MATERNAL EDUCATION AND INFANT MORTALITY IN THAILAND:

Comparison Between the Proportional Hazards Models with Multiplicative and Additive Risk Functions

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ABSTRACT

This study has two objectives: (1) to compare the fit of the proportional hazards models with the multiplicative risk function to the one with the additive risk function by applying both functional forms to infant mortality data, and (2) to investigate the association between maternal education and other socioeconomic, demographic, environmental and health care factors in relation to infant mortality in Thailand. The data, used in this study, came from the *1987 Thailand Demographic and Health Survey* (1987 TDHS).

Results showed that the proportional hazards model with the multiplicative risk function fitted the infant mortality data in Thailand better than the additive one. The investigation of the associations between maternal education and its associations with other factors mentioned above in relation to infant mortality suggested that maternal education had a significant negative effect numerically on infant mortality even when all other variables under study were controlled. The education was strongly associated with family economic condition, place of residence, toilet facilities, and birth order greater than one with short preceding birth intervals.

There was suggestion of interaction effects between maternal education,

on the one hand, and place of residence, birth order greater than one with short preceding birth interval, and health care utilization, on the other, on infant mortality. The effects of these factors were significantly reduced if maternal education was increased from lower than secondary to at least secondary level. Suggestions are offered to reduce infant mortality in Thailand as follows:

1. The compulsory education should be strengthened and controlled to ensure that all graduates from school could read with comprehension.

2. Different governmental departments, such as education, public health, economic, community development, should take part in planning for reducing infant mortality.

3. Safe drinking water supply should be launched and carried out by local authorities; special attention should be paid for those living in urban areas, where safe water supplies were not accessible.

4. Breastfeeding program should be initiated to encourage working mothers to breastfeed their children during working hours.

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CHAPTER I

INTRODUCTION

Infant mortality which is defined as the deaths of children under one year of age has long been regarded as a sensitive index reflecting the levels of the socioeconomic and health care service development of a country (Shapiro, et al., 1968; Preston, 1976; WHO, 1978). In developed countries where economies and medical services are more advanced, infant mortality rates are much lower than those of the developing countries (Vallin, 1976; Hayase, 1986; Newland, 1989; UNICEF, 1982-1994). Causes of infant deaths vary with the levels of mortality; where infant mortality is high, the predominant causes of death are infectious and parasitic diseases, reflecting the environmental health conditions in that community, while low levels are associated with congenital conditions (Vallin, 1976).

One factor that has been frequently found to have significant relationship with infant mortality and recognized as an effective indicator of an individual family's socioeconomic condition is maternal education. Education, in fact, was recognized as an important factor in reducing mortality many decades ago (Penrose, 1934). Its significant effect on infant mortality has been found in all regions, both developed and developing countries. During the last two decades, researchers have paid attention to its roles in determining infant mortality (Puffer and Serrano, 1975; Caldwell, 1979; Fosu, 1981; Frenzen and Hogan, 1982; Hobcraft, et al., 1984; Park, 1986; Cleland and van Ginneken, 1988; Kost and Amin, 1988; Tresserras, et al., 1992; Tsuya, et al., 1993; Bakketeig, et al., 1993; Park, et al., 1994). In fact, Mensch and colleagues have strongly emphasized the importance of maternal education in relation to child mortality in developing countries in this way:

> "...even the sum of "direct" mortality effects of doubling everyone's income, providing every household with a flush lavatory and piped water, and turning every agricultural labor into a professional white collar worker, would be less than the "direct" effect of providing 10 years of schooling for each woman."

(Mensch, et al., 1983). The question is: How does maternal education affect mortality? Obviously, it does not affect mortality directly.

Many studies found the relationships between maternal education and other variables such as knowledge and practices in prevention and control of diseases (Caldwell, 1979; Fosu, 1981; Rozensweig and Schultz, 1982; Ahmed, et al., 1991) and family economic status (Maclean, 1974; Ware, 1984) which, in turn, affected the standard of living and the well being of the family's members, including fetuses and infants.

In 1984, Mosley and Chen proposed a child survival model which postulated that the socioeconomic factors, including maternal education, operated to affect infant mortality through the more proximate variables such as maternal and environmental factors, personal prevention and treatment of illnesses, accidents and injuries (Mosley and Chen, 1984).

If such relationships mentioned above really existed unconditionally everywhere, the risk of having infant mortality among mothers with higher education should be less than that among mothers with lower education, given that they were exposed to the same risk factors. However, an international comparison of the relationships among maternal education, infant mortality and other variables such as family income and maternal factors showed varying results from country to country (Bicego and Boerma, 1993). Other studies also showed variable results and were inconclusive and even in conflict (Caldwell, 1979; Rozensweig and Schultz, 1982; Cleland and van Ginneken, 1988; Barbieri, 1990). The relationships, in fact, could also be affected by other extraneous factors, such as beliefs, cultures, tradition, etc., as well as the quality of health care services in that community (Ware, 1984).

Clearly, our knowledge about the relationship between maternal education and other variables is still minimal (Cleland and Van Ginneken, 1988; Bicego and Boerma, 1993) and the generalization about its effects from other settings is probably not sensible.

In studying the relationships between maternal education and other proximate variables in relation to infant mortality at the individual level, a wide range of information, especially pregnancy history data, is needed. This has been impossible in the past due to the lack of detailed information, especially in developing countries where the information systems were not well developed and the vital statistics from the registrar office were incomplete. Only recently that the individual pregnancy history data, collected as a part of fertility surveys, have been available in many developing countries.

However, it is not only the data that is important to the study of the mortality determinants, but also the statistical method that is employed in the analysis. Using the wrong or inappropriate statistical model can distort the results of the study. In the analysis of infant mortality to explain the relationship between mortality and independent variables, probably the most appropriate statistical method is the one that measures the effects of mortality determinants using all information on the individual and taking into account the information on age at death. One of the statistical methods that possesses the aforementioned properties is the proportional hazards model which was introduced by D.R. Cox (Cox, 1972). The model assumes that risk factors affect the baseline hazard in the multiplicative manner. Because of its desirable properties, the model has been widely used. Recently, however, some researchers have questioned the assumptions of this model and have argued that the multiplicative relative risks may not be suitable for some biological data, such as dose-response; and its implication for public health intervention was less appropriate than the additive one.

Modifications to the original proportional hazards model were introduced. The most notable one was the proportional hazards model with the linear or additive risk function. Comparisons between the proportional hazards models with the multiplicative risk and the one with the additive risk functions were carried out. Results from these studies did not show any significant difference in terms of the effects estimated from each of these models (Thomas, 1981; Breslow and Storer, 1985). However, by comparing the relative risks estimated from different risk functions, Breslow and Storer (1985) and Thomas (1981) found the additive risk function fit the data better than the multiplicative one (Greenland, 1979; Thomas, 1981; Breslow and Storer, 1985).

Thailand has experienced a rapid reduction in infant mortality since the 1950s. At the national level, the decline has been accompanied by an increase in the literacy rates of women, gross national product (GNP) per capita, and health care service coverage (UNICEF, 1982-1992); and, at the individual level, infant mortality has been found to be associated with socioeconomic and demographic factors such as maternal education, place of residence, maternal age at birth, birth order of the child, birth interval, duration of breastfeeding, and sex of the child. The decline in infant mortality has slowed down since the

1980s but the level of mortality is still considered to be high (Chamratrithirong and Pejaranonda, 1986), and mortality differentials by socioeconomic and demographic factors are still substantial. Though the differences by some socioeconomic factors have been lessened over the years (Economic and Social Commission for Asia and Pacific, 1976; Sirijiamrata, 1976; Knodel and Chamratrithirong, 1978; Kiranandana, 1979; Chamratrithirong, 1980; Boonkaew, 1985; Voraponsathorn, et al., 1986; Suwanaphong, 1988; Tsuya, et al., 1992; Park, et al., 1994), the effect of maternal education is still substantially significant (Sirijiamrata, 1976; Knodel and Chamratrithirong, 1978; Kiranandana, 1979; Bicego and boerma, 1993; Tsuya, 1993).

In Thailand, as in many other developing countries, not only has examination of the relationships between maternal education and other proximate variables in relation to infant mortality been lacking, but also multivariate analyses of the relationship between infant mortality and its determinants at the individual level (Tsuya, et al., 1993). The national survey data that contained pregnancy histories have become available only recently.

Some of the most recent pregnancy history data was collected in 1987 in the *1987 Thailand Demographic and Health Survey.* The data was rich in information on socioeconomic, demographic and health factors, especially in fertility and contraception, allowing the investigation of the roles of maternal education in determining infant mortality in Thailand. Such an investigation can play a role in a comprehensive plan to reduce infant mortality. As has been mentioned earlier, the relationships among maternal education, other more proximate variables and infant mortality could be affected by extraneous factors such as beliefs, cultures, tradition, as well as the quality of health care services in the community. The generalization of the relationship between maternal education and other variables in relation to infant mortality from other sources could be misleading.

It is, thus, important to understand the roles of maternal education's effect on infant mortality in a particular society; and in order to arrive at unbiased results so that the roles of maternal education in relation to infant mortality reduction can be properly understood and utilized in comprehensive planning, an appropriate statistical model is needed. Therefore this study will focus on:

1. comparing the performances of the proportional hazards models with multiplicative risk function to that with additive risk function. The comparison will be carried out with respect to the goodness-of-fit of these two models to the infant mortality data in the *1987 Thailand Demographic and Health Survey*. The model that better fits the data will be used in the further analysis of the relationship between maternal education and other proximate variables in relation to infant mortality.

2. investigating the relationship between maternal education and other

socioeconomic, demographic, and environmental and health care factors in relation to infant mortality in Thailand.

Results from this study will provide insight into which risk function is more appropriate for infant mortality data in Thailand and will be useful for making operational plans for reducing infant mortality in Thailand. It can also provide the baseline information for further detailed study on the mechanism through which maternal education operates to affect infant mortality.

CHAPTER II

REVIEW OF THE LITERATURE

This chapter reviews the related literature on the following topics:

1. The definition of infant mortality.

2. The significance of infant mortality.

3. Trend of infant mortality and factors contributing to its decline.

4. Infant mortality determinants.

5. Maternal education and its relationship with other more proximate variables in relation to infant mortality.

6. Infant mortality in Thailand.

7. Statistical methods that have been used in the analyses of infant mortality.

1. Definition of Infant Mortality

Infant mortality, defined as the death of a child from birth to one year old, is conventionally divided into two time periods: (1) neonatal mortality, death from birth to age 28 days, and (2) post-neonatal mortality which is death from ages older than 28 days to one year.

The leading causes of neonatal deaths are endogenous factors such as genetic factors and factors affecting growth and development of fetuses; while the predominant causes of post-neonatal deaths are exogenous factors originating in the external environment causing conditions like infections, parasitic diseases, etc. These factors include environmental contamination and nutritional intake of the child (Stockwell, et al., 1987).

The ratio of neonatal and post-neonatal mortalities roughly depends on the level of infant mortality in that particular area. Where infant mortality is high, in general, the ratio between neonatal and post-neonatal mortality is less than one; and it is greater than one when infant mortality is low (Vallin, et al., 1985; Rip, et al., 1989). This is because the exogenous factors which are the leading causes of post-neonatal deaths are much easier to prevent and control than endogenous factors which cause neonatal mortality (Bailey, et al., 1990).

2. The Significance of Infant Mortality

The level of socioeconomic and health service development of a country is reflected by the level of infant mortality within a country (Shapiro, et al.,1968; Preston, 1976; WHO, 1978). In developed countries which are more prosperous and which have more advanced medical and health care technologies, infant mortality rates, during the same period of time, are much lower than those of the developing countries (Hayase, 1986). In 1992, infant mortality rates in most developed countries were below 15/1,000 live births, while those of the developing countries ranged from 191/1,000 live births in the tropical African region to 28-95/1,000 live births in Latin America and East Asia (Vallin, 1976; Newland, 1981; UNICEF, 1994).

3. Trend of Infant Mortality

The relationships between socio-economic factors and the medical and health care technological development and the decline of infant mortality have been well documented (Notestein, 1945; Davis, 1945; Meegama, 1980; Stolnitz, 1989; MacDorman and Rosenberg, 1991; Bhuiya and Streatfield, 1992; Lardelli, et al., 1993). This was clearly evident from the mortality decline in the United States between 1930 and 1983. At the beginning of the 1930s, infant mortality, especially post-neonatal mortality, had been rapidly declining because of the development of medical technology and environmental sanitation. The decline had been slowing down during the 1950s because infectious diseases and environmental problems had largely been controlled. However, infant and child mortality differentials by socioeconomic and genetic factors still existed and needed to be tackled. After 1965, infant and child mortality in the United States started to decline again because social welfare enabled deprived mothers to have access to prenatal care and well baby clinics (Shapiro, et al., 1984). Nevertheless, infant mortality differentials by socioeconomic status still remained significant (Puffer and Serrano, 1975; Miller, 1985; Stockwell, 1987; Tresserras, et al., 1992; Nordstrom, et al., 1993; Hogue and Hargraves, 1993). It was evident that even if health care services were made available and accessible to all groups of mothers, infant mortality differentials by socioeconomic factors were still significant.

The infant mortality decline among developing countries started its course much later than the developed countries, yet the rates of decline slowed down at a much earlier stage and leveled off at much higher mortality levels than those in developed countries (Chaurasia, 1986). After World War II, infant mortality rates among developing countries were reduced from 150/1,000 live births during 1950 to 1955 to 91/1,000 live births during 1980 to 1985; while those among developed countries reduced by 70%, from 56/1,000 live births to 17/1,000 live births, during the same periods of time (Hayase, 1986).

The reduction of infant mortality in developing countries was also found to be related to the socioeconomic development, demographic factors, the decline of infectious diseases and the increase in the coverage of health care services (Vallin, 1976).

Results from previous studies have shown that at the individual level, infant mortality was affected by socioeconomic, demographic and health care factors, such as social status, parental education, place of residence, family income, standard of living, occupation, maternal age at birth, birth order, birth intervals, breastfeeding, ethnicity, previous child survival, sex of the index child, water supply, toilet facilities, prenatal care and other health care service utilization.

The following section will discuss the effects of selected socioeconomic, demographic, environmental sanitation and health care variables on infant mortality that are related to this study.

4. Infant Mortality Determinants

4.1. Socioeconomic Factors and Infant Mortality

a. Place of Residence

It is evident that living in an urban area determines an easy access to and a wider availability of medical services and other modern facilities such as transportation, sewage systems, etc., especially in developing countries (Barbieri, 1990). Results from many empirical studies found urban residents have lower infant and child mortality than their rural counterparts (Puffer and Serrano, 1975; Knodel and Chamratrithirong, 1978; Davanzo, et al., 1983; Martin, et al., 1983; Trussell and Hammerslough, 1983; Hobcraft, et al, 1983; Park, 1986). However, its effect was weakened when other socio-demographic variables, i.e., education, availability and accessibility of health care facilities, were controlled for (Caldwell, 1979; Behm, et al.,1984). Caldwell (1979) concluded that it was, in fact, the differential in distribution of these variables, which were closely related to infant and child mortality, that caused the mortality differentials between rural and urban areas.

b. Family Economic Condition

The family socioeconomic condition, usually measured by family income, is associated with the ability of the family to provide adequate food, medical and health care, clothes and shelter for children. These factors are important to their survivorship, especially during infancy which is the most vulnerable period. It has been found to have a significant effect on infant mortality in both developed and developing countries. Infants born to families of higher economic status were at lower risk of mortality than those who were born to families of low economic status (Kulkarni, Krishnamoorthy, and Devaraj, 1990; Bhuiya and Streatfield, 1992; Lardelli, et al., 1993).

c. Maternal Education

Maternal education has been regarded as an effective indicator of the family's socioeconomic status. It was found to be directly related to social status, family income, working status, living standards, health care utilization, health behavior, etc (Rozensweig and Schultz, 1980; Ahmed, Eberstein, and Sly, 1991; Otta, 1992). It was also found to be significantly related to infant and child mortality, both in developed and developing countries (Puffer and Serrano, 1975; Caldwell, 1979; Cochrane, 1980; Rozenzweig and Schultz, 1982; Martin, et al., 1983; Trussell and Hammerslough, 1983; Ware, 1984; Mensch, et al., 1983; Park, 1986; Choe, et al., 1987; Pebley and Stupp, 1987; Barbieri, 1990; Tsuya, et al., 1993; Tresserras, et al., 1992; Bicego and Boerma, 1993; Hogue and Hargraves, 1993; Nordstrom, et al., 1993; Park, et al., 1994). The effect of education was generally stronger during post-neonatal than neonatal periods (Curtis and McDonald, 1991). There was evidence showing the threshold effect of maternal education on infant mortality. A study in the Philippines, Indonesia, and Pakistan found that only mothers with education higher than primary level had significantly lower infant mortality rates than those with no education. They also found the effect of each level of maternal education on infant mortality varied from country to country (Martin, et al., 1983). However, not all studies agreed with the value of a woman's education in the reduction of infant mortality. Frenzen and Hogan (1982), in their rural Thailand study, found maternal education did not increase the ability of mothers to provide adequate infant care, at least to the degree necessary to reduce infant mortality significantly (Frenzen and Hogan, 1982). Gubhaju's study in rural Nepal found no significant effect of maternal education on infant mortality, but found a significant effect on child mortality (Gubhaju, 1983). The reason the latter two studies did not find any significant effect of maternal education may be due to the fact that the variations of maternal education in these populations were very small.

