. 1 (March 1964), 28-45.

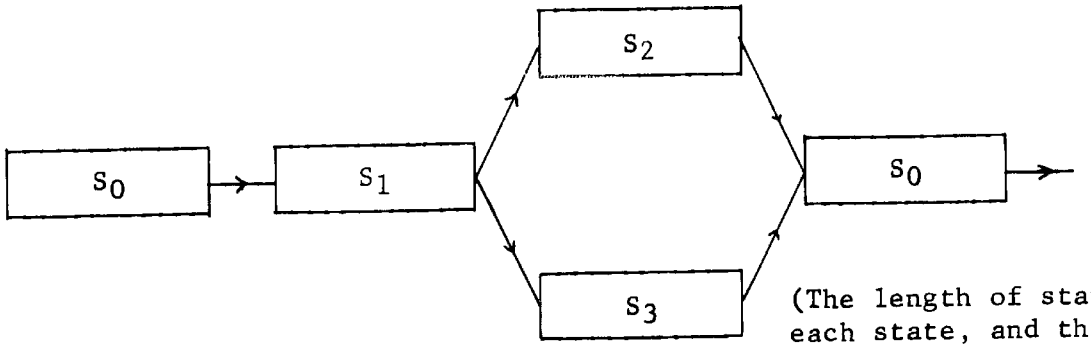
parameters of the model are estimated from the data collected by field surveys. This is an illustration of one of the uses of the estimated fecundity components. These estimates similarly can be used as input data in any other fertility model for understanding the very complicated process of human reproduction.

Before presenting the specific comparisons let us first review some of the basic assumptions underlying the Perrin and Sheps model and consider how well these assumptions are met by our data. In this model four distinctive states are considered: a nonpregnant, fecundable state S_0; a pregnant state S_1; an infecundable period following a pregnancy loss[2] in state S_2; and an infecundable period following a live birth in state S_3. The model assumes that at the time of marriage women start in the nonpregnant fecundable state S_0, during which they are subject to some fixed probability of conception. After a random length of time they pass to state S_1. The duration of their stay in state S_1 depends upon the outcome of pregnancy. Following the termination of a pregnancy women pass to state S_2 or state S_3. During their stay in states S_2 or S_3 women are temporarily infecundable, i.e., the probability of conception during their stay in these states is zero. Duration of stay in these states depends upon the outcome of pregnancy. If the pregnancy terminates in a pregnancy loss, women pass from state S_1 to state S_2; if the pregnancy terminates in a live birth women pass to state S_3. From states S_2 or S_3 women pass to state S_0 and become fecundable again, and thus the process starts once more.

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[2]Here pregnancy loss includes spontaneous abortions, induced abortions and stillbirths, whereas in the original version stillbirths were separated from spontaneous and induced abortions.

Schematically:



(The length of stay in each state, and the outcome of each pregnancy are independent random variables.)

S_0 - Nonpregnant fecundable state
S_1 - Pregnant state
S_2 - Infecundable period following an abortion
S_3 - Infecundable period following a live birth

In the "pure" version of the model, women are assumed to be homogeneous with respect to all parameters, and these parameters are assumed to be independent of age and the order of the pregnancy. The length of stay in each state and the outcome of pregnancy are assumed to be independent random variables. Moreover, the length of the reproductive period is assumed to be unlimited. In actuality Taiwanese women in the present sample are not homogeneous, the parameters are dependent on age and pregnancy order (see earlier chapters), and the reproductive period is limited. With these limitations of the original model the relationships for predicting the averages and variances of the three indices are oversimplified. The expressions for predicting the variances are especially oversimplified, because different covariance terms are assumed to be zero, or at best compensatory; i.e., the sum of covariance terms is assumed to be zero. Since we are using the values of parameters estimated from real data in this "modified" version of the model, we are roughly taking into account the heterogeneity among women

with respect to the concerned parameters and the variability of parameters with respect to time. For example, we are estimating the average and variance of conception delay and of pregnancy intervals by using actual frequency distributions of all heterogeneous women observed during a period from marriage to the date of interview, and similarly we are estimating the probability of pregnancy loss from all pregnancies during this period. In applying the results of the Perrin and Sheps model, we assume that all women included in the analysis are homogeneous with respect to these estimated overall parameters, and that these overall parameters remain constant throughout the observed reproductive period.

Two assumptions, homogeneity and stationarity of the parameters, are only partly taken care of in this modified version of the model. The other two assumptions of the model, independence between different states and an unlimited reproductive period, are not met at all in actuality. Given these limitations of the model and the data, we do not expect that the observed averages and variances will agree closely with the corresponding estimated values. Nevertheless it is useful to measure how small or great are the discrepancies between the values observed in a real situation and the values predicted by a model which has the virtue of simplicity.

In the following sections we have compared the observed averages and variances with the corresponding estimates from the model separately for the three demographic indices mentioned earlier.

First Birth Interval

The first birth interval is the waiting time between onset of marriage and the first live birth. For estimating the average and variance of the first birth interval we shall use the following estimates of different parameters:

1. The probability of a pregnancy loss, estimated in Chapter VI, is 133 per 1,000 completed pregnancies or 153 per 1,000 live births.

2. The average and variance of time added by one pregnancy wastage are 1.71 and 33.51 respectively. These estimates are obtained by using the expressions (2) and (4) shown in Chapter III, and using the corrected estimates of averages and variances of pregnancy intervals following an abortion, presented in Chapter VII.

3. The average and variance of conception delay are 8.20 and 138.82 respectively obtained from the actual frequency distribution of periods between the beginning of marriage and the beginning of the first conception, for all women who got pregnant after marriage and who had at least one pregnancy by the time of interview. Women who had used contraception during this interval are excluded.

Based on the above estimates we get the theoretical average length and variance of the first birth interval as 18.9 and 173 respectively (see Table 8.1). The length of first birth intervals was also obtained directly for each woman by subtracting the date of marriage from the date of the first live birth. From these data the observed average and variance of the first birth interval come out to be 18.8 and 238 respectively. These estimates are for nonusers[3] of

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[3]In this analysis nonusers are those women who definitely did

contraception, who had at least one live birth, and who were not premaritally pregnant. These estimates are based on 1797 women. The results are summarized in Table 8.1

Table 8.1: Comparisons of Theoretical and Observed Averages and Variances of the First Birth Interval in the Absence of Contraception

Interval	Average (months)	Variance
1. Fecundable period[a]	8.20	138.82
2. Time added by pregnancy wastage[b]	1.71	33.51
3. Gestation[c]	9.00	1.00
4. First birth interval		
(i) Theoretical first birth interval[d]	18.91	173.33
(ii) Observed[e]	18.76	237.81

[a]Based on the observed frequency distribution of "first pregnancy interval," i.e., the period between the onset of marriage and the beginning of first pregnancy for all married women.

[b]For expressions of average and variance see Chapter III. For this purpose the estimate of the average and variance of pregnancy intervals following a pregnancy wastage are based on women under 30 years.

[c]By assumption.

[d]Sum of rows 1, 2, and 3. For mathematical expressions see Chapter III.

[e]Average and variance based on the observed frequency distribution of women by the period between the onset of marriage and the first birth.

The difference of 0.1 found between the theoretical and the observed average length of the first birth interval is negligible and could be due to random fluctuations. On the other hand, the theoretical

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not use any form of contraception between marriage and the beginning of the last pregnancy before interview.

variance of the first birth interval (173) is significantly lower than the observed variance (238).

Here the theoretical variance is obtained by summing the variances of three components: the fecundable period, the gestation period, and the time added by pregnancy wastage. This procedure is appropriate only if the three components are uncorrelated, with the sum of their covariances equal to zero. The observed variance will exceed the theoretical if the sum of covariances is positive. In the Taichung sample one might expect the sum of covariances to be positive due to the association of age both with the fecundable period and with the probability of a pregnancy loss. Besides the effect of age, women prone to pregnancy wastage might also be slower to conceive due to lower fecundability. Thus the main reason for getting a higher observed variance of first birth intervals might be the positive covariances between its components, i.e., the interdependences between different states of the model.

Completed Birth Intervals

The theoretical average length and variance of birth intervals based on Perrin and Sheps's model are 27.8 and 141 respectively (see Table 8.2). The average and variance of completed birth intervals from the observed data for each live birth are 26.7 and 114 respectively. These estimates are based on all completed birth intervals for women who were nonusers of contraception and had at least two live births. Women who were definitely premaritally pregnant are excluded. The results are summarized in Table 8.2.

Table 8.2: Comparisons of the Theoretical and Observed Averages and Variances of Completed Birth Intervals for Taiwanese Women and for Indian Women in the Absence of Contraception

Interval	Average	Variance
1. Live birth to next conception[a]	17.11	106.21
2. Time added by pregnancy wastage[b]	1.71	33.51
3. Gestation period[c]	9.00	1.00
4. Theoretical birth interval[d]	27.82	140.72
5. Observed birth interval[e]	26.67	114.14
Theoretical birth intervals expressed as per 100 observed		
6. Taichung sample	104.31	123.29
7. Khanna sample[f]	104.24	127.96

[a]Source: Table 7.7.

[b]Source: Table 8.1.

[c]Assumption

[d]Sum of rows 1, 2, and 3. For mathematical expressions see Chapter III.

[e]Computed from observed frequency distributions of completed birth intervals.

[f]Here expected values are expressed as per 100 observed values and are based on the data given in Table 6, R. G. Potter, Jr. et al., "A Case Study of Birth Interval Dynamics," Population Studies, XIX, No. 1 (July 1965), 91.

The difference of 1.1 found between the theoretical and the observed average birth interval is larger than that expected on the basis of sampling fluctuations only. The theoretical variance 141 overestimates the actual variance by about 23 per cent. Furthermore, these

differences between the observed and theoretical values are underestimated because the observed values are probably inflated as a result of several factors: (1) the under-reporting of early infant deaths, and (2) the positive association between the components of birth intervals.

The basis for expecting a positive association between different components of birth intervals follows. The three components of a birth interval are: the gestation period, the pregnancy interval following a live birth, and the time added by pregnancy wastage. The last component is a function of the probability of pregnancy wastage, its gestation period, and the pregnancy interval following it. We have seen in earlier chapters that the probability of pregnancy wastage, and pregnancy intervals following it both increase with the advancing age of women. Therefore, we can expect the time added by pregnancy wastage to increase with the advancing age of women. We have also seen in Chapter VII that the length of pregnancy intervals following live births also increases with the advancing age of women. Given the positive association of age with two components of the birth interval, we can expect these two components to be positively correlated. Moreover, the observed variances of pregnancy intervals include covariance terms between the fecundable periods and the infecundable periods. We know that the average infecundable period following live births is longer than that following pregnancy wastage, and it is possible that the average fecundable period following live births is also longer than that following fetal wastage. We could not test the latter assumption from the Taichung sample, but if it is correct then even with age held constant we can expect a positive association between the fecundable period and

the infecundable period. Thus, the observed variances of pregnancy intervals will include this positive covariance term and so would the birth interval. Hence, without these "biasing" factors the observed variance of birth interval would have been smaller than 114, and the differences between the observed and the theoretical variances would have been even larger than that noted earlier.