How does maternal education affect mortality? Of course, infants do not die simply because their mothers did not go to school. There must be intermediate links between education and mortality. These will be discussed later.

4.2. Demographic Factors and Infant Mortality

a. Sex of the Child

In general male infants have higher mortality at all ages (Holland, 1987), but in some cultural settings with a strong preference for males, female mortality is higher during childhood than male mortality (Scrimshaw, 1978; Trussell and Hammerslough, 1983; Choe, 1987; Tsuya and Choe, 1989; Reddaiah and Kapoor, 1992). However, some studies found no sex differentials in infant and child mortality (Choe, et al., 1987; Retherford, et al., 1987).

b. Birth Order

Birth order of the child was found to be related to infant mortality. Its effects, nevertheless, varied from study to study. Some studies found birth order has a curvilinear effect on mortality with first birth order and order of four and higher having higher mortality rates (Puffer and Serrano, 1975). Another investigation found first birth had higher infant mortality rates, but there was no evidence of elevated mortality for higher orders (Hobcraft, et al., 1984). Another study found birth order of the child had a positive relationship with infant mortality (Kiranandana, 1979). There was also evidence showing that the effects of birth order were reduced once the mother's age at birth and previous birth interval were controlled (Choe, 1983; Trussel and Hammerslough, 1983; Trussel and Pebley, 1984). This was probably due to the fact that the effect of birth order could be either caused by biological, socioeconomic, or environmental factors. If the biological effects play an important role, infants of first birth order were at a higher risk of mortality, particularly when they were born to teen mothers since these mothers may not have been physically ready to have children. The higher risk of mortality among infants of higher birth order could be due to nutritional deficiencies and infections, caused by the crowded conditions in the families, insufficient food intakes, and poor hygienic conditions. It could be due also to maternal depletion, causing prematurity, low birth weight, congenital anomalies, etc.

c. Maternal Age at Birth

Maternal age was another important factor affecting infant and child mortality. Infants born to teen-age mothers were at high risk of dying possibly because these mothers were physically and psychologically immature which could cause abnormal labor or birth injuries. It could also be because of other socioeconomic disadvantages found among these mothers that could affect their nutritional status and standard of living, and thus, the well being of the fetuses and infants. It was also found that infants born to mothers aged 35 or older were at higher risk of mortality because of the mother's physical deterioration which affected the growth and development of the fetus and infant, as well as birth injuries (Puffer and Serrano, 1975; Frenzen and Hogan, 1982; DaVanzo, et al.,1983; Trussell and Hammerslough, 1983; Park, 1986; Choe, et al., 1987; Pebbey and Stupp, 1987).

d. Birth Interval

Birth intervals, both preceding and succeeding the birth of a child, have been found to have strong effects on infant and child mortality. Their effects were generally stronger during the neonatal than post-neonatal period (Wolfers and Scrimshaw, 1975; Hobcraft, et al., 1983; Cleland and Sathar, 1984; Palloni and Millman, 1986; Park, 1986; Choe, et al., 1987; Retherford, et al., 1987; Curtis and McDonald, 1991). The preceding interval affected child mortality through the mother's physical depletion since a short interval would not have allowed the mother to have enough time to recover from previous conception and lactation, thus affecting fetal growth and development. This may have resulted in low birth weight, premature birth, small for date infant, or even other congenital anomalies which put the infants at high risk of mortality (Winikoff, 1983; Cleland and Sathar, 1984; Pebley and Stupp, 1987).

The short succeeding interval could affect the index child by means of premature weaning, competition for family's resources and attention and care between the two siblings. The short birth interval was also closely related to the family size such that infants of both short preceding and succeeding intervals would be at high risk of infections because of crowding and possibly poor sanitary conditions in the household (Cleland and Sathar, 1984; Pebley and Stupp, 1987).

Nevertheless, the environmental effects of short birth interval mentioned above could be confounded by premature death of the preceding child which reduced infections and the competition for attention and family resources between the two siblings, thus reducing the effect of birth interval.

Unusually long intervals without using any kind of contraception, however, could be a sign of mother's health problems. Therefore, infants born to these women were also at high risk of mortality since the health of the mother directly affects the growth and development of the fetus and the baby (Winikoff, 1983).

e. Breastfeeding

Child survival depends a great deal on adequate nutrient intake and the ability to resist or recover from infections. Breastmilk can provide major nutrients as well as immunity to the baby, thus increasing its resistance to infectious diseases. Breastfeeding, if practiced properly, would help reduce the ingestion of certain infectious agents. In addition, it contributes significantly to child survival through extending the period of anovulation and lengthening birth intervals.

Duration of breastfeeding and infant mortality were found to have an inverse relationship (Knodel and Debavalya, 1980; Retherford, et al., 1987). The longer the duration of breastfeeding, the lower the risk of infant mortality. However, after the third month of age, a child's nutritional energy requirements cannot be met by breast milk alone and introduction of supplementation is recommended at this point (Palloni and Millman, 1983; WHO, 1985; Choe, et al ,1987).

4.3. Environmental and Health Care Factors and Infant Mortality

a. Environmental Factors

Infants are susceptible to infections since their immune system is not well developed. Personal hygiene and cleanliness were important factors in infant care in reducing susceptibility to infectious diseases, especially gastrointestinal infection. Inappropriate sources of drinking water and toilet facilities that allowed insects to contact feces freely exposed infants, particularly those not breastfed, to gastrointestinal infections. Many studies found environmental factors such as type of water supply and toilet facilities to have significant effects on infant and child mortality. Households equipped with flush or water sealed toilet and piped water were found to result in a decline in infant and child mortality (Patel, 1980; Martin, et al., 1983; Trussell, 1983; Crognier, 1987; Holian, 1988; Barbieri, 1990).

b. Health Care Services

When young children become sick, their survivorship depends on how serious the illness is, how soon they receive medical treatment, and their nutritional status. Without any medical treatment and with poor nutritional status, a mild illness could become a serious one and could cause death. But if these sick children receive medical care soon enough, the illness would probably not cost them their lives.

Previous studies found that the availability of and the accessibility to health care services in the community significantly reduced infant mortality in both developed and developing countries (Shapiro, et al., 1965; Silva Aycaguer and Denan Macho, 1990; Macdorman and Rosenberg, 1991; Frankenberg, 1992). The use of health care services such as prenatal care was found to be negatively related to infant mortality. Mothers who received prenatal care services during pregnancy had lower infant mortality rates than those who did not (Bicego and Boerma, 1993; Tsuya, et al., 1993). However, the argument was not only whether the woman had any prenatal care, but also the time she started to receive the service, and the contents and quality of the service as well (Suwanaphong, 1988; Tsuya, et al, 1993).

Among all variables discussed above, the proximate variables or the variables that are closely related to the factors that directly affect infant mortality are the demographic, the environmental and health care variables.

These variables are related to such factors as birth injuries, birth weight, nutritional status and infections which directly affect infant mortality.

The following section will discuss the relationships among maternal education, the proximate variables such as demographic, health behavior and health related factors and infant mortality.

5. Relationships Among Maternal Education, the Proximate Variables and Infant Mortality

Among the socioeconomic factors, maternal education has often been found to have significant association with infant mortality, and has been regarded as the best indicator reflecting the socioeconomic status of the family. Mothers with little or no education have often been found in families with low income, poor housing, deficient water supply and sanitary facilities, and without adequate prenatal or other medical care services (Puffer and Serrano, 1975; Caldwell, 1979; Cochrane, et al., 1980; Martin, et al., 1983; Trussell and Hammerslough, 1983; Hobcraft, et al., 1984; Mensch, et al., 1985; Park, 1986; Cramer, 1987; Choe, et al., 1987; Cleland and Van Ginneken, 1988; Barbieri, 1990).

It is thus clear that higher education is associated with higher socioeconomic status and standard of living. The following section will discuss the factors that possibly cause lower infant mortality among educated mothers.

Education has been found to be related with health and health related behavior of women (Ahmed, et al., 1991). In less developed areas girls attending school were exposed to modernity and higher standards of living such as sanitary latrines, vaccinations, higher levels of personal hygiene, which were unlikely available to them at home. In addition to these experiences, they were exposed to new scientific knowledge which broadened their mind and affected their attitudes and perception such that they were more likely to accept new ideas than those who did not attend the school (Rozenzweig and Schultz, 1982; Caldwell and Caldwell, 1985; Palloni, 1985).

Educated mothers were found to be better nourished and less subjected to hard physical work, since parents of these women were willing to invest in children whom they sent to school.

During their pregnancies, these educated mothers would normally know how to take better care of themselves to prepare for healthy babies and could afford the costs of doing so (Ware, 1984). Because of the biological links between a mother and an infant during pregnancy and lactation, a mother's health and nutritional status as well as her reproductive pattern influenced the health and the survival of the child (Chaurasia, 1986).

After the babies were born, they were willing to break the traditional practices of favoring adults and paid more attention to the young ones (Puffer and Serrano, 1975; Caldwell, 1979; Hobcraft, et al., 1984).

Education also provided a woman with skills and knowledge in caring for her baby and enabled her to manage to overcome the situations inimical to good health, such as living in poor conditions (Caldwell, 1979; Schultz, 1982; Mosley, 1984; Pebley and Stupp, 1987). It also played an important role in diffusing knowledge of medical and sanitary requirements which could range from simple elements of child care involving cleanliness and sterilization to more complex knowledge of what drugs and vaccinations were required.

Mothers with higher education were found to be more capable of providing adequate care to family members than those with a lower educational level (Gortmaker, 1979; Frenzen and Hogan, 1982; Hobcraft, et al., 1984). In Nigeria, Caldwell (1979) found educated mothers were more willing to seek help from modern health care sectors and follow the doctors' order and instructions; and if the children did not improve, they were more likely to take them back for follow-up care. He discovered educated women had a wider social network and were better able to deal with the outside world and draw the attention of others, particularly government officials at health care institutions (Caldwell, 1979).

In an attempt to incorporate the socioeconomic, demographic and health factors into their child survival model, Mosley and Chen (1984) proposed that socioeconomic or background variables affected mortality through other more proximate determinants. These determinants, in turn, influenced factors such as birth weight and nutritional status of infants, which affected the risk of developing diseases and infections, and, finally, mortality. The proximate determinants are demographic, or more specifically maternal factors such as maternal age at birth, parity, breastfeeding, birth intervals, mothers' health and nutritional status; environmental contamination such as air, water and food contamination, which could be prevented by, for example, safe drinking water, sanitary toilets, personal hygiene, etc.; nutrient deficiencies; injuries; and personal health behavior and illness control (Mosley and Chen, 1984).

This model has been adopted and used by researchers. A number of studies on the relationship between background variables, especially maternal education, and other proximate variables in relation to infant mortality were carried out. Results from these studies, however, were varied and inconclusive and some of the results were even in conflict. Some studies found the significant effect of maternal education on child mortality independent of other variables (Mosley, 1984), while other studies found the effect of maternal education was attenuated by the availability and accessibility of health care services (Rozenzweig and Schultz, 1982). Nevertheless, another investigation found that the effect of maternal education was amplified by the presence of health care services in the area (Orubuloye and Caldwell, 1975). Others found the effect of maternal education was not affected by the access to health care services (Al-kabir, 1984), and Barbieri conducting her study in Senegal concluded that the effect of maternal education on child survival did not operate through differential health service utilization (Barbieri, 1990).

Park and his colleagues found the effect of maternal education on infant mortality was modified by birth interval (Park, 1986: Park, et al., 1994), but Cleland and van Ginneken, 1988, on the other hand, found the effects of demographic factors such as maternal age at giving birth, birth interval, and birth order of the index child were independent of maternal education (Cleland and van Ginneken, 1988). A small-scale study in Indonesia found that the specific knowledge about immunization schedules rather than formal education per se led mothers to ensure that their children received available vaccine (Streatifield, et al., 1990).

It was evident that the relationship between maternal education and other more proximate variables in relation to infant mortality varied from place to place. The theories and assumptions about the relationships between maternal education and other variables on child survival mentioned before have been challenged by the results of these empirical studies. It was speculated that these relationships may have been influenced by extraneous factors such as culture, tradition, beliefs, quality of health care services, etc., (Ware, 1984). Thus a country-specific study on the relationship between maternal education and other proximate variables in relation to infant mortality should be carried out rather than generalizing from the experiences of other countries.

6. Infant Mortality in Thailand

Thailand has experienced considerable decline in infant mortality in recent decades (Economic and Social Commission for Asia and Pacific, 1976). The infant mortality rates obtained from the first Survey of Population Change during 1964 to 1965 was 84.3/1,000 live births and from the Second Survey of Population Change during 1974 to 1976, 51.9/1,000 live births (National Research Council, 1980). An indirect estimate of infant mortality by using data on number of children ever born from 1970 Census and Second Survey of Population Change, confirmed that the infant mortality declined from more than 100/1,000 live births during the mid 1950s to less than 60/1,000 live births during the early 1980s (Knodel and Chamratrithirong, 1978). The infant mortality decline has also been accompanied by the increase in women's literacy rates, GNP per capita and health care service coverage (UNICEF, 1982-1992). The decline, however, has recently leveled off at a relatively high mortality level (Chamratrithirong and Pejaranonda, 1986).

Though infant mortality in Thailand has steadily declined since 1950, its differentials by socioeconomic and demographic factors were still substantial (Knodel and Chamratrithirong, 1978; Chamratrithirong and Pejaranonda, 1986).

Results from previous infant mortality studies in Thailand were generally similar to those found in other countries. Factors that have been found to have significant relationship with infant mortality are the birth order of the child

(Khanjanasthiti, 1986; Suwanaphong, 1988); the interaction between birth order and birth interval (Frenzen and Hogan, 1982; Tsuya, et al., 1993); previous child survivorship (Frenzen and Hogan, 1982; Suwanaphong, 1988; Park, et al., 1994); maternal age at birth (Kiranandana, 1979; Khanjanasthiti, 1986; Tsuya, et al., 1993); preceding birth intervals (Suwanaphnong, 1988; Park, et al., 1994); duration of breastfeeding (Suwanaphong, 1988; Tsuya, et al., 1993); sex of the child (Knodel and Chamratrithirong, 1978; Tsuya, et al., 1993); health care service utilization (Sirijiamrata, 1976; Boonkaew, 1985; Tsuya, et al., 1993; Bicego and Boerma, 1993); the use of flush or water-sealed toilet (Boonkaew, 1985); and sources of drinking water (Sirijiamrata, 1976).

Infant mortality differentials by geographic region and by rural and urban areas still existed. The north and northeast regions had higher infant mortality rates than other regions; while Bangkok had the lowest of all (Sirijiamrata, 1976; Knodel and Chamratrithirong, 1978; Kiranandana, 1979; Chamratrithirong, 1980; Vorapongsathorn, et al., 1986; Tsuya, et al., 1993). The infant mortality differentials by place of residence, however, decreased over the years (Sirijiamrata, 1976; Knodel and Chamratrithirong, 1978; Tsuya, et al., 1993). A recent study by Park, et al. (1994) did not find any significant effect of place of residence on infant mortality.

The effect of maternal education on infant mortality was evident in Thailand and, as has been found in most cases, the effect was stronger during the post-neonatal period (Knodel and Chamratrithirong, 1978; Chamratrithirong, 1980; Sirijiamrata, 1976; Vorapongsathorn, et al., 1986; Boonkaew, 1985; Chayovan, et al., 1987; Bicego and Boerma, 1993; Tsuya, et al., 1993). However, the attempt to find out how education affected mortality was still lacking. The relationships between maternal education and other proximate variables have not been thoroughly studied. Only a few studies have partially dealt with this aspect. Park and his colleagues found that the effect of maternal education on infant mortality was modified by preceding birth intervals (Park, et al., 1994).

An international comparison study on the relationship between maternal education and other variables has included Thailand in this study. Its objective was to find the effect of maternal education on infant mortality and the extent to which this effect was affected by other proximate variables. It was found that the effect of maternal education on infant mortality was confounded by the economic condition of the family. The education of mothers was also found to be related to the propensities to receive prenatal care and tetanus toxoid injection during pregnancy (Bicego and Boerma, 1993).

The number of educated women in Thailand has been increasing; health care service coverage has also increased. The life styles of most people have become proportionately more westernized. In such circumstances, it is interesting to investigate the role of maternal education in the survivorship of infants in greater detail. In order to create an efficient plan to reduce infant mortality in a country, health planners need to know not only how the effect of maternal education on infant mortality is affected by other variables, but also how maternal education affects the relationship between other more proximate variables and infant mortality as well. In so doing, an appropriate statistical method is needed. The following section will discuss statistical methods that have been used in the infant mortality studies.