These results are consistent with those obtained by Potter[4] et al. for Indian women from the Khanna study, as shown in Table 8.2. Comparing rows 6 and 7 we can say that the ratios of theoretical to observed averages and variances from the Taichung sample are about the same as from the Khanna sample. In the Khanna study, as noted by Potter et al., two biases were operating which inflated the theoretical average and variance of birth intervals. These two biases are: (1) increased usage of contraception during the prospective period, and (2) the effects of pregnancy losses between the last live birth and the interview. In addition to these two biases, another explanation was advanced by Potter et al. for the theoretical variance being so much larger than the observed one; "the sum of covariances among components of birth interval may shift from positive to negative between the first and second half of the reproductive period."[5]

In the present sample, the effect of contraception probably is not as serious as in the Khanna sample, because we have excluded the

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[4]R. G. Potter, Jr., J. B. Wyon, M. Parker and J. E. Gordon, "A Case Study of Birth Interval Dynamics," Population Studies, XIX, No. 1 (July 1965), 81-96.

[5]Ibid., 92.

intervals during which contraception was used. However, as noted in Chapter VII there might be some unreported use of contraception, especially following induced abortions, which would inflate the two components of birth intervals: (a) the interval between a live birth and the next conception, and (b) the time added by pregnancy wastage. Such inflation of the components in turn would inflate the theoretical average and variance of birth intervals.

The second source of bias, which might inflate the theoretical average and variance of birth intervals, as noted by Potter et al., is the pregnancy loss between the last live birth and the date of interview. As noted in Chapter VII, the pregnancy intervals following abortions increase with the advancing age of mother. Thus, we can expect that the pregnancy intervals following these late fetal wastages probably would be longer than the average. This implies that the average and variance of time added by pregnancy wastage would be inflated, which in turn would inflate the theoretical average length and variance of birth intervals. On the other hand, these pregnancies would not inflate the observed average and variance of birth intervals, because the "open birth intervals" have been excluded in obtaining these observed values.

In obtaining the theoretical variance of birth intervals it has been assumed that the components of birth intervals are independent, or that the sum of covariance terms is zero. It is quite possible, as noted by Potter et al., that the sum of covariance terms is negative during the second half of the reproductive period. This could happen due to the limited length of the reproductive period. Perrin and Sheps's model assumes an unlimited reproductive period, whereas in the present

sample only women between ages 20 to 39 are included. These women have not completed their reproductive periods and are at different stages in their reproductive periods; thus are not homogeneous with respect to the length of the reproductive period. The limited length of the reproductive period works in the direction of producing negative association between the components of the birth interval. The rationale as noted by Potter et al., is as follows:

> The later a birth interval is, the more its completion (before end of the reproductive period) [or before the date of interview] depends on a short duration. This progressive selection for brevity . . . means that if postpartum amenorrhea is longer than the average, then to avoid a long duration the menstruating interval ["or the fecundable period"] must be short and pregnancy wastage avoided. In this way pressures are exerted in behalf of negative associations amongst postpartum amenorrhea, menstruating intervals and the time added by pregnancy wastage.[6]

The progressive selection for brevity would also deflate the observed averages of birth intervals, in addition to deflating the observed variance through the negative association between components of the birth interval. As the time of last birth approaches the date of interview, shorter completed birth intervals have better chances of being included in the calculation of the observed average birth interval than do the longer birth intervals.[7] In case of pregnancy intervals this bias was compensated by the memory bias (see Chapter VII) and thus the theoretical average length of birth intervals are not inflated; but

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[6] Ibid., 92.

[7] The effect of this bias, known as truncation bias, can be estimated by comparing the averages of birth intervals classified by the age of mother when the ages of mothers are measured separately at the beginning of birth intervals and at the end of birth intervals. Similar procedure was applied in Chapter VII for estimating the effect of the truncation bias on the average pregnancy intervals.

this bias would deflate the observed average birth interval, because memory bias in reporting live births probably would be much smaller than the bias in reporting abortions.

Live Births During "t" Months of Marriage

Perrin ahd Sheps's model provides approximate mathematical expressions for estimating averages and variances of the number of live births at the end of "t" months after marriage. These are shown in Chapter III and the estimated values of required components are shown in Table 8.3. As noted by Perrin and Sheps[8] these expressions yield good approximations to exact moments after five years of marriage, i e., after five years of marriage the moments obtained by using approximate expressions are the same as those obtained by using exact expressions. Substituting the estimated values (shown in Table 8.3), in expressions of Chapter III we obtained expressions for the average and the variance of live births per woman after t months of marriage. These expressions are: 0.03590 t - 0.0888 for the average live births and 0.00654 t + 0.13590 for the variance of live births. By substituting t = 1,2,3,... etc., we can obtain expected number of live births in one, two, etc., months after marriage and also their variances.

We compare the above with the averages and variances of live births after t months of marriage obtained for women in the sample. If we consider women married for at least t months and their live births during these months, we get frequency distributions of women by number

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[8]Perrin and Sheps, op. cit., 43-44.

Table 8.3: Estimates of Parameters Required for Predicting the Averages and the Variances of Number of Live Births in the Absence of Contraception

Items	Symbol	Value
1. Average conception delay[a]	M(FP)	6.43
2. Variance of conception delay[a]	V(FP)	66.55
3. Third moment of conception delay about origin[a]	T(FP)	3049.59
4. Average gestation period for live birth[b]	M(G/LB)	9.00
5. Variance of gestation period for live birth[b]	V(G/LB)	1.00
6. Average gestation period for abortion[b]	M(G/AB)	3.00
7. Variance of gestation period for abortion[b]	V(G/AB)	1.00
8. Probability of a pregnancy terminating in an abortion[c]	P(AB)	0.133
9. Probability of a pregnancy terminating in a live birth[c]	P(LB)	0.867
10. Average period from live birth to next conception[d]	M(LBNC)	17.11
11. Variance of period from live birth to next conception[d]	V(LBNC)	106.21
12. Third moment about origin of period from live birth to next conception[d]	T(LBNC)	13189.56
13. Average period from abortion to next conception[d]	M(ABNC)	8.19
14. Variance of period from abortion to next conception[d]	V(ABNC)	73.96
15. Third moment about origin of period from abortion to next conception[d]	T(ABNC)	4006.47

[a]Estimated from the frequency distribution of first pregnancy intervals for women married for 3 to 8 years.

[b]By assumption.

[c]Estimated from the proportion of completed pregnancies terminated in abortions or in live births, see Chapter VI for details.

[d]Estimated from the frequency distributions of periods between termination of one pregnancy and the beginning of next pregnancy.

of live births for each month after marriage. From these frequency distributions the averages and variances of live births can be calculated. However, for simplicity the moments of live births are calculated for one year intervals, i.e., for women married for at least 12, 24, 36, 48, ..., etc. months. The observed and estimated values are compared in Table 8.4 and in Figures 8.1 and 8.2.

In the first eight months the observed births are zero because we excluded premarital conceptions. During 1 to 7 years after marriage, the observed and the predicted number of live births are in good agreement after which the difference between the two series increases rapidly with the duration of marriage. For women married nine years or more the theoretical number of live births during nine years of marriage is about 9 per cent higher than the observed average number of live births and this difference increases gradually to 37 per cent for women married 20 years or more. The expression relating the theoretical number of live births and the duration of marriage assumes a constant rate of increase in number of live births. Actually, this is not true. Due to increasing frequency of secondary sterility with advancing age, every year some women stop contributing more births, and some women do not produce births as quickly as they did at earlier ages. Thus the rate of increase in average number of live births does not remain constant, starts declining with ascending marriage duration, and finally the rate of increase becomes zero when all women reach the end of their childbearing. In other words, the relationship between the observed number of live births and the length of the marriage duration will not be linear as predicted by the Perrin and Sheps model, but would be

Table 8.4: Comparison of Observed and Theoretical Average and Variance of Live Births Per Woman in t Months of Marriage in the Absence of Contraception

Marriage duration (in completed years)	Average number of live births			Variance of live births		
	Observed	Theoretical[a]	I[c]	Observed	Theoretical[b]	I[c]
1	0.339	0.342	0.9	0.231	0.214	-7.4
2	0.843	0.773	-8.3	0.211	0.293	13.9
3	1.245	1.204	-3.3	0.389	0.371	- 4.6
4	1.696	1.634	-3.7	0.489	0.450	- 8.0
5	2.057	2.065	0.4	0.640	0.528	-17.5
6	2.463	2.496	1.3	0.770	0.607	-21.2
7	2.831	2.927	3.4	0.938	0.685	-27.0
8	3.161	3.358	6.2	1.119	0.764	-31.7
9	3.483	3.788	8.8	1.356	0.842	-37.9
10	3.796	4.219	11.1	1.573	0.921	-41.4
11	4.131	4.650	12.6	1.820	0.999	-45.1
12	4.367	5.081	16.5	2.085	1.078	-48.3
13	4.635	5.512	18.9	2.382	1.156	-51.5
14	4.864	5.942	22.2	2.635	1.235	-53.1
15	5.121	6.373	24.4	2.841	1.313	-53.8
16	5.303	6.804	28.3	3.109	1.392	-55.2
17	5.526	7.235	30.9	3.306	1.470	-55.5
18	5.720	7.666	34.0	3.678	1.549	-57.9
19	5.946	8.096	36.2	4.240	1.627	-61.6
20	6.219	8.527	37.1	4.720	1.706	-63.9

[a]Theoretical average live births per woman in t months of marriage = 0.0359 t - 0.0888.

[b]Theoretical variance of live births per woman in t months of marriage = 0.00654 t + 0.1359.