7. Statistical Methods Used in Infant Mortality Studies

Until recently, the statistical methods that were often used in the analysis of the effects of explanatory variables on infant mortality were the linear regression and the logistic models. These methods of analysis use the probability of dying or the survival status before exact age one as the indicators of mortality, therefore the information on those who die soon after age one is not used and that information is wasted. In addition, the models assume that there is no difference between those who die right after birth and those who die close to age one which is likely to be a faulty assumption (Allison, 1982; Choe, 1983).

A statistical method that can estimate the effects of explanatory variables using all information from all individuals and taking the information on age at death into account is desirable (Choe, 1983). Such a statistical method has been proposed by D.R. Cox and the following section will discuss this particular method.

7.1 Cox's Proportional Hazards Model

In 1972, D.R. Cox proposed the Proportional Hazards Model which is viewed as a multivariate life table by incorporating the covariates of interest into the analysis. In ordinary life table analysis, it is assumed that the population is homogeneous, meaning that each sample member has the same underlying hazard function. In proportional hazard models, the hazard is not only a function of time, but also a function of specified predictor variables. Its main use is not to calculate life tables, but rather to assess the effects of the predictor variables on the hazard function, which is viewed as the response variable; and variables included in the model are the predictor variables. The underlying assumption for this model is that the covariates under study have multiplicative effects on the baseline hazard function. It does not assume any distribution form of the baseline hazard function. This model has many desired properties. They are:

1. The estimated effect of a covariate is positive for the entire domain of the covariate.

2. The effect of a covariate is monotonic. If β is the regression coefficient of the covariate, one unit increase in the covariate, holding

other covariates in the model constant, multiplies the hazard function by e^{β}. The quantity e^{β} is called a relative risk.

3. The vector of covariates can include any type of variables to adjust for confounding factors and to test for interaction among variables.

4. It is mathematically tractable (Walter and Holford, 1978) and a finite maximum likelihood estimate of β always exists; observed and expected information matrices are equal; and the Newton-Raphson iteration procedure usually produces rapid convergence even with large number of parameters.

5. The coefficients of covariates are easy to interpret.

Because of its desirable properties, the model has been used extensively.

Recently some researchers, however, have questioned the multiplicative assumption of this model. They have noted that though the proportional hazards model with multiplicative risk function is flexible and robust, it may not adequately fit some biological data (Greenland, 1979; Thomas, 1981; Buckley, 1984; Breslow and Storer, 1985). Thomas pointed out that many dose-response studies could not be expressed in terms of the multiplicative relative risk function even after the transformation of the exposure variables. With respect to public health intervention, the magnitude of the problem was lost when the multiplicative risk function, whose effect was interpreted as a relative risk, was used (Greenland, 1979; Thomas, 1981; Breslow, 1985). For example, mortality rates from lung cancer of non-smokers and smokers were, respectively, 0.01/1,000 person-years and 0.10/1,000 person-years had the same relative risk as mortality rates from coronary heart disease of 10/1,000 person-years and 100/1,000 person-years for those who had normal and high blood pressures, respectively. The severity of these two problems, however, were different. Thus, by using only relative risk, one could not tell the severity of the problem.

Another limitation of the multiplicative risk function was the assumption that the relationship among covariates was multiplicative, as such, the product variables could be used to test whether the interactions were greater or less than multiplicative; but the additive effect which might be the true effect could not be tested (Thomas, 1981; Prentice and Mason, 1986). It also provided poor fit to grouped data (Thomas, 1981).

Alternative risk functions for the proportional hazards model were introduced to replace the multiplicative risk function to suit the data. Among these risk functions, the additive or linear risk function had often been mentioned along with Cox's multiplicative Proportional Hazards Model (Dayal, 1980; Thomas, 1981; Buckley, 1984; Breslow and Storer, 1985; Saseini, 1992; Andersen, et al., 1993).

The following section will discuss the similarities and the differences between the proportional hazards models with the multiplicative and that with the additive risk functions.

7.2 Multiplicative and Additive Risk Functions

a. Multiplicative Risk Function

Basically, the coefficient of a covariate of any statistical model should have a meaning. The coefficient of an independent variable in the regression model, for example, means that by increasing one unit of the independent variable, the change of the value of the dependent variable is equal to the value of the coefficient of that independent variable. But the meaning of the coefficients of different models are not the same.

First, we look at the original model, the multiplicative risk function. As has been mentioned above, this model assumes that the covariates under study have multiplicative effects on the baseline hazard as well as on other covariates in the model. It has the functional form as follows:

$$\lambda(t;z) = \lambda_0(t)e^{\beta z} \tag{2.1}$$

where $\lambda(t;z)$ is the hazard or instantaneous death rate at time t for an individual with covariate z;

$\lambda_0(t)$ is an arbitrary unspecified base-line hazard function for individual with covariate $z = 0$.

β is an unknown regression coefficient associated with z.

The exponential of β coefficient, or the effect, of each covariate is interpreted as the relative risk in developing the response (disease or death, etc.) as compared to its reference category. For example, assuming that there is a dichotomous variable z which takes the values zero and one and its effect is to be estimated. This can be carried out by dividing both sides of the above equation by $\lambda_0(t)$

We will get

$$\frac{\lambda(t;z)}{\lambda_0(t)} = \frac{\lambda_0(t)e^{\beta z}}{\lambda_0(t)} = e^{\beta z} \tag{2.2}$$

which is the relative risk due to the covariate z.

b. Additive Risk Function

The model with additive risk function has the functional form as follows:

$$\lambda(t;Z) = \lambda_0(t)[1 + \beta Z] \tag{2.3}$$

where $\lambda_0(t)$, β, *and* Z are similarly defined as those in the model with multiplicative risk function.

This model, without the product terms among the individual exposure variables, presumes that the increment in relative risk as a function of one of the exposure level is additive and independent of the levels of the other exposures under consideration. Thus when measuring an individual effect of a covariate by taking the ratio between two nested models, the numerator and the denominator are not canceled out completely; only the base line hazard is. The individual coefficients of the covariates are interpreted as relative excess risk (RER) (Greenland, 1979; Dayal,1980). To estimate the effect of the dichotomous covariate z in the above example by using the additive risk function, $\lambda_0(t)$ is subtracted from both sides and we get:

$$\lambda(t;z_i)-\lambda_0(t) = \lambda_0(t)[\beta z] \tag{2.4}$$

Then divide both sides by $\lambda_0(t)$, we get:

$$RR(t;z) - 1 = \beta z \tag{2.5}$$

So that βz is interpreted as relative excess risk and the relative risk will be equal to:

$$RR(t;z) = 1 + \beta z \tag{2.6}$$

Researchers who preferred the additive function to the multiplicative function claimed that it had a better biological, as well as, public health implications, especially, for the dose-response type of study (Dayal, 1980;

Thomas, 1981; Buckley, 1984; Breslow and Storer, 1985; Saseini, 1992; Andersen, et al., 1993). It was also regarded as a natural scale in measuring the interactions for public health purposes (Rothman, Greenland, and Walker, 1980; Prentice and Mason, 1986).

Though the weaknesses of the multiplicative risk function were pointed out by many researchers (Thomas, 1981; Breslow and Storer, 1985), there was still a substantial number of those who preferred to use the multiplicative risk function because it was simpler; and because of its exponential form, the estimated hazard rates will always be positive, and the convergence is fast (Walter and Holdford, 1978; Prentice and Mason, 1986). It can take any type and any kind of covariates-dichotomous or continuous, fixed or time dependent (Walter and Holford, 1978; Thomas, 1981).

There were also some arguments over weaknesses of additive risk functions. In this model, the parameter estimates were problematic because the maximum likelihood estimate was not well developed (Walter and Holford, 1978), The estimates could be diverged or the convergence was slow, or it could give rise to negative risk estimates, especially, when the distribution of the covariate was skewed, no matter how carefully the coding of the covariates had been carried out (Walter and Holford, 1978; Thomas, 1981; Prentice and Mason, 1986; Saseini, 1992). Failure to converge was more common in the presence of censoring in the small sample size. Even if the parameters could be estimated, tests and confidence interval based on the asymptotic distribution of the coefficients may be substantially inaccurate (Prentice and Mason, 1986). Another problem with the additive risk function was that the number of covariates taken by the function were quite limited (McKeague, 1993). In addition, coefficients estimated from the additive risk function was more difficult to interpret and understand (Saseini, 1992).

The studies that were carried out to compare these two functions did not fully support their arguments because the differences among the estimates from these functions were slight and not statistically significant. The estimates fell within the confidence intervals of the observed values which obtained directly from the data. In addition, most of these studies were confined to the dose-response type (Thomas, 1981; Breslow and Storer, 1985).

The arguments over the choice between the multiplicative and additive risk functions are still inconclusive. Would there be any differences if these risk functions were tested with other types of data? Would both functions yield the same results? If not, how could we decide which one should be used. Since the choice of model influences the results, as well as, the relative importance of different covariates (Breslow and Storer, 1985), the selection of the model must be carried out carefully. Though it is not clear exactly how to choose the model, we should not make our decision based on our own convenience or attachment to a particular model (Walter and Holford, 1978).

Walter and Holford said:

> "...To admit only one model without a rational foundation is presumptuous, and constricts the otherwise healthy interplay of statistical and epidemiologic thought."

(Walter and Holford, 1978).

In summary, results from previous infant mortality studies showed that maternal education had significant effect on infant mortality in both developed and developing countries. There were only small number of studies that investigated the links between maternal education and other socioeconomic, demographic, environmental and health care factors in relation to infant mortality. Results from these studies, however, varied and inconclusive. It was speculated that the relationships between maternal education and these factors could be affected by the culture, tradition, and beliefs, as well as, the quantity and quality of health care services in that society. Due to these specific conditions, it is important to conduct a country-specific study rather than generalize from results in other settings. In order to arrive at unbiased results, an appropriate statistical model is needed. Therefore, the fits of the proportional hazards model with the multiplicative risk function and that with the additive risk function to infant mortality data will be compared. The model that fits the data better will be used in this study.

CHAPTER III

DATA AND METHODOLOGY

This chapter will present and discuss the conceptual framework, hypothesis to be tested, the data that were used in this study, the assumptions, precautions, data analysis, and limitation of the study.

The structure of this study has been formed by the results of previous studies on the effects of education on health behaviors and health related factors and the modification of the child survival model proposed by Mosley and Chen (1984).

1. Conceptual Framework

From the literature reviewed, education confers women knowledge, skills, and propensity to have better economic condition as follows:

1.1. Knowledge and Skills

Educated mothers are apparently less fatalistic about disease and death, are more knowledgeable about disease causation, prevention and treatment, and nutritional requirements of infants and children than their uneducated counterparts (Fosu, 1981; Cleland and van Ginneken, 1988). They are more willing to seek help from modern health care sectors and follow doctors' orders and instructions; and if the children are not improving, they are more likely to take them back for follow-up treatment (Caldwell, 1979).

1.2. Socio-Economic Betterment

Education provides women a wider social network and new reference groups and grants them the ability to deal better with the outside world and to request help from others, particularly government officials at health care service institutions (Caldwell, 1979).

Educated mothers have greater decision-making power on health related and other matters, and they are willing to reallocate more family resources to the young rather than to the old (Caldwell, 1979).

They are economically better off, for educated women tend to marry better educated and economically secure men. They can also get better paying jobs than their uneducated counterparts (Ware, 1984).

The factors mentioned above, in turn, affect well being and therefore, the survival status of the infants through the following mechanism:

a. Biological Effects

Parents of educated women have invested more in their children whom they sent to school. They have fed these children better food and kept them from hard work in the fields (Ware, 1984). As such, educated mothers are better nourished and less subjected to hard physical labor in their work than the uneducated ones and tend to deliver healthier infants. A mother's health and nutritional status influence the health and survivorship of the child because of the link between a mother and her fetus during pregnancy and between the mother and her infant during lactations (Mosley and Chen, 1984).

b. Behavioral Effects

Formal schooling exposes a girl to modernity or higher standards of living which would probably not be available at home. Such exposure affects her attitude on and comprehension of health messages that may inculcate new codes of behavior which persist into her adulthood and may improve the health of her children (Fosu, 1981).

1.3. Child Survival Model

The concept of child survival model developed by Mosley and Chen (1984) was applied to this study to investigate the relationship between maternal education and more proximate variables in relation to infant mortality. This model stated that all socioeconomic determinants, including maternal education, operate to affect infant mortality through the following proximate variables:

1. Demographic factors which included maternal age at giving birth,

birth order of the index child, and birth intervals.

2. Environmental contamination which referred to the transmission of infectious agents to mothers and children.

3. Nutrient deficiencies which related to the intake of three major classes of nutrients: calories, protein, and vitamins and minerals.

4. Injury which included physical injuries, burns, and poisoning.

5. Personal illness and control which encompassed individual preventive measures to avoid disease, both traditional and modern, and preferred medical treatment (Mosley and Chen, 1984).

A conceptual framework (Figure 3.1) represents the posited relationship among maternal education, other socioeconomic and proximate variables, and survival status of the child. The framework builds on the conceptual model of Mosley and Chen (1984) with modifications based on the empirical knowledge about the relationships between maternal education and health and health related behavior.

Because of the specific objectives of this study and the limitations and structure of the 1987 TDHS data, the conceptual model (Figure 3.2) for this study was modified from the above conceptual framework to suit the objectives and the data available.