[c] $I = \frac{\text{Theoretical - Observed}}{\text{Observed}} \times 100.$

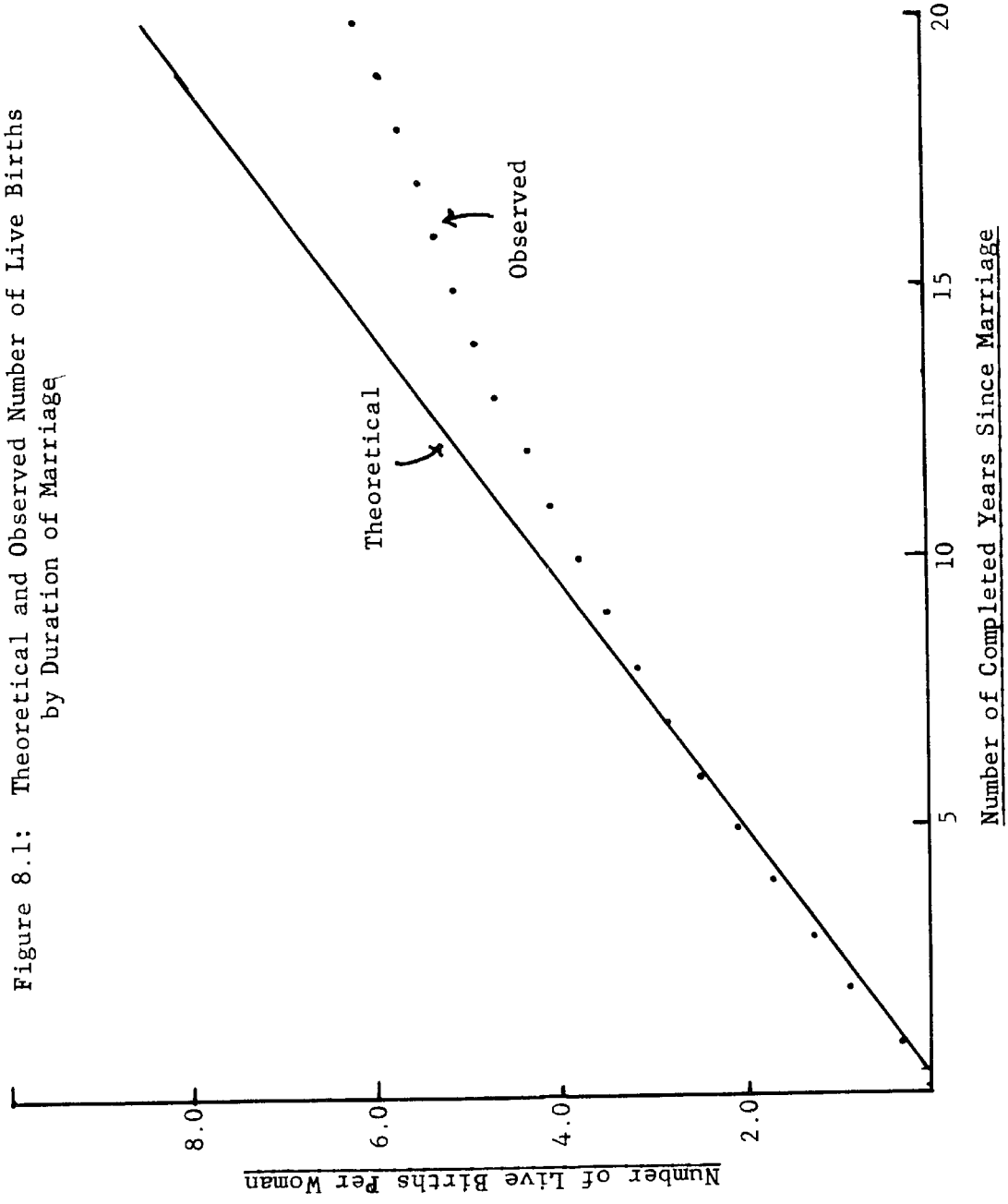
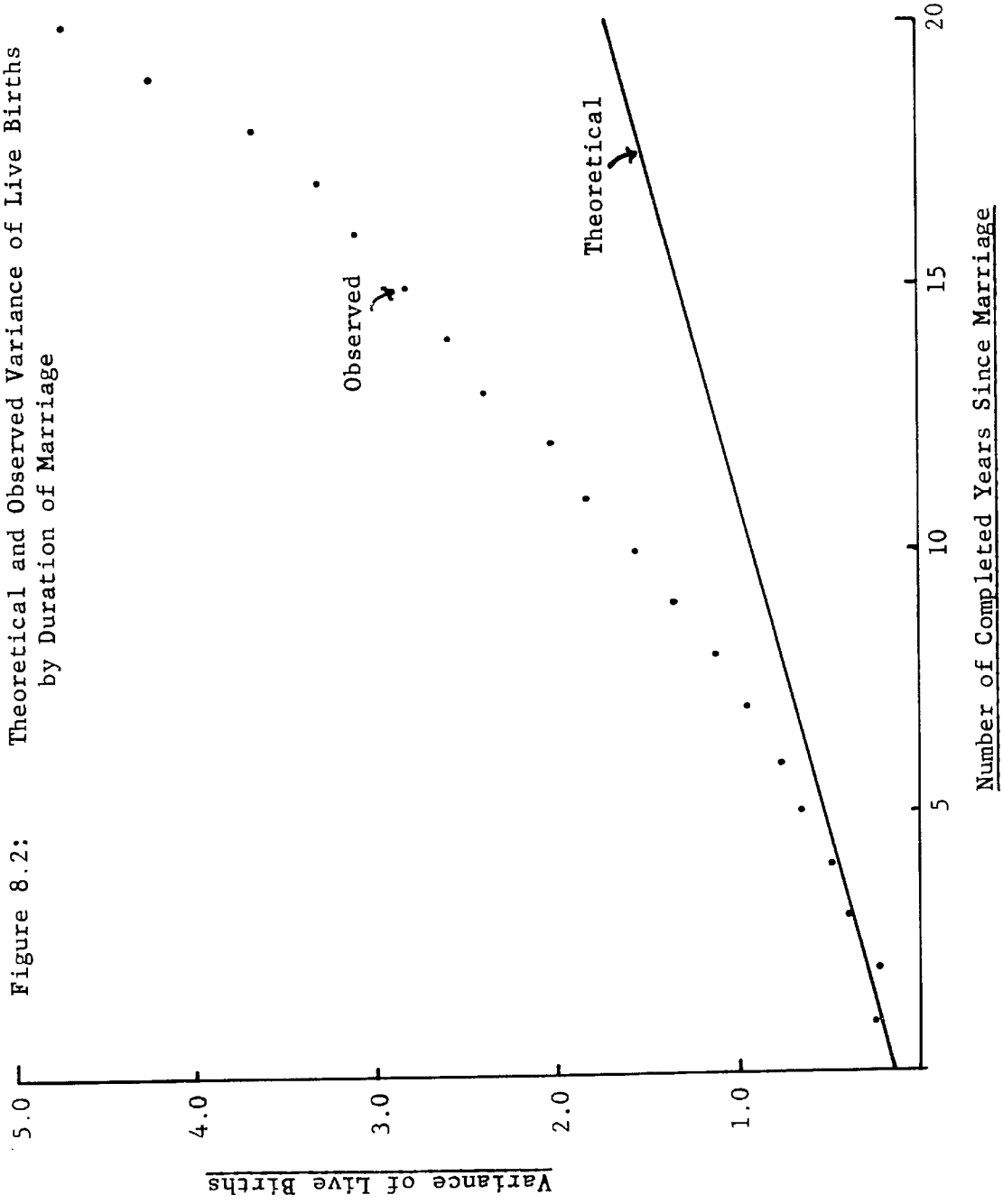


Figure 8.1: Theoretical and Observed Number of Live Births by Duration of Marriage

Figure 8.2: Theoretical and Observed Variance of Live Births by Duration of Marriage



curvilinear. This seems to be the main reason for divergencies between the theoretical and the observed numbers of live births.