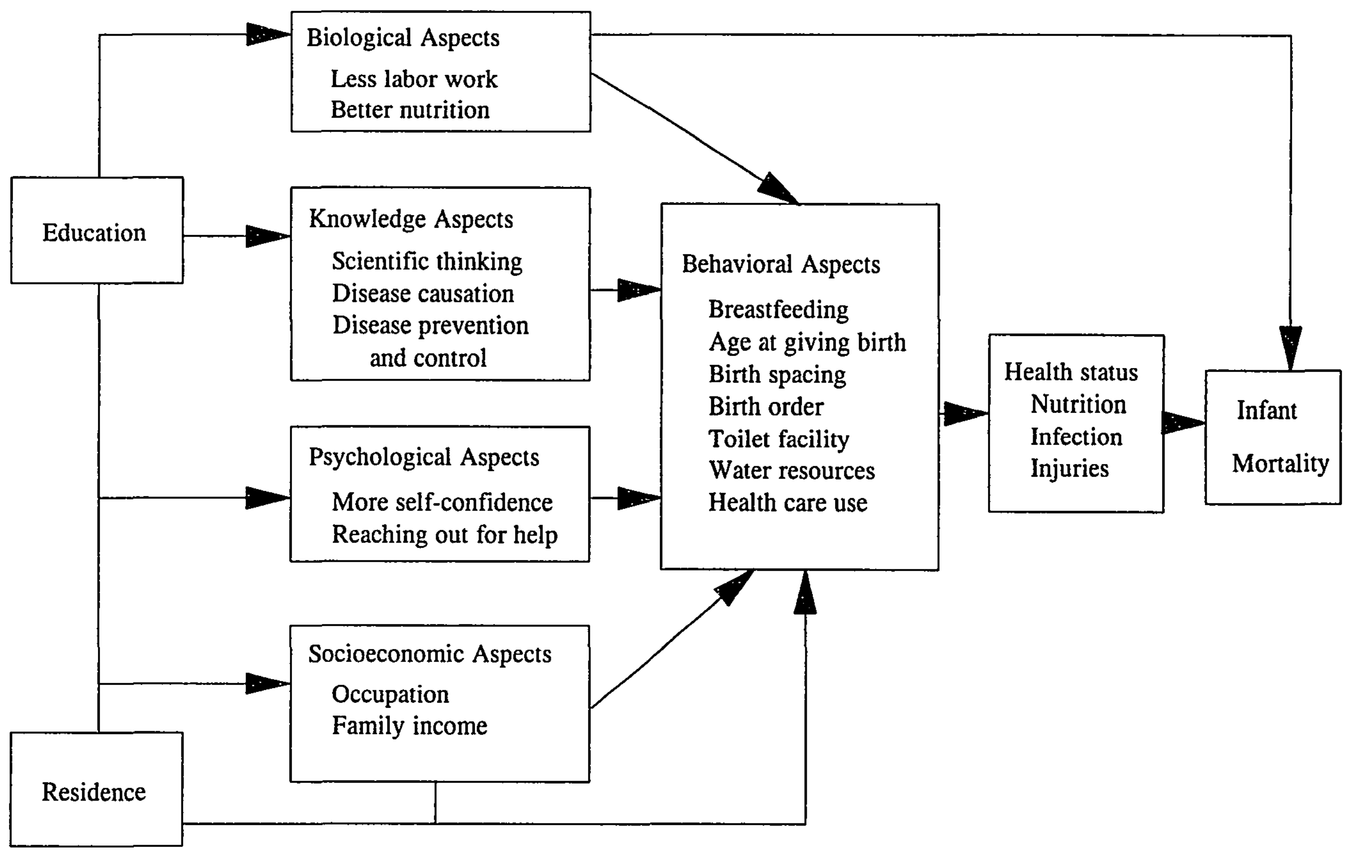

Figure 3.1 Conceptual Framework

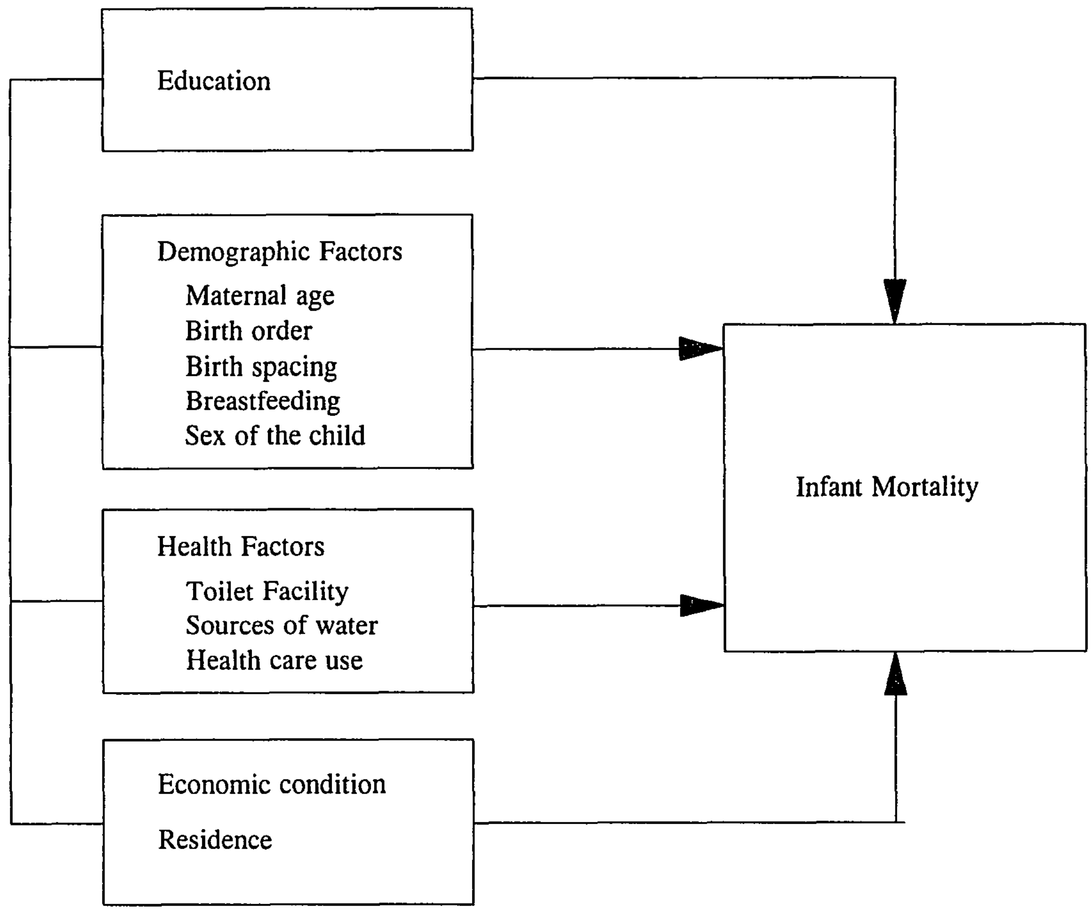

Figure 3.2 Conceptual Model

2. Hypotheses to be Tested

2.1. Demographic factors, such as mother's age at birth is younger than 20 years or 35 years and older, birth interval is shorter than 24 months, and duration of breastfeeding is less than six months, have negative effects on the survival of the child, all things being equal.

2.2. All other things being equal, the less frequent a mother used health care services, the higher the chance of infant death.

2.3. All other things being equal, infant mortality is higher if a sanitary toilet is not available within the residence.

2.4. All other things being equal, infant mortality is higher if the family drinking water is from an unsanitary source.

2.5. The lower the economic condition of the family, measured by the economic index which will be defined later, all other things being equal, the higher the infant mortality.

2.6. Infants born to mothers living in rural areas are at higher risk of mortality, all other things being equal.

2.7. Since maternal education has been assumed to be an important factor conferring women an autonomy and knowledge and skills in bringing up and taking care of their children, it is hypothesized that, all other things being equal, mothers with higher education will have significantly fewer infant deaths than those with lower education. The effect of maternal education will be stronger during the post-neonatal than the neonatal period.

2.8. From hypothesis number 2.7, it is thus hypothesized that the effects of other socio-economic, demographic and health care factors on infant mortality should be modified by the effect of maternal education. These factors include family economic condition, place of residence, maternal age at giving birth, birth order and birth interval, duration of breastfeeding, access to sanitary toilet facilities and safe water supplies, and health care utilization.

2.9. It has been shown that in the rural areas where health care services are not readily available or too distant, educated mothers will make more of an effort to get health care services (Rozenzweig and Shultz, 1982) or use their skills and knowledge to save their children's lives. Hence, it is hypothesized that in rural areas such as these, where living conditions are also more difficult, the effect of maternal education on infant mortality will be stronger than in the urban areas.

2.10. It is hypothesized that the effect of maternal education will be weaker among families with high economic condition than among those with low economic condition.

3. Data

Data used in this study were reported in the *1987 Thailand Demographic* *and Health Survey* which were cross sectional data collected through interviews by the Population Institute, Chulalongkorn University in collaboration with the Westinghouse Institute for Resource Development, USA. The interviews took place from March to June, 1987. The sample in this survey was designed to represent the whole country geographically. It covered the North, Northeast, Central (excluding Bangkok), and South regions. The sampling for Bangkok was done separately. The purposes of this survey were mainly to provide data on fertility and maternal and child health to program managers and policy-makers to facilitate evaluation and planning program, and to researchers in population and health to assist them in analyzing demographic and health situations.

3.1 Sampling Techniques

The sampling method employed for this data collection was a multi-stage stratified sampling design with probability proportional to population size (pps). The selection of samples from Bangkok, other urban areas, and rural areas had been done separately.

A specified number of sampled areas were selected systematically from geographically/administratively ordered lists. For areas selected, new lists of households were prepared, from which the sample households were systematically selected. The sampling intervals for the selection of households was determined so as to yield a self weighing sample of households within each domain (for more details, see Thailand Demographic and Health Survey 1987, Institute of Population Studies, Chulalongkorn University, Bangkok, Thailand, 1988).

The total number of sampled provinces was 65 out of a total of 73, 16 in the North, 15 in the Northeast, 21 in the Central, 12 in the South, and 1 in Bangkok. Data had been collected at three different levels:

1) Community level. Basic information on community characteristics and facilities in rural areas were collected from designated leaders and functionaries in the community with some supplementary information compiled from administrative and other sources. These data were not available for urban areas.

2) Household level. All individual household members, both regular residents and temporary visitors, were listed and basic demographics, such as age, sex, marital status, and educational information pertaining to each individual were collected from any adult regularly living in that household. Those residing in institutions or under other special arrangements outside private households and foreign households were excluded.

3) Individual level. Ever-married women age 15-49 in private households, on the basis of a de facto definition, were interviewed. Those aged under 15 were excluded. Information obtained at this level were:

a. Respondent's background

b. Reproductive history

c. Contraceptive knowledge and practices

d. Health and breastfeeding

e. Marriage

f. Fertility preference

g. Husband's background and wife's occupation

h. Heights and weights of children

The total number of households interviewed was 9,045 which was 97.5 percent of the units listed. Total number of ever-married woman aged 15-49 in this data set was 6,775. Information available from these data, besides community characteristics, socioeconomic and demographic information of the respondents and husbands, were pregnancy histories, which included, for each child, birth order, multiple birth status, year of birth, sex of the child, age at death, and preceding and succeeding birth intervals. For those who were born within five years before the survey, the additional information included place of delivery, birth attendant, prenatal care, tetanus toxoid injection, and breastfeeding duration.

3.2 Reliability of the Data

To investigate the reliability of the data, the percent distribution of ever-married women aged 15-49, sex ratio by five-year age groups, marital status, and educational level by age and sex, as well as current and cumulative fertility levels were compared with other data sources. These were data from NESDB projections, based on 1980 census for 1987; 1980 census; and SPC 1984.

There were some age group discrepancies among these data because the NESDB projections were based on higher fertility schedules and TDHS ages were reported ages while ages in SPC and the census were derived from birth dates whenever possible. Since ages stated by Thai people are frequently referred to age at next birthday rather than age at last birthday (Chamratrithirong, Debvalaya, and Knodel; 1978), some of the children were thus transferred from age 0-4 age group to the 5-9 age group and from 5-9 age group to 10-14 age group. For this reason and together with the higher fertility schedule of the NESDB projection, the proportions of the two youngest age groups of TDHS were lower than that of other data sources.

Results also showed that the TDHS had a slightly greater representation of the least and the most educated women.

The comparison of the fertility level with the data from CPS3 showed that the mean number of children ever born, estimated from TDHS, was lower than that of CPS3 and all other data sources for all age groups. There were three possible reasons underlying the relatively low estimates of the fertility level found in the TDHS. First, some women may have omitted actual births when relating their birth histories. Second, the assumption that never-married women had no births was not totally realistic. Third, there is indisputable evidence of a high level of contraceptive prevalence in Thailand during the last two decades, and all other data were collected at least three years prior to the TDHS survey taking place. As a result, the fertility schedule of 1987 TDHS was lower than the other (for more details see Thailand Demographic and Health Survey 1987).

Generally speaking, the accuracy of TDHS data was acceptable, therefore, usable for unbiased estimates of infant and child mortality.

3.3 Definitions of Variables

1) Infant mortality is defined as the death of children under one year of age, which is conventionally divided into two periods:

a. Neonatal period, death of a child age less than one month.

b. Post neonatal period, death of a child age one month to one year.

2) Maternal education (Mat Ed) is the number of years of formal schooling the mother has completed. This variable is not treated as dichotomous because the numbers of samples and infant deaths that fall in higher education categories are very small, which can affect the level

of significance of the covariate.

3) Place of residence (RES) is designated as:

RES = 0 for urban; 1 for rural

4) Sex of the child (SEX) is dichotomous variable:

SEX = 0 for females; 1 for males

5) Maternal age at birth (MACAT) is treated as a dichotomous variable:

MACAT = 0 for maternal ages 20 - 34 years; 1 for all others

6) Birth order and preceding birth interval are combined into one variable. This variable has three categories: 1) first birth order, 2) birth of order greater than one with a preceding birth interval shorter than 24 months, and 3) birth of order greater than one with a preceding birth interval of at least 24 months. Two dichotomous variables, BINT1 and BINT2, are created from this new variable with first birth order as the reference category for both variables. The combination of these two variables was performed in order to study the effect of preceding birth intervals without losing all first birth order cases which constituted over one-third of total number of sample in this study. In addition, it was found that infants of first order in Thailand had lower mortality than higher order (Tsuya, et al., 1993).

BINT1 = 1 for births of order higher than one with previous birth interval shorter than 24 months; 0 for all others.

BINT2 = 1 for births of order higher than one with previous birth interval of 24 months or longer; 0 for all others.

7) Breastfeeding (BF), the duration the index child has been breastfed, is a dichotomous variable which is treated as a time dependent. This variable is defined as:

BF = 1 for breastfeeding of duration equal to or longer than six months, or in the case of a child deceased before six months, but breastfeeding until death or breastfeeding cessation stopped less than one month before the child died; 0 for all others.

8) In order to test whether the effect of duration of breastfeeding on infant mortality depended on time, the variable BFT has been created by multiplying the variable BF with time.

BFT = BF x t.

Given the coefficient of BF is β_{11} and that of BFT is β_{12}, by changing the value of BF from 0 to 1, the effect of breastfeeding on infant mortality at time t is $e^{\beta_{11} + \beta_{12} t}$.

9) The availability of a proper toilet facility to the household is SAN. The original value for this variable is multinomial and a new dichotomous variable has been created:

SAN = 0 if the household had access to a flush or septic tank toilet; 1 for all others.

10) Sources of drinking water is WATER. The original value for this variable is multinomial and a new dichotomous variable has been created:

WATER = 0 if the family's sources of drinking water are from piped water connected into the residence or from a public tap; 1 for all others.

11) The score of health care utilization (HCU) has been created by combining dichotomous variables for prenatal care, birth attendant, place of delivery, and tetanus toxoid injection. Score of 1 each is assigned to those who received prenatal care from doctors or trained nurses; those who had doctors or trained nurses attending their deliveries, those who gave birth in hospitals, private clinics or health center; and those who

received tetanus injections during their pregnancies. The score of 0 is assigned to all others.

The score ranges from zero to 4, and a dichotomous variable named HEALTH was created:

HEALTH = 1 if total score for health care utilization was three or less; 0 for all others.

12) The family economic condition scores (ECONTOT) has been created by combining the scores assigned to items owned by the family as follows:

A family that owns a flush toilet, has electricity in the house, owns a radio or a television set is assigned a score of 1 for each item, and 0 if it does not.

A family that owns a refrigerator or a motorcycle is assigned a score of 2 for each item and 0 if not.

A family that owns a car is assigned score of 3 and 0 if it does not.

The score for the family economic condition ranges from 0 to 11, and a dichotomous variable ECON was created:

ECON = 1 if economic score was less than 5; 0 for all others.

4. Assumptions

4.1. It is assumed that the accuracy of this data set is acceptable.

4.2. All information including sanitation factors are applicable to the index child.

4.3. All independent factors, except duration of breastfeeding, have the same effects on mortality throughout the period.

4.4. The effect of breastfeeding on child survival varies according to age of the child.

4.5. The quality of health care services are the same in both rural and urban areas.

5. Precaution

Because the survey data were obtained by interviewing women of child bearing ages, 15-49 years, one has to keep in mind that:

5.1. Those who were born to women in the ages 49 years and older at the time of the survey are not considered. Thus, only births to younger women are included in the earlier period. Since maternal age is an important determinant of infant mortality, this truncation can result in biases in estimating past infant mortality.

5.2. The survey asked for information concerning past events, for example, pregnancy history, so the information may have recall bias.

5.3. The survey is cross-sectional and some information may not be applicable to children who were born in the past, for example, toilet facility or sources of water.

6. Data Analysis

Units of analysis were single live births born within five years prior to the survey. Because of the inclusion of preceding birth intervals, breastfeeding duration, health care services utilized at the place of delivery, birth attendant, prenatal care, and tetanus toxoid injection during pregnancy, the units of analysis were restricted to births within five years prior to the survey. The number of children included in the analysis was 3,647. The number of children age one to five years who died was only 13 out of 3,595, and unfortunately, analysis of these children was not performed.

6.1 Statistical Model

The statistical method used in the analysis of this study was the proportional hazards model, proposed by D.R.Cox in 1972. The underlying assumptions for the proportional hazards model were that the covariates under study have multiplicative effects on the baseline hazards function and the effects were constant throughout the period of study.

The hazard function is defined as the probability that an individual fails in the very small time interval Δt, given that this individual survived at the beginning of time t, or

$$\lambda(t) = \lim_{\Delta t \to 0} \{\frac{prob(t \leq T < t + \Delta t | T > t)}{\Delta t}\} \tag{3.1}$$

Where $\lambda(t)$ is the hazard or the instantaneous death rate at t.

T is the random variable indicating age at death.

The above equation can be expressed in the following form:

$$\lambda(t) = \frac{f(t)}{1-F(t)} \tag{3.2}$$

where f(t) is the probability density for T,

F(t) is the cumulative distribution function for T.

In order to assess the relation between the distribution of failure time and covariates of interest, the model is constructed as follows:

$$\lambda(t;z) = \lambda_0(t)r(\beta Z) \tag{3.3}$$

where β is a p x 1 vector of unknown parameters;

Z is a p x 1 vector of covariates;

$\lambda_0(t)$ is an unknown baseline hazard function for the set of Z=0;

$r(\beta,z)$ is the risk function which is equal to

a. $e^{\beta z}$ for the multiplicative risk function,

b. $1 + \beta z$ for the additive risk function.

The controversy about the advantages and disadvantages of the above risk functions was discussed in the previous chapter, and no conclusion could be drawn.

The proportional hazards models with the multiplicative and the additive risk functions would be compared. The one that fit the infant mortality data better in *1987 Thailand Demographic and Health Survey* would be used in the study of the relationships between maternal education and other independent variables in relation to infant mortality. The comparison of these two risk functions will be discussed in the following section:

6.2 Comparison Between Multiplicative and Additive Risk Functions

The comparisons were carried out for both the univariate and the multivariate analyses as follows:

a. The univariate analyses of all variables under study except breastfeeding, which was a time dependent variable, were carried out by applying both proportional hazards models, the multiplicative and the additive risk functions. The coefficients of each variable estimated from these models were examined with respect to their size, standard errors, and levels of significance. The estimated relative risks associated with each variable estimated from both risk functions were then compared to the observed values which were estimated directly from the data as follows:

$$RR_i = \frac{R_i}{R_0} \tag{3.4}$$

where RR_i = Relative risk associated to risk factor i

R_i = Infant mortality rate among those who are exposed to risk factor i

R_0 = Infant mortality rate among those who were not exposed to risk factor i.

b. The multivariate analyses. The demographic covariates (maternal age at birth, sex of the child, and birth order and birth intervals), the background covariates (place of residence, maternal education, and family economic condition) were fitted by these two proportional hazards models.

The comparison between the two risk functions was made in the following manners:

1. Comparison of the observed against the expected relative risk estimated from both forms of the proportional hazards models. Ninety five

percent confidence intervals of the observed relative risks were used to examine the deviations of the estimated from the observed ones.

2. Goodness-of-fit statistics of each model was estimated by comparing the number of observed to the number of expected deaths predicted by each risk function.

Estimation of the number of deaths is obtained by the method proposed by Moreau, O'Quigley and Mesbah (1985). For this method, the coefficients of parameters were allowed to vary with time but are held constant within predefined intervals. To estimate the number of deaths from the model, the data for both the exposed group which is referred to as group I and the non-exposed which is referred to as group II are organized in r distinct time intervals. Each of these intervals has k survival times; and t_j, $j=1,\ldots,k_j$, are the distinct survival times at t_j interval. The Goodness-of-fit statistics is defined as follows:

$$\chi^2_{[(r-1)p]} = \sum_{j=1}^{r} [\frac{(O_{1j}-E_{1j})^2}{E_{1j}} + \frac{(O_{2j}-E_{2j})^2}{E_{2j}}] \tag{3.5}$$

where p is the number of parameters estimated,

j is the number of time intervals, $j=1,\ldots,r$

O_{1j} and O_{2j} are the number of observed deaths in interval j,

E_{1j} and E_{2j} are the number of expected deaths for the exposed (group I) and the non-exposed (group II), respectively, in the t_j interval. The expected number of deaths in each group is conditional upon risk sets and is estimated by:

$$E_{1j} = \sum_{i=1}^{k_j} e_{ij} \text{ and } E_{2j} = \sum_{i=1}^{k_j} (1-e_{ij}) \tag{3.6}$$

$$\text{where } e_{ij} = \frac{n_{1ij} e^{\hat{\beta}}}{n_{2ij}+n_{1ij} e^{\hat{\beta}}} \tag{3.7}$$

n_{1j} and n_{2j} are the number of subjects at risk in the two groups at t_j. $\hat{\beta}$ is the coefficient estimated. For the additive risk function e^{β} was replaced by $1 + \beta$.

When ties are present:

$$E_{1j} = \sum_{j=1}^{k} m_j e_j \quad \text{and} \quad E_{2j} = \sum_{j=1}^{k} m_j (1-e_j) \tag{3.8}$$

where m_j is the number of deaths in both groups at t_j.

In this study the effects of covariates included in the comparisons were assumed to be constant during the first year of life; the estimation of number of deaths was, therefore, modified as follows:

The data have been classified into multi-dimensional contingency tables and reorganized into two groups such that the data for each combination of risk factors in the model could be paired together, and the total number of deaths for each pair could be obtained. The number of deaths for each cell could then be estimated by applying Moreau's method. For the model with two dichotomous risk factors, A and B, which took the values of zero and one, for example, there would be four groups of the samples--exposed to none of these factors, exposed to factor A only, exposed to factor B only, exposed to both factors. These groups were matched into pairs. In this example the two pairs could be matched in either way as follows:

1. $\bar{A}\bar{B}$ versus $A\bar{B}$ and AB versus $\bar{A}B$ or

2. $\bar{A}\bar{B}$ versus $\bar{A}B$ and AB versus $A\bar{B}$

Given that A = being exposed to A

$\bar{A}$ = not being exposed to A

B = being exposed to B

$\bar{B}$ = not being exposed to B

The pairs could be any other combinations of these two risk factors, as long as there was no repetition of the data.

The number of deaths was estimated for each pair separately by applying the method of Moreau, et al., (1984) as follows:

$$\chi^2_{(r-p)} = \sum_{j=1}^{r} [\frac{(O_{1j}-E_{1j})^2}{E_{1j}} + \frac{(O_{2j}-E_{2j})^2}{E_{2j}}] \tag{3.9}$$

where j is the number of pairs, $j=1,\ldots,r$

O_{1j} and O_{2j} are the number of observed deaths for group I and II, respectively, for the j^{th} pair.

E_{1j} and E_{2j} are the number of expected deaths for group I and II, respectively, for the j^{th} pair.

p is the number of parameters estimated.

The expected number of deaths in each group is conditional upon risk sets and is estimated by:

$$E_{1j} = e_j \textit{ and } E_{2j} = 1-e_j \tag{3.10}$$

Where

$$e_j = \frac{n_{1j}e^{\sum \hat{\beta}_{1j}z_{1j}}}{n_{2j}e^{\sum \hat{\beta}_{2j}z_{2j}}+n_{1j}e^{\sum \hat{\beta}_{1j}z_{1j}}} \tag{3.11}$$

n_{1j} and n_{2j} are the number of subjects at risk in the two groups for the j^{th} pair. Z_{1j} is the set of risk factors associated with β_{1j} experienced by the members of group I of the j_{th} pair. Z_{2j} is the set of risk factors associated with β_{2j}

experienced by the members of group II of the j_{th} pair. For the additive risk function $e^{\beta z}$ was replaced by $1 + \beta z$.

When ties are present:

$$E_{1j} = m_j e_j \quad and \quad E_{2j} = m_j(1-e_j) \tag{3.12}$$

where m_j is the number of deaths in both groups for the j^{th} pair.

Criteria in Comparison of the Risk Functions

A risk function was considered to fit the data better than the other if:

1. The expected relative risks fell within 95% confidence intervals of the observed ones. If these estimates from both risk functions were all within 95% confidence interval, the magnitudes of the deviations of the expected relative risks from the observed ones would be taken into account. The one with smaller deviations was considered as "better" than the other.

2. The chi-square estimated from goodness of fit for the same set of covariates was smaller.

6.3. Relationships between Maternal Education and other Covariates in Relation to Infant Mortality

Eight nested models were tested to determine the contributions of the covariate or the group of covariates to infant mortality and the relationship between maternal education and other covariates in relation to infant mortality.

Model 1: IMR = f(Macat,Bint1,Bint2,Sex,BF,BFT)

Model 2: IMR = f(Mat Ed,Macat,Bint1,Bint2,Sex,BF,BFT)

Model 3: IMR = f(San,Water,Health)

Model 4: IMR = f(Mat Ed,San,Water,Health)

Model 5: IMR = f(Res,Econ)

Model 6: IMR = f(Mat Ed,Res,Econ)

Model 7: IMR = f(Res,Econ,Macat,Bint1,Bint2,Sex,BF,BFT,San,Water,Health)

Model 8: IMR = f(Mat Ed,Res,Econ,Macat,Bint1,Bint2,Sex,BF,BFT,San,Water,Health)

These four pairs of nested models were examined to determined the relationship between maternal education and other covariates in each group, as well as the possible spurious association between maternal education and a particular covariate, caused by the correlation between education and other covariates under study.

To investigate the modifying effect of maternal education on other socioeconomic, demographic, environmental and health care factors, maternal education is categorized into two groups: four years or less and more than four years. Full model (Model 8) was reanalyzed by replacing the continuous education variable by the categorized education variable. The interaction between dichotomized education and family economic condition, place of residence, maternal age at birth, Bint1, Bint2, sex of the child, sources of drinking water, and health care service utilization were also incorporated into the new model. The differences between cross-classified categories of each interaction term were then tested for significance by using Z-test.

The analyses of the full model (Model 8) were also stratified by place of residence, and by family economic condition.

The computer statistical software used in this analysis were BMDP2L for survival analysis and BMDP4F for simple crosstabulations; and SPSS-X for creating individual child files and for r x c crosstabulations in case of either r or c has more than 10 categories which could not be handled by BMDP4F.

7. Limitations of the Study

7.1. The Thailand Demographic and Health Survey, 1987 is a cross-sectional survey data with pregnancy histories. Some of the information may not be applicable to the index child, such as toilet facilities, place of residence and sources of drinking water. There may be problems of recall bias or under-reporting of deaths during the first year of life, particularly for neonatal deaths.

7.2. The quality of some information from these data is questionable, particularly environmental and health care factors. Even the questions in the questionnaire could be misleading. For example, one of the choices for the questions about sources of drinking water is "bottled water". This could mean purified water or water that respondents store in the bottle. These two answers are totally different. If the interviewers did not clarify the question to the respondents, the answers might not be accurate. Another example is prenatal care. The question concerns only the quantity, not the quality of the services. If the respondent had made only one visit to the prenatal care clinic, even in the last month of her pregnancy, she was considered to have prenatal care. This could bias the result of the study.

7.3. Some information that is needed to understand more about the role of maternal education on infant mortality such as knowledge about disease causation, prevention and control, birth weights, maternal nutritional status, causes of death, etc., is not available in this data. Therefore, the study is limited by the information available.

CHAPTER IV

CHARACTERISTICS OF THE SAMPLE

This chapter will present the characteristics of the study sample and infant mortality rates associated with these characteristics from univariate analysis. The infant mortality rates for these characteristics, controlling for maternal education categories and for place of residence are also presented.

The number of births included in the analysis was 3,647. All children in the analysis were single live births whose ages were five years or younger at the time of the survey. Due to the very small number of deaths of children one to five years of age, the multivariate analysis on child mortality was not performed.

1. Characteristics of the Sample

Thailand has been divided into four major geographic regions with each different in terms of climate, geography, cultural and socioeconomic context. In addition, Bangkok, although located centrally, was designated a separate region because of its unique characteristics. It is the most economically prosperous and has the greatest number of facilities and services. In contrast, a sizable proportion of its population are migrants from rural areas who contribute to environmental problems by exacerbating unsanitary living conditions in the slums and urban fringe. The northeast, the plateau region, is well known for its drought and is economically the poorest. With respect to the social and cultural context, the south has the most distinctive characteristics, particularly in terms of languages and religion. It has the largest proportion of Moslem people in the country. Unlike other regions of the country, its dialects are very different from the standard Thai language. This often causes conflicts between government officials, who are non-locals, and local people. The main employment in the south is on rubber plantations and associated businesses. The north is the mountainous area, the second poorest in the country. Agriculture is its mainstay, similar to the central plain. The following sections will present the characteristics of the sample in this study in detail.

Tables 4.1, 4.2 and 4.3 present the percentages of the sample by socioeconomic, demographic and environmental and health factors, respectively. Table 4.4 shows the average values of ages at birth, birth intervals, lengths of breastfeeding, maternal education, number children ever born, economic scores and health care utilization scores by geographic region, place of residence, and maternal education categories. Table 4.5 shows infant, neonatal, post neonatal and child mortality by different characteristics of the sample. Table 4.6 presents the distribution and infant mortality by socioeconomic, demographic and environmental and health care factors by maternal education categories. Table 4.7 shows the distribution and infant mortality by socioeconomic, demographic and environmental and health care factors by place of residence.

1.1. Geographical Regions and Place of Residence

Table 4.1 illustrates some of the characteristics of the sample under the study, and table 4.6 shows infant mortality by category of these characteristics. The sample was distributed by geographical regions as 18.5%, 20.3%, 20.0%, 23.2%, and 18.0% for the north, northeast, central, south, and Bangkok, respectively. Compared to the distribution of the female population from the Registrar's Office which showed 19.5%, 35.0%, 22.6%, 12.5%, and 10.5% for the respective regions, the proportions of females in this study were higher for Bangkok and the south, but lower for the northeast (Ministry of Public Health, Thailand, 1989). Since the whole Bangkok area is considered urban, the proportion of urban areas in this study was higher than that listed in the National Vital Registration. About 33% of the sample lived in urban areas, whereas the number from the National Vital Registration showed about 20% of the population in Thailand living in urban areas (Ministry of Public Health, 1990).

1.2. Parental Education

Because of the over-representation of samples from Bangkok, the average number of years of school attendance for this sample was 5.6 years, with only 8% of mothers having no formal education. The percentage of mothers with no education was only about half of that obtained from the Survey of Population Change in 1984 (National Statistical Office, 1984). The majority of the mothers had primary education (74%). About 18% of them had education higher than primary level. Those living in urban areas had higher levels of average years of education (7.9 years for urban and 4.6 years for rural). The level of maternal education was also different by geographical regions. Mothers in the north region had the lowest average years of education (5.12 years), while mothers in Bangkok had the highest (7.5 years), with those in the northeast, central, and south region falling in between with similar educational levels. This reflected the fact that Bangkok offered better educational opportunities to its residents as well as the fact that highly educated people in rural areas tended to migrate to Bangkok to find a better job.

It is interesting to note that although 92% of these women had a formal education, higher than in many other developing countries (Martin, et al., 1983), about 40% of them either could not read or had difficulty reading (Tables 4.1 and 4.4).

Fathers, on the average, seemed to have better education than mothers.

The proportion of fathers with no education was 4%, about half that of the mothers, and 27% had secondary or higher education. Very few mothers with higher education were married to fathers who had no education (Table 4.6). This supports the concept that women with high education tended to marry men with similar or higher educational levels. In urban areas, 51% of the fathers had secondary or higher educational levels while the level for those living in rural areas was 16% (Table 4.7).

1.3. Family Economic Condition

Sixty three percent of the children were born to families classified as low economic condition (Table 4.1). The proportions of high and low economic classes were substantially different in urban and rural areas. Sixty two percent of the children in urban areas were born to the families in the high economic class, while only 24% of the children in rural areas were; and the average economic scores for urban and rural areas were 5.30 and 2.97, respectively. Bangkok, which was the center of business and more affluent than other regions, had the highest economic score (5.14), while the northeast region, known for its poverty, had the lowest one (2.56). Mothers with education higher than the secondary level had an average economic score of 7.68, and it was 2.21 for mothers with no education (Table 4.4). It is obvious that maternal education had a strong relationship with the family's economic condition, supporting the assumption that maternal education was a good indicator of family economic level (Tables 4.1, 4.4, 4.6, 4.7).

1.4. Maternal Age at Birth

About 77% of the mothers in this sample gave birth to their children between the ages of 20 and 34, and the average age at birth was 25.9 years. The average age at birth for mothers with lowest and highest education were similar, 28.4 and 28.5 years, respectively; and those with primary and secondary education were similar, 25.7 and 24.4 years, respectively (Table 4.4).

1.5. Birth Order

Over one-third of the children were first order births (Table 4.2), and the average number of children ever born per woman was inversely related to mothers' educational levels: 3.96, 2.69, 1.84, and 1.76 for mothers with no formal education, primary education, secondary education, and education higher than secondary, respectively, with the overall average of 2.6. Mothers in the south region had the highest average number of children ever born (3.27), while mothers in Bangkok had the lowest (2.18). This was probably due to the fact that most mothers in the south were Moslems, who had higher fertility than the others, and it was consistent with the fact that the proportion of married

Table 4.1 Characteristics of the Sample: Socioeconomic Factors. Thailand Demographic and Health Survey 1982-1987

CHARACTERISTICS	PERCENT
Geographic Region	
North	18.51
Northeast	20.26
Central	20.02
South	23.20
Bangkok	18.01
Residence	
Urban	33.37
Rural	66.63
Mother's Education	
No education	8.00
Primary	73.70
Secondary	12.00
Higher	6.30
Father's Education	
No education	4.10
Primary	68.10
Secondary	19.60
Higher	8.20
Mother's Education	
Reads easily	59.56
Reads W/Difficulty	29.01
Cannot read	11.43
Economic Status	
Low	63.04
High	36.96

Table 4.2 Characteristics of the Sample: Demographic Factors. Thailand Demographic and Health Survey 1982-1987

CHARACTERISTICS	PERCENT
RELIGION	
Buddhist	87.60
Islam	10.40
Christian	1.20
Other	0.60
Don't know	0.20
MARITAL STATUS	
Married	96.20
Widowed	0.80
Divorced	0.60
Not live together	2.40
MATERNAL AGE	
Less than 20 years	13.90
20 - 34 years	76.60
Over 34 years	9.50
PREVIOUS INTERVAL	
< 24 months	24.60
=> 24 months	75.40
SEX OF THE CHILD	
Male	51.50
Female	48.50
BIRTH ORDER	
First Order	37.24
Higher Order	62.76
BREASTFEEDING	
< 6 months	37.30
=> 6 months	62.70

Table 4.3 Characteristics of the Sample: Environmental and Health Factors.
Thailand Demographic and Health Survey 1982-1987

CHARACTERISTICS	PERCENT
TOILET	
No facility	33.70
Flush Toilet	3.51
Septic Tank	59.80
Pit	2.96
DRINKING WATER	
Piped water	24.60
Bottled water	5.26
Public tap	1.10
Private well	18.84
Public well	17.77
River spring	3.32
Tanker truck	1.15
Rain water	18.67
Other	0.25
Neighbor's well	8.45
Neighbor's pipe	0.69
PRENATAL CARE	
None	18.10
Doctor	53.80
Trained Nurse	27.30
Trad.Birth attend.	0.80
Relatives	0.10
TETANUS INJECTION	
No	33.40
Yes	66.60

Table 4.3 Characteristics of the Sample: Environmental and Health Factors.
Thailand Demographic and Health Survey 1982-1987
(Continued)

CHARACTERISTICS	PERCENT
PLACE OF DELIVERY	
Govt. hospital	53.70
Private hospital	5.10
Health center	7.90
Private clinic	3.20
Home	29.10
Other	0.90
BIRTH ATTENDANT	
None	0.90
Doctor	51.80
Trained nurse	22.60
Birth attendant	20.10
Relatives	4.10
Other	0.50
HEALTH CARE UTILIZATION	
Less frequent	46.75
More frequent	53.25

women aged 15 - 44 years who practiced contraception was lowest in the south (Institute of Population Studies, Chulalongkorn University, 1989). The number was slightly different between urban (2.18) and rural (2.86) areas (Table 4.4).