Comparisons of variances show a different pattern. Except for the second year, the observed variances are always higher than the theoretical. For women married at least three years the theoretical variance is 5 per cent lower than the observed variance; this difference increases gradually to 64 per cent for women married for at least 20 years. This pattern in the differences could arise for a variety of reasons, one of which is discussed below. The expression relating the theoretical variance to the duration of marriage assumes a constant rate of increase in the variance of live births. Actually this is not so because of the heterogeneity among women with respect to the "effective length of reproductive period" which is the period between the marriage and the last live birth prior to the interview. Thus if we consider women married for at least 15 years and consider their reproductive experiences during the first fifteen years of marriage, then although these women are homogeneous with respect to their reproductive period included in the analysis they are not homogeneous with respect to their effective reproductive period, because this group includes subgroups of women who had their last live birth during the first, second, third, ..., fifteenth year after marriage. This happens due to the increasing frequency of secondary sterility with advancing age. Thus, women in this group are much different with respect to their attained parity. Now as the length of marriage duration increases, the heterogeneity among women with respect to their attained parity also increases and so does the observed variance of live births. The observed variance

will continue to increase until all women in the sample reach the end of their reproductive period estimated around 45 years. For the group of women who got married at the age of 20 years, the length of reproductive period will be about 25 years. After 25 years of marriage duration, for this group of women, the rate of increase in the observed variance of live births will be zero, whereas the theoretical variance will still continue to increase with the same constant rate of increase. Given an unlimited length of the reproductive period, as assumed in the Perrin and Sheps model, at some point the observed and the theoretical curves will intersect after which for all years the theoretical variances will be higher than the observed variances.

Another reason for the apparent divergencies between the observed and the theoretical variances of live births might be the violation of the assumption of independence between different states of the model. For obtaining the theoretical variances all the covariance terms are assumed to be zero; given positive association between different states one might expect positive covariances. The reasons for expecting positive covariances have already been discussed earlier.

It is difficult to separate the effects of these two factors on the divergences between the observed and the estimated variances.

Summary and Conclusions

In this chapter we have made an attempt to illustrate one of the uses of estimated fecundity components for nonusers of contraception among the Taichung sample. We used these estimates in the Perrin and Sheps stochastic model of human reproduction to predict the values of

three demographic indices. These theoretical values were then compared with the corresponding observed values obtained directly from the Taichung sample. The following remarks summarize the results of these comparisons.

1. The difference between the theoretical and the observed average length of birth interval is negligible and could be attributed to the sampling fluctuations. On the other hand, the observed variance of the first birth interval is somewhat higher than the corresponding theoretical variance. This difference could mainly be attributed to the positive associations between the components of the first birth interval.

2. The theoretical average and variance of the completed birth intervals are higher than the corresponding observed values. These differences could arise due to a variety of reasons: (1) the model assumes independence between different states, whereas in reality these states are probably interdependent, (2) the estimates of different components are corrected for two biases, the memory and the truncation bias, whereas the observed values are not corrected for these two biases, and (3) in the present "modified" version of the model we have included stillbirths, miscarriages and induced abortions in one state, whereas in the original version stillbirths were considered separately from the miscarriages and the induced abortions. Since we know that the infecundable periods associated with live births are higher than the infecundable periods associated with infant deaths, these two states should also be considered separately.

3. The theoretical averages and variances of live births are different from the observed values. The main reason for these

discrepancies seems to be the heterogeneity among women with respect to the "effective" length of the reproductive period, which is defined as the period between the marriage and the last live birth prior to the interview. Due to this heterogeneity, the relationships between the observed averages and variances of live births and the length of marriage duration are not linear as predicted by the model. Some of these discrepancies could also arise due to a variety of other reasons, including some deficiencies in the data. Even if we were able to remove all these deficiencies the values of averages and variances of live births predicted by the model will not be close to the observed values because, due to the decreasing fecundity with advancing age, the relationships between marriage duration and the averages and the variances are not linear as predicted by the model. In this respect the model needs some modifications.

4. In order to be more abstract the Perrin and Sheps model necessarily makes unrealistic assumptions, but we have demonstrated in earlier chapters what happens to these parameters in a real population in which there is more variability in some respects than the model assumes. In this chapter we have shown the variations in the values predicted by the model if the parameters estimated from a real population with more variability than the model assumes, probably appropriate in a hypothetical population, are used instead.

CHAPTER IX

SUMMARY AND CONCLUSIONS

In this report we have mainly tried to answer two questions:

1. How can different fecundity components be measured from the data collected retrospectively from a field survey in Taiwan, a developing country, and how do these estimates vary with important demographic and socio-economic characteristics of couples?

2. How can these estimates be utilized for predicting the values of demographic indices measuring fertility level by using the Perrin and Sheps stochastic fertility model, and how do these theoretically predicted values differ from the corresponding observed values?

The three fecundity components are considered: fecundability, the level of fetal wastage, and the infecundable periods following the termination of pregnancy. The first two components are estimated directly from the available data, but the third component could not be estimated directly from the available information. This is indirectly estimated from the completed pregnancy incervals--the period between the termination of a pregnancy and the beginning of the following pregnancy. To keep the work required within reasonable limits, socio-economic differentials are studied only for fecundability. The socio-economic differentials in the other two components will be studied at a later stage.