1.6. Birth Intervals

The intervals between the births of the preceding child and the index child, ranged from 7 months to 20 years, with the average for the whole samples at 45.5 months. This was a very long average birth interval. Surprisingly, the higher the education a mother had, the shorter was the birth interval. The average length of birth intervals for mothers with no formal education and for those with primary education was 46.5 months and 46.2 months, respectively; and for mothers with secondary education and for those with higher education was 40.4 months and 41.9 months, respectively. This could be due to the fact that mothers with higher education started having children at older ages and planned to stop having children earlier, thus shortening the birth intervals. Another possible explanation was the under-reporting of abortion, miscarriages, stillbirths, etc. among mothers with low education.

1.7. Breastfeeding

As in many other developing countries, the reported duration of breastfeeding was heaping at ages 12, 18 and 24 months (Figure 4.1). The average duration of breastfeeding was 10.8 months and varied with the levels of maternal education. The higher the education of the mother, the shorter the duration of breastfeeding. The average length of breastfeeding for mothers with no education was the same as those with primary education (12.1 months); while those of mothers with secondary and higher than secondary education were 5.6 and 4.1 months, respectively (Table 4.4). This was consistent with previous studies which found maternal education having an inverse relationship with the duration of breastfeeding (Knodel and Debvalaya, 1980; Retherford et al., 1987).

The duration was also different by geographical regions and by place of residence. Mothers in the northeast region had the longest duration of breastfeeding (14.63 months) while Bangkok had the lowest (6.72 months). Mothers in urban areas breastfed their children substantially shorter periods than those in rural areas. The average duration of breastfeeding for mothers in urban areas was 7.01 months, while it was 12.72 months for those in rural areas. This may be attributed to mother's education, occupation, and lifestyles in urban areas that stopped breastfeeding sooner (Table 4.4). Sixty two percent of the children were breastfed at least six months or were breastfed up to one month before they died, in case the children died before six months of age (Table 4.2).

This finding was lower than that reported in the 1985 Survey of Fertility in Thailand which revealed that the average duration of breastfeeding was 12.9 months; 13.4 months for those with primary education, 9.2 months for those with secondary education and 5.2 months for those with higher education (National Statistical Office, 1985).

This study did not smooth the heaping of duration of breastfeeding for two reasons. First, it is common practice for most mothers in Thailand to wean their children at ages of multiples of six months such as six, twelve, and 18 months (Knodel and Debvalaya, 1980). This trend could, therefore, be real. Second, in the multivariate analysis, breastfeeding is treated as dichotomous variable with the cut off point of six months, thus the heaping will not affect the analysis.

1.8. Toilet Facilities

About 63.3% of the children were born into households with hygienic toilets, flush or septic tanks (Table 4.3). Fifty three percent of mothers with education less than secondary level lived in houses with sanitary toilets, compared to 88% of those with secondary education or higher (Table 4.6). The proportion also varied with place of residence. Ninety four percent of people in urban areas lived in the households with sanitary toilets, while only 48% of people in the rural areas had such facilities (Table 4.7).

Table 4.4 The Average Values of Some Characteristics of the Sample by Geographic Regions, Place of Residence, and Maternal Education Infant Mortality in Thailand, 1982 - 1987

Variables	Age at Giving Birth (Years)	Birth Interval (Months)	Length Breastfeeding (Months)	Mother's Education (Years)	Children Ever born	Econom ic Score	Health Score
Region							
North	25.29	55.39	10.31	5.12	2.28	3.61	2.94
Northeast	25.72	43.47	14.63	5.22	2.72	2.56	2.61
Central	25.96	44.32	9.99	5.34	2.54	4.13	3.21
South	26.57	41.54	11.77	5.35	3.27	3.48	2.47
Bangkok	25.77	45.96	6.72	7.50	2.18	5.14	3.49
Residence							
Urban	25.67	45.38	7.01	7.86	2.18	5.30	3.53
Rural	26.01	45.56	12.72	4.57	2.86	2.97	2.61
Mother Education							
No education	28.44	46.53	12.05		3.96	2.21	1.98
Primary	25.65	46.17	12.12		2.69	3.16	2.83
Secondary	24.37	40.39	5.57		1.84	6.33	3.61
Higher	28.46	41.89	4.07		1.76	7.68	3.66

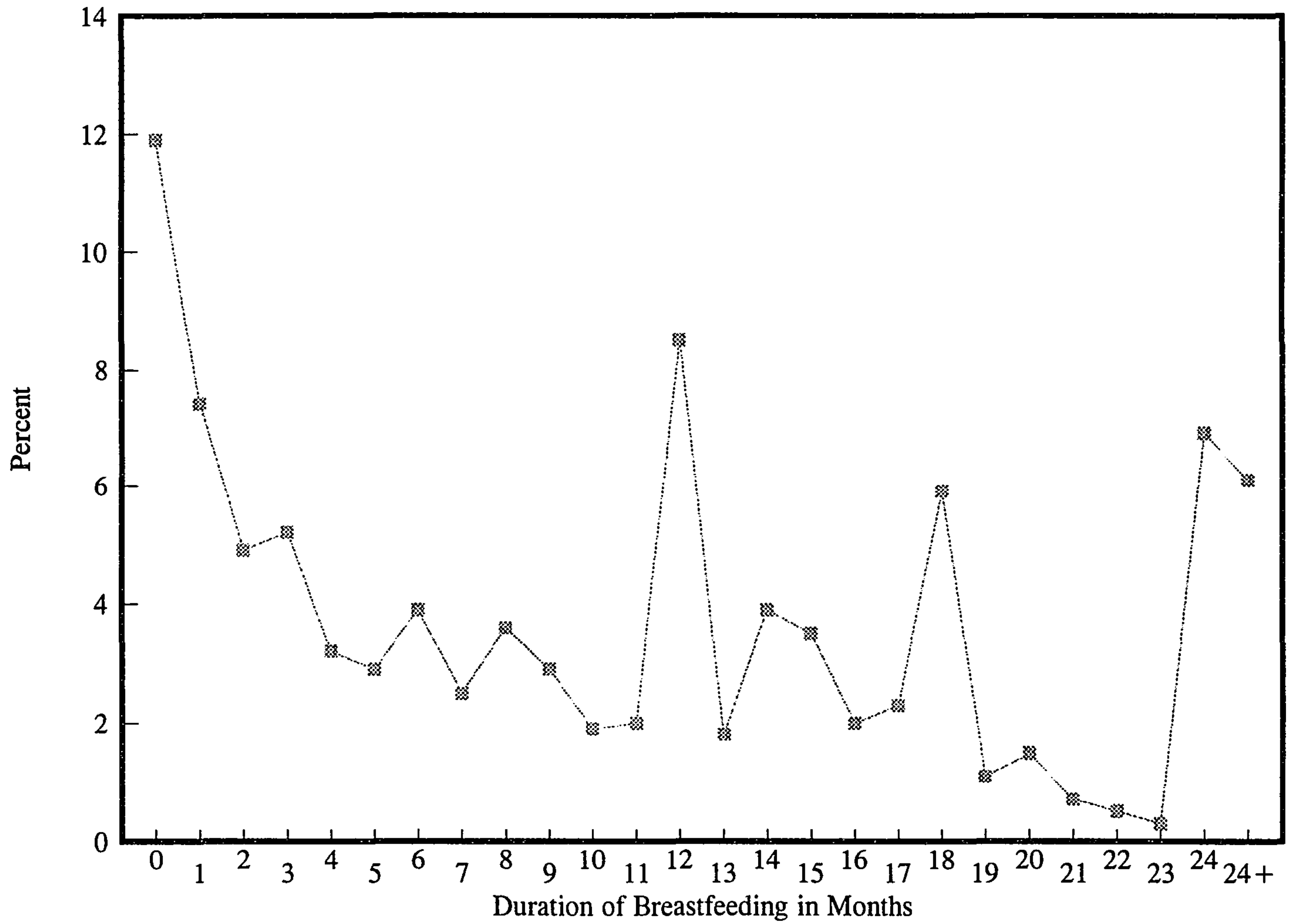

Figure 4.1 Reported Duration of Breastfeeding in Months

1.9. Sources of Drinking Water

Twenty six percent of the sample had an access to safe drinking water, piped water connected into households or water from public tap (Table 4.3). Ninety five percent of mothers with at least secondary education had access to safe drinking water, while only 19% of mothers with low education did (Table 4.6). Sixty percent of mothers in urban areas could get drinking water from proper sources, while only 9% of those in rural areas could do so (Table 4.7).

1.10. Health Care Utilization

Eighty one percent of mothers received prenatal care from medical doctors or nurses during pregnancy, but only 67% of them received tetanus toxoid. Seventy four percent of the children were delivered by qualified personnel, doctors and nurses; and 70% of them were delivered in the hospitals, private clinics, or at health centers. The single index of health care utilization showed that 53% of these mothers often use health care services (Table 4.3). Health care utilization also varied with place of residence and the level of mother's education. Mothers with higher education made greater use of health care services than others. The average health care utilization score for mothers with education higher than secondary level was 3.66, while that of mothers with no education was 1.98. This was also true for mothers living in urban areas, who had an average health care utilization score of 3.53, while that for mothers living in rural areas was 2.61 (Table 4.4).

2. Infant Mortality

The total number of infant deaths in this sample was 103 and, by using the life table method, the infant mortality rate was 29 per 1,000 live births, with neonatal and post-neonatal mortality at 18.2 and 11.1 per 1,000 live births, respectively. Figure 4.2 illustrates the distribution of probability of dying during the first year of life, with the majority of infant deaths occurring during the first month and spread out in later months. Figure 4.3 shows the cumulative probability of surviving during the first year of life; the major drop of the probability of surviving during the first month. These estimates were higher than those obtained from the National Vital Registration, which showed that infant mortality during 1982 to 1987 ranged from 12.4 in 1982 to 9.5 in 1986 (National Statistical Office, 1989, 1990). However, the estimates from this sample turned out to be lower than those provided by the Health Department, Ministry of Public Health, which indicated that the infant mortality rate in 1987 was 38 per 1,000 live births (Ministry of Public Health, 1991).

It was documented that infant mortality in Thailand has been decreasing since 1950s. The infant mortality during that period was more than 100/1,000 live births (Knodel and Chamratrithirong, 1978). By using the infant death data from 1970 to 1987, it was evident that infant mortality in Thailand was declining from 71/1,000 live births in 1970 to 27/1,000 live births in 1987 with slight increases in 1974 and 1981 (Figure 4.4). The infant mortality by different characteristics of the sample in this chapter were estimated by using the life table method. The neonatal and post neonatal mortality were estimated from simple crosstabulations. The results were presented in the following sections.

2.1. Infant Mortality by Geographic Regions

Table 4.5 shows infant, neonatal, post-neonatal, and child mortalities, by different characteristics of the samples; while tables 4.6 and 4.7 show these mortalities by the same characteristics of the samples stratified by maternal education and place of residence, respectively.

There were infant mortality differentials by geographic regions. It was highest in the northeast region (46 per 1,000 live births), followed by the north region (32 per 1,000 live births), lowest in Bangkok (16 per 1,000 live births). Risk of mortality among infants born in the northeast region was about three times higher than those born in Bangkok (Table 4.5). When the stratifications were carried out by maternal education categories and place of residence, the regional differences in infant mortality among mothers with higher education and among mothers who lived in urban areas were substantially reduced.

Table 4.5 Infant, Neonatal, Post neonatal and Child Mortality per 1,000 live births by Covariates Included in the Study

COVARIATES	Mortality			
	Infant	Neonatal	Post	Child
SOCIOECONOMIC				
Region	*		**	
North	32.10	19.30	13.00	8.00
Northeast	45.90	21.70	24.80	0.00
Central	22.50	13.70	8.90	3.00
South	27.90	22.60	5.30	5.00
Bangkok	15.50	13.90	3.30	2.00
Residence	**		*	
Urban	17.60	13.20	4.50	3.00
Rural	34.70	20.60	14.40	4.00
Mother's Education	**	*	*	
No education	46.10	31.00	15.50	4.00
Primary	32.80	19.80	13.30	4.00
Secondary	6.80	6.80	0.00	2.00
Higher	4.40	4.40	0.00	0.00
Father's Education	**	***		
No education	82.90	61.00	23.30	0.00
Primary	35.10	19.70	11.10	4.00
Secondary	14.70	4.30	10.40	3.00
Higher	17.30	13.70	3.60	0.00
Economic status	***	**		
Low	36.40	24.00	12.70	4.00
High	16.30	8.20	8.20	2.00

Table 4.5 Infant, Neonatal, Post neonatal and Child Mortality per 1,000 live births by Covariates Included in the Study

(Continued)

COVARIATES	Mortality			
	Infant	Neonatal	Post	Child
DEMOGRAPHIC				
Maternal age	***	***	**	
< 20 or >34	51.30	34.10	17.80	8.01
20 - 34	22.20	13.30	9.00	5.52
Sex	**	*		
Male	37.60	24.00	13.90	3.00
Female	19.90	11.90	8.00	3.00
Birth order	*		*	
First order	20.30	14.00	6.30	6.20
Higher order	34.10	20.60	13.80	6.00
Birth Interval	*	*	*	
< 24 months	51.20	33.80	18.00	10.00
=> 24 months	28.60	16.30	12.50	4.30
Breastfeeding	**	***		
< 6 months	68.20	56.30	12.50	8.00
=> 6 months	10.70	0.40	10.30	5.30
Birth order + interval	**	*		
First order	20.30	14.00	6.30	6.20
High+short	51.20	33.80	18.00	10.00
High+long	28.60	16.30	12.50	4.30

Table 4.5 Infant, Neonatal, Post neonatal and Child Mortality per 1,000 live births by Covariates Included in the Study

(Continued)

COVARIATES	Mortality (per 1,000 live births)			
	Infant	Neonatal	Post	Child
ENVIRONMENT				
Drinking water	**		*	
Not hygienic	33.50	19.90	14.40	4.00
Hygienic	16.40	14.00	2.40	2.00
Toilet	**	*	*	
Inappropriate	40.50	24.70	16.20	5.00
Appropriate	22.30	14.30	8.10	2.00
HEALTH CARE UTILIZATION	*	*	**	
Low	35.80	22.80	13.30	6.00
High	22.90	14.00	9.00	2.00