However the variations by important demographic characteristics have been studied for all three components.

We used the Perrin and Sheps model of human reproduction for predicting the averages and variances of three demographic indices: first birth intervals, completed birth intervals, and the numbers of births during "t" months of marriage. This model is used for illustrating one of the utilities of fecundity components. These components can also be used as input data in other analytical or simulation models for predicting fertility levels.

Brief Resumé of the Main Findings

1. The fecundability among Taiwanese women is distributed according to a Pearson's Type-I geometric distribution. The average fecundability of Taiwanese women, as estimated by using the type-I distribution, is 163 per 1,000 women with a standard error of 2. This estimate is subject to two types of biases. The memory bias, due to omitting abortions, deflates the apparent fecundability. The truncation bias, caused by the curtailing of the reproductive period, has the effect of inflating the apparent fecundability. The pregnancy histories of women who had been married for three to eight years appeared to be free of these two biases and the average fecundability for this group of women is 195 ± 3, which is quite close to estimates of the fecundability level of American women.

2. Fecundability decreases with ascending marriage duration, but this decline in measured fecundability with marriage duration is caused mainly by the joint effect of the memory and truncation biases. It is

not caused by the differences in the wife's age at marriage or her socio-economic status.

3. Fecundability increases with the wife's age at marriage up to 25 years. This increase in fecundability with age at marriage is only partly caused by the memory and truncation biases associated with the marriage duration. It is not caused by the differences in the socio-economic status of couples.

4. Measures of socio-economic status were positively associated with fecundability. This association is not explained by either the memory and truncation biases associated with the marriage duration or by the differences in wife's age at marriage.

5. Among seven measures of socio-economic status the husband's education showed the strongest positive association with fecundability. The couple's rural background, ethnic background, and family structure also showed distinct independent associations with fecundability. Wives of farmers have lower fecundability than other wives. Taiwanese couples have higher fecundability than those from mainland China. Women always living in nuclear families have higher fecundability than those in extended family units. The wife's education, ownership of modern objects and household's monthly income, either did not show much association with fecundability, or the association disappeared after controlling for husband's education.

6. The level of fetal wastage (spontaneous abortions + induced abortions + stillbirths), as reported by the respondents, is 120 per 1,000 recognized and completed pregnancies. The estimated level of under-reporting is about 53 per 1,000 completed pregnancies. Thus the

corrected estimate of fetal wastage in Taiwan is 173 per 1,000 recognized and completed pregnancies, which is quite close to the level of 200 in Western societies.

7. Pregnancies which follow the use of contraception are more likely than others to be ended by induced abortions, presumably because the contraception was intended to prevent these pregnancies but failed. The estimated levels of fetal wastage following the use and nonuse of contraception are 531 and 133 respectively.

8. The level of fetal wastage, in the absence of contraception, increases with the order of pregnancy even after controlling for the age of the mother. The relationship between the level of fetal wastage and the order of pregnancy is curvilinear. Not only the rate of fetal wastage but also its rate of change increases with the order of pregnancy. On the other hand, the level of fetal wastage shows a negative association with the age of the mother after controlling for the effect of the order of pregnancy, mainly because of the negative association between age of the mother and the level of induced abortions. When we exclude induced abortions, the level of fetal wastage shows positive associations with the age of the mother and with the order of pregnancy.

9. In the absence of contraception, women took an average of about 17 months to conceive following a live birth as compared to eight months following an abortion. The corresponding variances are 106 and 77 respectively. Whether abortion was induced or spontaneous did not affect the average. However, if a baby died in infancy the average time taken for a next conception was only about 12 months instead of the average of 17 months following all live births. As women get older the

average and the variance of time taken for conception increases following either a live birth or an abortion. In the present sample the effect on these averages and variances of memory and truncation biases are compensating.

10. In our sample the use of contraception increased the average length of completed pregnancy intervals by two to four months depending upon the outcome of the preceding pregnancy. This increase is not caused by the fact that older women used contraception. Women who used contraception in their late thirties were more successful in delaying their next pregnancies than younger women. Since about 87 per cent of the women in Taiwan who use contraception do so to limit their family size rather than to space births, the main effect of contraception appeared in the open pregnancy interval. The average length of the open pregnancy interval increased by about 12 months if women used contraception during this interval.

11. In the present sample women were more likely to use contraception following an induced abortion than following a miscarriage or a live birth. If women used contraception, then the average time taken for a next conception is considerably higher following an induced abortion than following a miscarriage. This seems to provide a plausible explanation for the fact that in Taiwan women take a longer period to conceive after an induced abortion than after a miscarriage.

12. The average and variance of infecundable periods (postpartum amenorrhea and anovulatory period) following the termination of a pregnancy are obtained indirectly by subtracting the moments of the fecundable period (estimated from the first pregnancy intervals) from the

corresponding moments of pregnancy intervals (estimated from all completed pregnancy intervals). The estimated average infecundable period following a live birth comes out to be about 11 months following a live birth, as compared to about two months following an abortion. The corresponding variances are 40 and 7 respectively.

13. The discrepancies between the observed and the theoretical averages and variances of first birth intervals, and of completed birth intervals, seems to arise mainly because of interdependence between different states of the model. In their model Perrin and Sheps assumed that all states of the model are independent, whereas in reality these states appear to be dependent on each other.

14. The discrepancies between the observed and the theoretical averages and variances of live births during "t" months of marriage are mainly due to the heterogeneity among women with respect to the "effective"[1] length of the reproductive periods. The model assumes that the length of the reproductive period is unlimited whereas in reality it is not so. Even if we control for the duration of marriage the resulting groups of women are still not completely homogeneous with respect to the effective lengths of the reproductive periods. This heterogeneity means that the curves relating the marriage duration to the average and the variance of live births are not linear as predicted by the model.

15. A part of the discrepancies may result from some deficiencies in the data. However, the model needs some modifications regarding two

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[1]Here the effective length of the reproductive period denotes the period between the marriage and the last live birth prior to interview.

main limitations mentioned above. These limitations cannot easily be relaxed in the mathematical model, and without such a relaxation the utility of the model is limited. These limitations can probably be relaxed more easily by using the techniques of computer simulation and Monte Carlo procedures. Hyrenius and Adolfson,[2] Ridley and Sheps,[3] and Potter and Sakoda[4] are working on such models.

Evaluation of the Present Study

This is one of the few empirical studies which has extensively examined the relationships between the main physiological determinants of fertility and the demographic and the socio-economic characteristics of couples. This is also one of the few studies in which these estimated fecundity components are utilized for predicting three demographic indices for a developing country by using the extensive analytical fertility model developed by Perrin and Sheps, although some similar work has also been done for India, the United States and France.

One of the limitations of this study was that the data were collected retrospectively. The memory bias arising out of this retrospective nature of the data had to be estimated indirectly. The results

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[2]H. Hyrenius and I. Adolfson, "A Fertility Simulation Model," Göteborg: Demographic Institute, University of Göteborg, 1964, Report No. 2, pp. 1-31. Also, "Demographic Models," Göteborg: Demographic Institute, University of Göteborg, 1966, Report No. 4, pp. 1-36.

[3]J. C. Ridley and M. C. Sheps, "An Analytical Simulation Model of Human Reproduction with Demographic and Biological Components," Population Studies, XIX, No. 3 (March 1966), 297-310.

[4]R. G. Potter, Jr. and J. M. Sakoda, "A Computer Model of Family Building Based on Expected Values," Demography, III, No. 2 (1966), 450-61. Also, "Family Planning and Fecundity," Population Studies, XX, No. 3 (March 1967), 311-28.

obtained in this study could be improved by collecting the required data prospectively, as was done in the Khanna study for Indian women.

A second main limitation was that in this study direct information about the length of the infecundable period was not collected. This restricted the scope of the present study in two ways: (1) the estimates of the infecundable periods had to be obtained indirectly from the distributions of all completed pregnancy intervals and the distribution of first pregnancy intervals. Hence we could not obtain the estimates of the infecundable periods for different age groups, and (2) we could not use the higher order pregnancy intervals to estimate fecundabilities. Hence we could not study the age differentials in fecundability after age 25.

A third main limitation of the present study was that the sampling variances of all parameters were based on the assumption of a simple random sample whereas in actuality a sample of clusters was selected systematically. The effect of the sampling design is to increase the variances of parameters. It will be interesting to see the magnitude of such differences at a later stage. This can be done by means of "balanced repeated replications" with considerable difficulty.

Despite the shortcomings of the present study, we believe that we have made a contribution to the knowledge of fecundity components. Particularly we have developed some techniques to obtain reliable estimates of fecundity components from the data collected retrospectively despite its many deficiencies. Although the results are strictly applicable only to the Taiwanese women living in Taichung, the

techniques developed in this study are not restricted to the present sample only. These techniques can also be applied to similar data from any country.

Two main findings which may have important practical implications are the fecundability differentials by wife's age at marriage, and by the couple's socio-economic status. We have established with a reasonable degree of confidence that in Taichung fecundability increases with wife's age at marriage up to age 25. The fecundability is at a maximum between ages 21 and 25. There are some indications in our data that it then starts declining, though the evidence is not conclusive. If further research establishes more firmly that fecundability does decline after age 25, then those interested in policies for decreasing birth rate may acquire more interest in delaying the age of marriage. Advancing the age of marriage would decrease the fertility level due to the fact that after age 25 women would be subject to lower fecundability in addition to the fact that the length of their reproductive period will be shorter.

We have also established beyond reasonable doubt that in Taichung fecundability increases with the socio-economic status. This finding has serious implications for future family planning programs, because with the improvements in general health conditions and economic status, we would expect that in the future the fecundability of couples will rise and so would their fertility, unless drastic measures are taken for widespread use of contraception.

For measuring the exact effect of changes in fecundability on fertility we have to consider the changes in the values of two other

components; the level of fetal wastage, and the length of infecundable periods following the termination of a pregnancy. Different combinations of the values of these three fecundity components can produce different effects on fertility levels. Thus any increase in fecundability due to improvements in health and economic conditions does not necessarily imply an equal increase in fertility, unless the level of fetal wastage and the length of the infecundable periods remain unchanged. The joint effect of the changes in all three components might be even greater than that expected on the basis of changes in fecundability alone. On the other hand, it is also possible that the other two components might change in such a way that the joint effect of these changes is to decrease the fertility. This is possible if the level of fetal wastage increases due to increasing use of induced abortions and/or, the length of the infecundable period increases due to increase in the practice of breastfeeding. The joint effect of changes in fecundity components on fertility is complicated, because in reality any change in one component probably will bring some changes in the other two components too. This requires further research.

The conclusions of this study strictly apply to Taiwanese women living in Taichung. It will be misleading to say that these conclusions will definitely apply to all Taiwanese women, not to mention to women in other countries. In Chapter I it was mentioned that the estimates of fecundity components are culturally bounded and do not measure biological parameters alone. Whether and in what ways our conclusions are general can only be determined by comparisons with other populations varying biologically and culturally. It is only by patient accumulation

of such studies that we will be able to differentiate between the biological and cultural nature of fecundity components.

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