Note: * = p< .05
** = p<.01
*** = p<.001

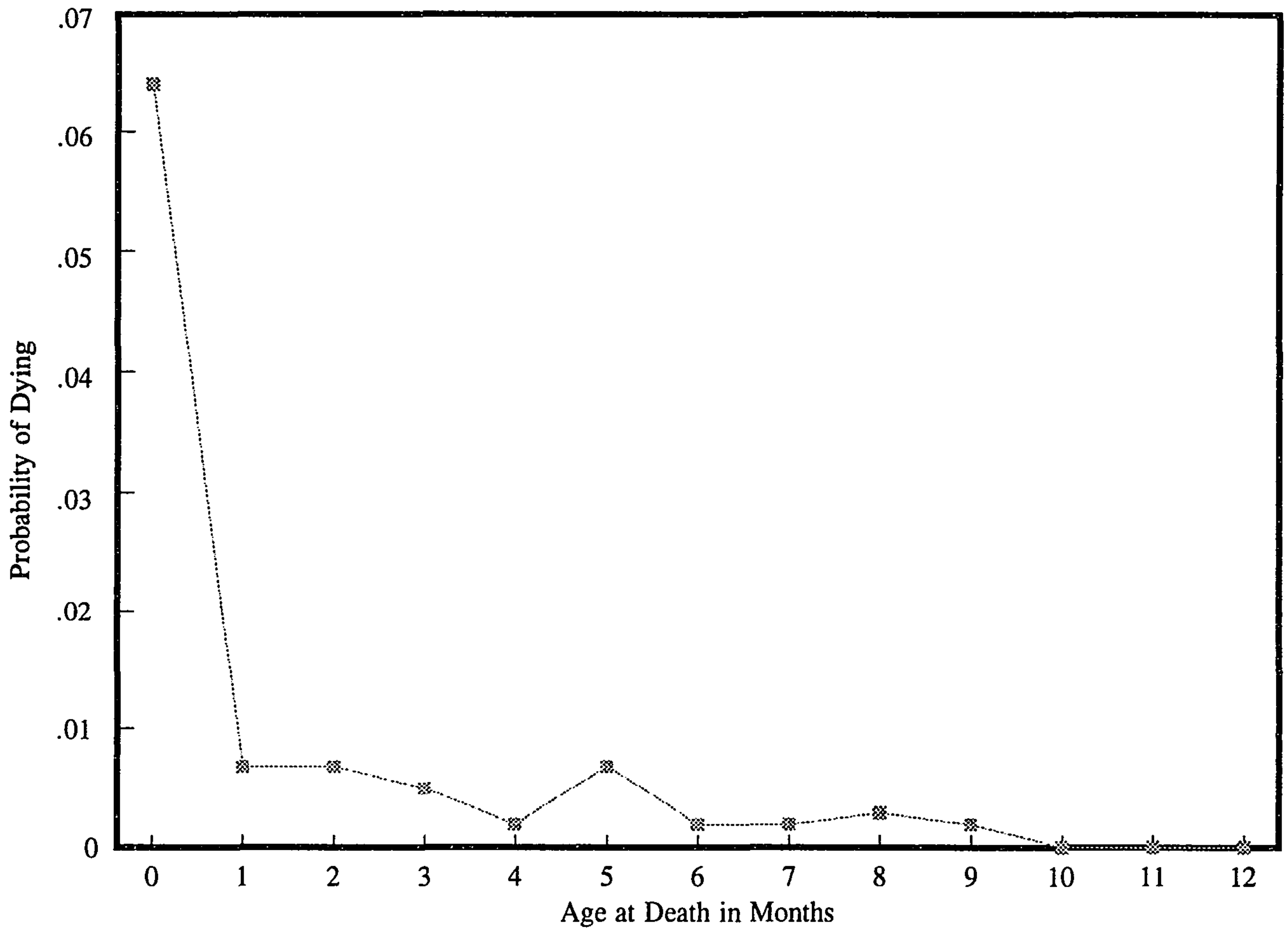

Figure 4.2 Conditional Probability of Dying During the First Year of Life

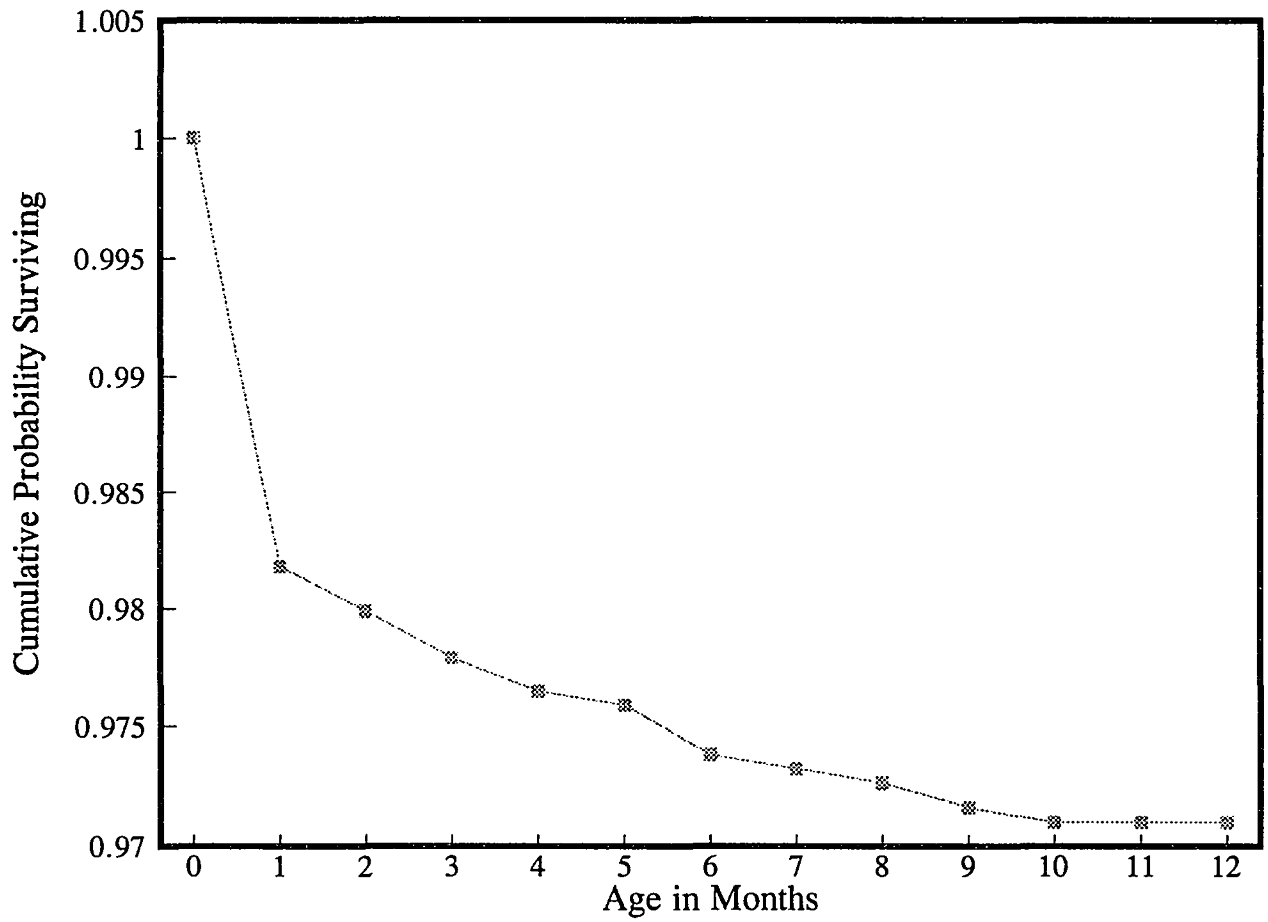

Figure 4.3 Cumulative Probability of Surviving
During First Year of Life

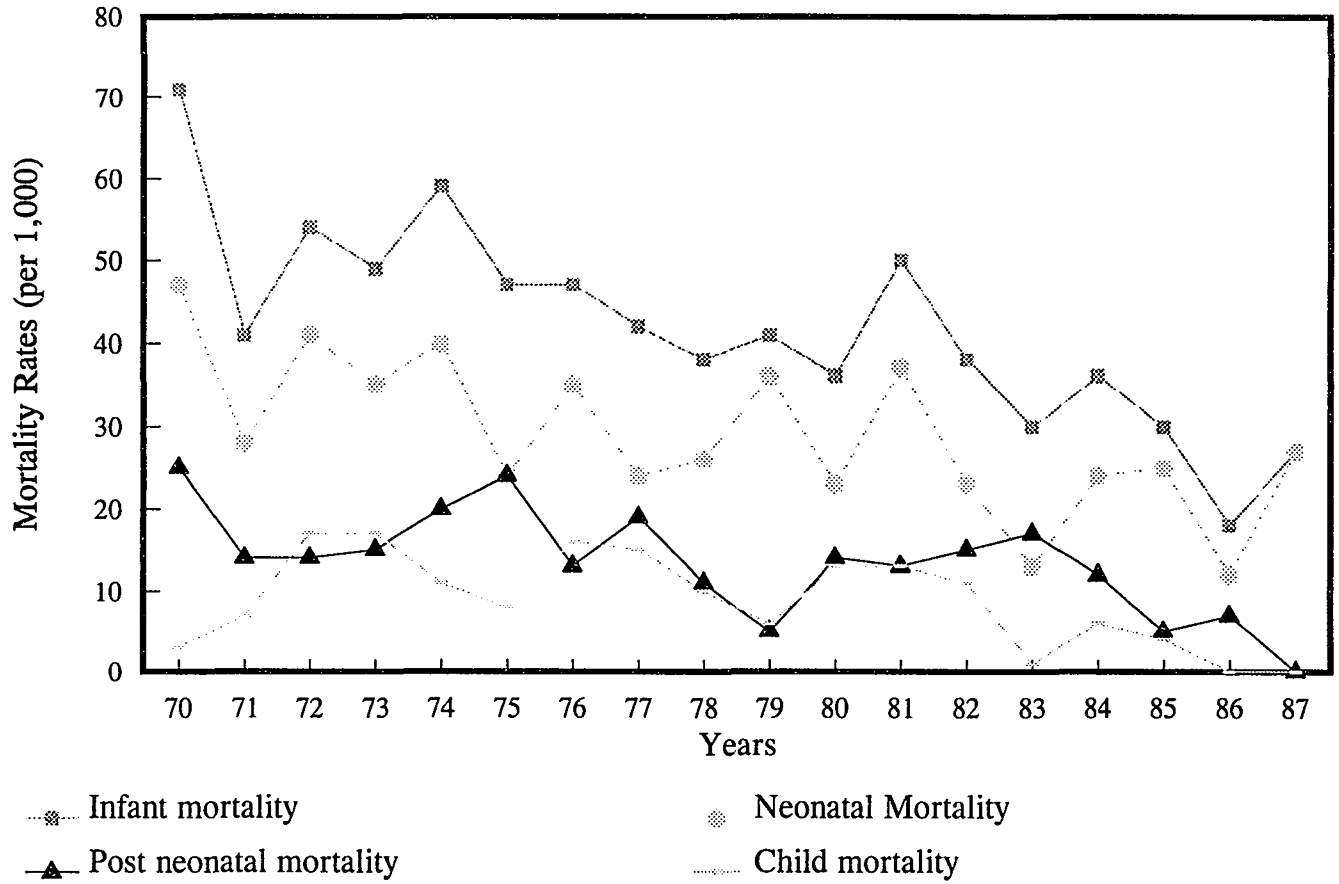

Figure 4.4 Infant, Neonatal, Post-neonatal, and Child Mortality During 1970 to 1987

Nevertheless, infant mortality rates among mothers with lower education and those living in rural areas remained virtually the same as for the whole sample (Tables 4.6 and 4.7). However, the northeast region still stood out as having the highest infant mortality both in urban and rural areas (Table 4.7).

2.2. Infant Mortality and Socio-economic Factors

a. Place of residence

At the time of the interview, infants born to mothers living in rural areas had twice the risk of death than those born to mothers living in urban areas. This effect was significant during the post neonatal period, but not during the neonatal period (Table 4.5). When the analysis was stratified by maternal education categories, its effect was still significant for mothers with lower education, but not for those with higher education (Table 4.6).

b. Mother's education

Education of mothers was divided into four categories: no education, primary, secondary, and higher education. As expected, maternal education which represented the socio-economic status of the family had an inverse relationship with infant mortality. The risk of infant mortality was reduced as maternal education increased. Infants born to mothers with no education were at the highest risk of dying, followed by those born to mothers with primary education. Children born to mothers with primary education were at 29% lower risk of mortality than those born to mothers with no education; and those born to mothers with secondary education and higher education were at about 85% and 91% lower risks, respectively. Its effect was stronger during the post neonatal than neonatal period (Table 4.5). The effect, however, was reduced drastically when place of residence was controlled for and was only slightly significant for rural areas (Table 4.7).

c. Father's education

Father's education, categorized in the same way as mother's, also had a significant effect on infant mortality. Infants born to fathers with secondary and higher education had 82% and 79% lower mortality rates, respectively, than those born to fathers with no education. The effect was stronger and significant during the neonatal period but was not significant during the post neonatal period (Table 4.5). When the analysis was stratified by mother's educational categories, the effect of father's education among mothers with higher education was greatly reduced (Table 4.6). Its effect was not significant when controlling for place of residence (Tables 4.7).

d. Family Economic Condition

The economic condition of the family seemed to play an important role in determining mortality of the infants. It was apparent that infants born to families with high economic condition had significantly lower mortality. The effect was strong and significant during the neonatal, but not during the post neonatal period (Table 4.5); and it was significant only for infants who were born to mothers with lower education (Table 4.6) When place of residence was controlled for, the effect was significant only for urban areas where those who were better off economically could take the advantage of greater services and facilities, while those who were poor were forced to live in crowded and unsanitary areas, exposing small infants to higher risk of death (Table 4.7).

2.3. Infant Mortality and Demographic Factors

a. Maternal age at birth

Results from this study showed that mothers giving birth during ages 20 to 34 years had about 57% less chance of having infant death than mothers who gave birth during the ages outside this range. The effect was significant for both neonatal and post neonatal periods, but stronger during the neonatal period (Table 4.5). Although the effect was reduced when maternal education was controlled for, the effect was still statistically significant. The effect was stronger for mothers with higher education (Table 4.6). Maternal age at giving birth did not have any significant effect on mortality after one year of age

(Table 4.5) and when place of residence was controlled for, the effect was not significant in urban areas, but it was still significant in rural areas (Table 4.7).

b. Birth order

The variable was dichotomized into two categories: first birth order and birth of order greater than one, so that first order births were compared against other orders. Infants of first birth order had 40% lower mortality rate than others, and the effect was significant for the post neonatal period (Table 4.5). This suggested that the effect of birth order was of environmental origin rather than biological. This was confirmed by the fact that the effect was no longer significant when either maternal education or place of residence were controlled for (Tables 4.6 and 4.7).

c. Sex of the Child

Biologically, male infants are known to have higher risk of mortality. Results from this study also showed that female infants had about 47% lower risk of death than their male counterparts, and the effect was significant only during the neonatal period (Table 4.5). The effect still persisted even when maternal education and place of residence were controlled for (Tables 4.6, 4.7).

d. Breastfeeding

Breastfeeding was one of the most important factors affecting infant mortality, especially in developing countries where resources can be scarce and breastfeeding alone must provide immunity and all essential nutrients. The World Health Organization had recommended that an infant be breastfed for at least six months with full breastfeeding for the first three months, followed by supplementation at about age of four to six months (Knodel and Debavalya, 1980; Palloni and Millman, 1983; WHO, 1984; Choe et al., 1987; Retherford et al., 1987). In the univariate analyses, the duration of breastfeeding had been categorized into two categories, duration shorter than six months and duration at least six months. As expected, breastfeeding had a strong effect on infant mortality. Infants who were breastfed at least six months had 86% lower risk of mortality than those who had been breastfed less than six months (Table 4.5). The strong effect still existed even after controlling for place of residence and maternal education (Tables 4.6 and 4.7). This showed that breastfeeding had a strong, independent effect on infant mortality.

e. Birth Intervals

Another variable that has often been mentioned is birth interval, which can be defined in many ways. In this study, birth interval was expressed as the interval between the births of the preceding child and the index child. Birth order and birth intervals were combined into one variable, to test the interaction effects between the two and was a better way to study the effect of birth interval without losing all first birth cases. This new variable had three categories: first order births, births of order greater than one with a preceding birth interval less than 24 months, and births of order greater than one with preceding birth interval of at least 24 months. The results showed that, among the three categories, first order births had the lowest infant mortality (20.30 per 1,000 live births), while births of order greater than one with a short birth interval had the highest infant mortality (51.20 per 1,000 live births). Those infants with birth order greater than one who were born after the preceding birth of at least 24 months had about 44 % lower risk of death than those with intervals shorter than 24 months. The effect was significant only during the neonatal, but not post neonatal period (Table 4.5). When place of residence and maternal education were controlled for, the effect was significant only for mothers who lived in rural areas and for those who had lower education Tables 4.6 and 4.7).

2.4. Infant Mortality and Environmental and Health Factors

a. Toilet Facilities

Proper toilet facilities can help reduce infections, especially gastro-intestinal tract problems, such as parasites and infections caused by oral and skin contamination. As expected, the result from this analysis showed that infants born to families with proper toilets, flush or septic tank, had a 45%

lower risk of mortality than others. The effect was stronger during the post neonatal period (Table 4.5). When place of residence and maternal education were controlled for, the effect was significant only for rural areas and for mothers with lower education (Tables 4.6 and 4.7).

b. Sources of Drinking Water

Infants born to families obtaining drinking water from piped water, privately or publicly, had 51% lower risk of mortality. As expected, the effect was significant during post neonatal period, but when place of residence was controlled for, the effect was significant only for the urban areas. With controlling for maternal education, the effect was significant only for mothers with higher education (Tables 4.5, 4.6, and 4.7).

c. Health Care Utilization

As measured by the index reflecting the level of health care service utilization as described above, those who often used health care services had 36% lower risk of infant death than otherwise, and the effect was stronger during post neonatal period (Table 4.5). The effect was no longer significance when place of residence was controlled for (Table 4.7). When the analysis was controlled for maternal education, the effect was significant only for mothers with lower education (Table 4.6).

Table 4.6 Infant Mortality by Selected Characteristics by Mother's Education.

COVARIATES	Less than secondary		Secondary or more	
	Percent	IMR	Percent	IMR
SOCIOECONOMIC				
Region				
North	19.10	41.00	17.20	5.00
Northeast	22.60	52.00	14.80	19.00
Central	20.60	21.00	18.70	2.50
South	24.60	32.00	19.90	1.40
Bangkok	13.10	15.00	29.40	1.60
Father's Education				
Less than Secondary	87.10	34.00	37.30	25.00
Secondary and Higher	12.90	28.00	62.70	9.00
Residence		*		
Urban	23.50	18.00	56.30	16.00
Rural	76.50	38.00	43.70	15.00
Economic status		*		
Low	76.30	38.00	32.20	23.00
High	23.70	20.00	67.80	12.00
DEMOGRAPHIC				
Maternal Age		***		**
< 20, => 34	23.50	57.00	23.20	36.00
20 - 34	76.50	27.00	76.80	10.00
Sex		*		*
Male	52.10	42.00	50.40	24.00
Female	47.90	25.00	49.60	7.00
Birth Order				
First order	29.00	24.00	56.50	15.00
Higher	71.00	38.00	43.50	17.00

Table 4.6 Infant Mortality by Selected Characteristics by Maternal Education.

(Continued)

COVARIATES	Less than secondary		Secondary or higher	
	Percent	IMR	Percent	IMR
DEMOGRAPHIC				
Birth interval				
< 24 months	31.80	42.00	45.90	22.00
=> 24 months	68.20	30.00	54.10	10.00
Breastfeeding		***		**
< 6 months	29.20	87.50	57.80	27.40
=> 6 months	70.80	12.80	42.20	4.20
Birth order and interval		**		
First order	29.00	24.00	56.50	15.00
Higher+short	15.60	63.00	15.00	18.00
Higher+long	55.40	30.00	28.50	16.00
ENVIRONMENT				
Drinking water				*
Not hygienic	81.10	36.00	58.80	22.00
Hygienic	18.90	25.00	41.20	7.00
Toilet		*		
Not hygienic	47.20	43.00	12.30	7.00
Hygienic	52.80	25.00	87.70	17.00
HEALTH CARE USE		*		
Low	53.30	40.00	32.10	14.00
High	46.70	26.00	67.90	16.00

Note: * = $p < .05$
** = $p < .01$
*** = $p < .001$
IMR = Infant mortality per 1,000 live births

Table 4.7 Infant Mortality by Selected Characteristics by Place of Residence.

COVARIATES	URBAN		RURAL	
	Percent	IMR	Percent	IMR
SOCIOECONOMIC				
Region				
North	10.80	15.00	22.30	35.00
Northeast	12.20	40.00	24.30	46.00
Central	14.70	11.00	22.70	25.00
South	8.20	10.00	30.70	29.00
Bangkok	54.00	15.00	--	--
Mother's Education				*
Less than Secondary	49.50	18.00	80.40	38.00
Secondary and Higher	50.50	16.00	19.60	15.00
Father's Education				
Less than Secondary	49.10	21.80	83.60	35.70
Secondary and Higher	50.90	12.90	16.40	17.70
Economic status		**		
Low	38.00	30.00	75.60	37.00
High	62.00	9.00	24.40	24.00
DEMOGRAPHIC				
Maternal Age				***
< 20, => 34	18.10	27.00	26.00	58.00
20 - 34	81.90	15.00	74.00	25.00
Sex		*		*
Male	50.80	26.00	51.90	42.00
Female	49.20	8.00	48.10	25.00
Birth Order				
First order	45.00	13.00	33.30	25.00
Higher	55.00	21.00	66.70	38.00

Table 4.7 Infant Mortality by Selected Characteristics by Place of Residence.

(Continued)

COVARIATES	URBAN		RURAL	
	Percent	IMR	Percent	IMR
DEMOGRAPHIC				
Birth interval				
< 24 months	28.00	37.00	23.20	56.00
=> 24 months	72.00	15.00	76.80	33.00
Breastfeeding		**		***
< 6 months	56.70	27.40	26.30	91.60
=>6 months	43.30	4.10	73.70	13.20
Birth order and interval				*
First order	45.00	13.00	33.30	25.00
Higher+short	15.40	37.00	15.50	56.00
Higher+long	39.60	15.00	51.20	33.00
ENVIRONMENT				
Drinking water		**		
Not hygienic	40.30	31.00	91.30	33.00
Hygienic	59.70	8.00	8.70	43.00
Toilet				*
Not hygienic	5.90	14.00	52.10	41.00
Hygienic	94.10	17.00	47.90	26.00
HEALTH CARE USE		*		**
Low	7.10	49.00	42.50	42.00
High	92.90	14.00	57.50	19.00

Note: * = $p<.05$
** = $p<.01$
*** = $p<.001$
IMR = Infant mortality per 1,000 live births

3. Summary

Findings from simple analysis showed that some characteristics of the samples varied with geographical regions, place of residence and level of maternal education. These characters were duration of breastfeeding, the average number children ever born, family economy, and health care use.

The results showed, infant mortality declining since 1970. Infant mortality rate from this data during 1982 to 1987 was 29 per 1,000 live births. Without controlling for other factors, infant mortality determinants disclosed by simple analysis were geographical region, place of residence, parental education, family economics, maternal age at giving birth, sex of the child, birth order, birth intervals, duration of breastfeeding, sources of drinking water, toilet facilities, prenatal care, tetanus toxoid injection during pregnancy, birth attendance, place of delivery and health care utilization. Among all of these variables, the most important factor to the survivorship of the infants was breastfeeding: it had strong effects during the neonatal period, but surprisingly not during the post neonatal period. Maternal education was highly correlated with the family economic status and exerted a considerable effect on infant mortality. Though its effect was stronger during the post neonatal period, because of the very small number of infant deaths occurring to mothers with high education, it must be interpreted with caution.

On the average, mothers in Bangkok had the most advantages with respect to the survivorship of the infants. They had the highest family economy score, highest education which probably enabled them to acquire appropriate knowledge and skills beneficial to the survival of the infants, and used health care services more often. Yet, they were also characterized by a trait that negatively affected the survivorship of the infants, short duration of breastfeeding. Nevertheless, mothers in Bangkok experienced the lowest infant mortality in the country.

Among all regions, mothers living in the northeast were the most deprived. They were characterized by having the lowest family economy and were the second to the last in making use of health care services. They had, however, the longest duration of breastfeeding, which is beneficial to the survival of infants, but this could not compensate for other disadvantages they had. The infant mortality was highest in this region.

Mothers in the south made the least use of health care services and had the highest number of children ever born. Mothers in the north, with almost all of their characteristics falling in the middle ranges, had the lowest average years of education.

Up until now, the urban areas, Bangkok in particular, had been blessed with abundant health care services, both government and private, and other public facilities that might not be readily available to those living in rural areas. Urban mothers had greater access to health care services and made more use of them; they were economically well off, had fewer number of children ever born and had higher average number of years of formal education. Even with shorter period of breastfeeding, the overall infant mortality rate for the urban areas was still lower than the rural areas.

Women with higher education (secondary and higher education) were economically better off, tended to marry men who had the same or higher educational levels, made more use of health care services, had less than the average number of children ever born, but had shorter durations of breastfeeding. Despite their shorter length of breastfeeding, the mothers with high educational levels experienced lower infant mortality rate than those less educated.

When maternal education and place of residence were controlled, there were some indications of interaction effects on infant mortality between maternal education and other variables, such as father's education, place of residence, family economics, and health care factors; and the interactions between place of residence and family economics, and sources of safe water supplies.

It was evident from the univariate analyses that most demographic variables had strong and independent effects on infant mortality, while most health care and socioeconomic factors were correlated with maternal education.

In the next chapter, the results of multivariate analyses are presented to investigate the relationships between maternal education and other variables under study in relation to infant mortality in detail. Some of the variables that were mentioned in this chapter may not be included in the multivariate analysis due to their high correlation with other variables.

CHAPTER V

COMPARISON OF RISK FUNCTIONS AND MULTIVARIATE ANALYSES

This chapter will first present the results of the comparison between the proportional hazards models with the multiplicative risk function and the one with the additive risk function. The comparisons were carried out for both univariate and multivariate analyses.

Next, the results from the multivariate analyses will be presented, using the proportional hazards model with risk function that is appropriate to the 1987 TDHS infant mortality data, resulting from the comparisons in the first part, to investigate the associations between maternal education and the proximate and background variables in relation to infant mortality in Thailand.

1. The Distribution and the Proportionality of the Variables

The distributions of all variables to be studied were investigated. Table 5.1 shows the distributions of the variables in the study and their observed relative risks on infant mortality, estimated directly from the data (for the estimation procedure, see Chapter 3). For dichotomous variables, which take value zero and one, the probability of being in the category of one (p) which is the same as the mean value of the variable are also presented. The variables that have p values less than 0.3077 are maternal age at birth and birth order greater than one with short birth interval.

Since it is required that the effects of the variables to be included in the proportional hazards models should be constant throughout the first year of life, the effects of all dichotomous variables were tested for proportionality. This was carried out by plotting log(-log $S_{i1}(t)$) and log(-log $S_{i0}(t)$) against time t, where $S_{i1}(t)$ and $S_{i0}(t)$ were cumulative surviving proportions up to time t for individuals with the value 1 and 0, respectively, for the i^{th} explanatory variable. These cumulative surviving proportions were obtained from life tables estimated separately for each category of the i^{th} variables. The variables are considered to have proportional effects on infant mortality if the two plotted lines are roughly parallel throughout the first year of life.

The proportionality of a variable can be tested by comparing the hazard function of the two categories of the variable directly. For example, there are male and female life tables, of which the hazard functions are proportional. Denoting these two life tables by subscripts f (female) and m (male), the proportionality can be represented by $\lambda_f(t)/\lambda_m(t) = e^k$. However, these individual hazard rates are usually based on very few failures so that they fluctuate a great deal due to sampling variability. The cumulative survival curve, S(t), is based on more failures, so that the plots of $\log(-\log(S_f(t)))$ against $\log(-\log(S_m(t)))$ are much smoother. The log has been taken twice so that the difference between these two terms is equal to k instead of e^k.

For example, from the hazard functions of male and female which are proportional, as such:

$$\lambda_f(t) = \lambda_m(t)e^k \tag{5.1}$$

and

$$\log[S_f(t)] = -\int_0^t \lambda_f(x)dx \tag{5.2}$$

Substituting (5.1) into (5.2), we obtain

$$\begin{aligned} \log[S_f(t)] &= -\int_0^t \lambda_m(x)e^k dx \\ &= [-\int_0^t \lambda_m(x)dx]e^k \\ &= (\log[S_m(t)])e^k \end{aligned} \tag{5.3}$$

So that we get $\log[-\log(S_f(t)] - \log[-\log(S_m(t)] = k$ which is constant throughout the first year of life.

Figures 5.1 to 5.9 illustrate the $\log(-\log(S_{ij}(t)))$ for all dichotomous variables under this study. The results showed no obvious sources of deviation from proportionality, except for sources of drinking water, for which the plots were not quite parallel during the first six months of life which could be due to small sample size in one group, and birth order greater than one with long birth interval, which had a cross-over effect during six to nine months of life.

Breastfeeding, which was treated as a time dependent variable was not tested for its proportionality.

2. Comparison of the Multiplicative and the Additive Risk Functions

2.1. Univariate Analyses

Table 5.2 shows the results from the univariate analyses. The magnitudes and the levels of significance of the coefficients estimated from the multiplicative and the additive risk functions are close and have the same directions. For dichotomous variables with probability of being in category of one, p, less than 0.3077, maternal age at birth and birth order greater than one with short birth intervals, the coefficients, estimated by the multiplicative risk function have smaller standard errors and higher levels of significance than those estimated by the additive risk function. The opposite is true for those with p greater than 0.5 (Table 5.2).

Table 5.1 The Distribution and the Associated Relative Risk of Variables Under the Study of Infant Mortality in Thailand, 1982-1987.

Variables	Means (p)	S.D.	Skewness	Observed Relative Risk
Mother's Education[a]	4.768	2.420	0.26	0.69[e]
Residence	0.666	0.472	-0.71	2.00
Economic Index	0.631	0.483	-0.54	2.30
Maternal age	0.234	0.423	1.26	2.40
Bint1[b]	0.155	0.361	1.91	2.50
Bint2[c]	0.472	0.499	0.11	1.40
Sex of the Child	0.516	0.500	-0.06	1.90
Toilet facility	0.367	0.482	0.55	1.80
Water	0.743	0.437	-1.11	2.000
HCU Index[d]	0.470	0.499	0.12	1.60

Notes: a = Number of years.
b = Birth order greater than one and birth interval shorter than 24 months.
c = Birth order greater than one and birth interval is at least 24 months.
d = Health care utilization index.
e = Relative risk: four years of education against no education.
p = probability of an individual variable having value of one for the dichotomous variables (all except education).

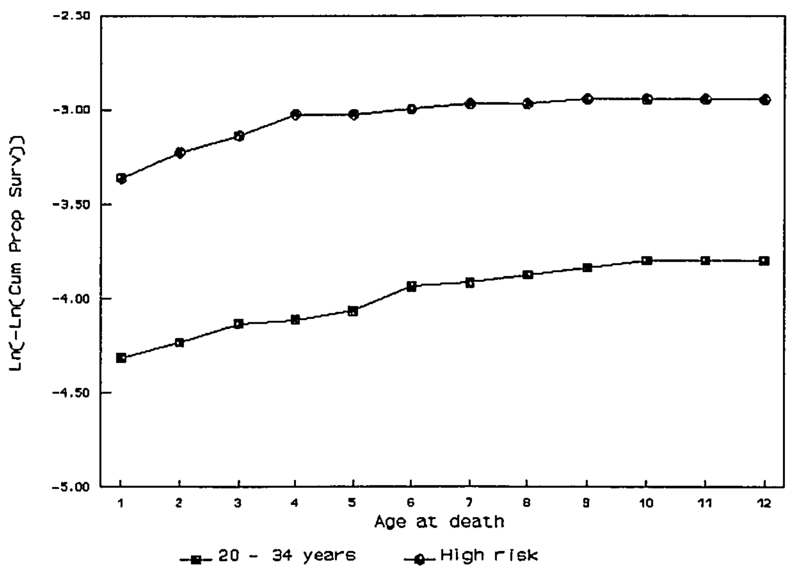

Figure 5.1 Ln(-Ln(S_i(t))) for maternal age at birth against time t in months

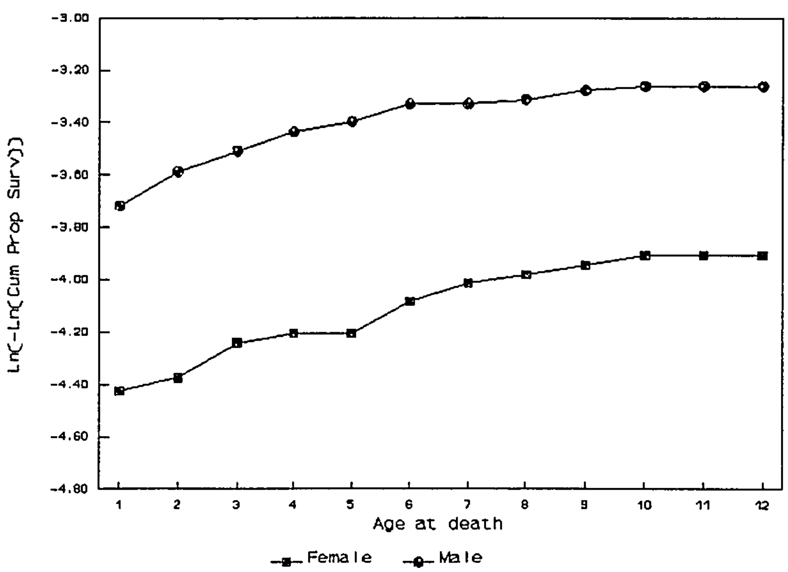

Figure 5.2 Ln(-Ln(S_i(t))) for sex of the child against time t in months

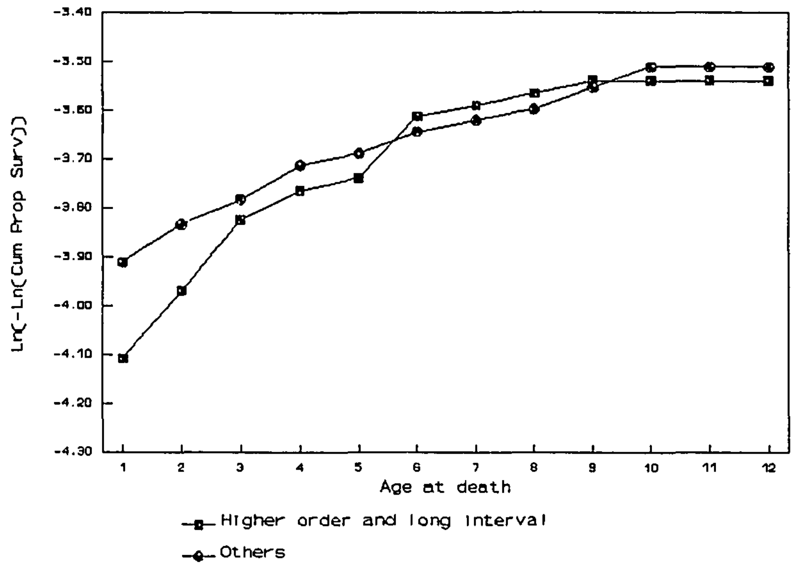

Figure 5.3 Ln(-Ln(S_i(t))) for birth order greater than one with long birth intervals against time t in months

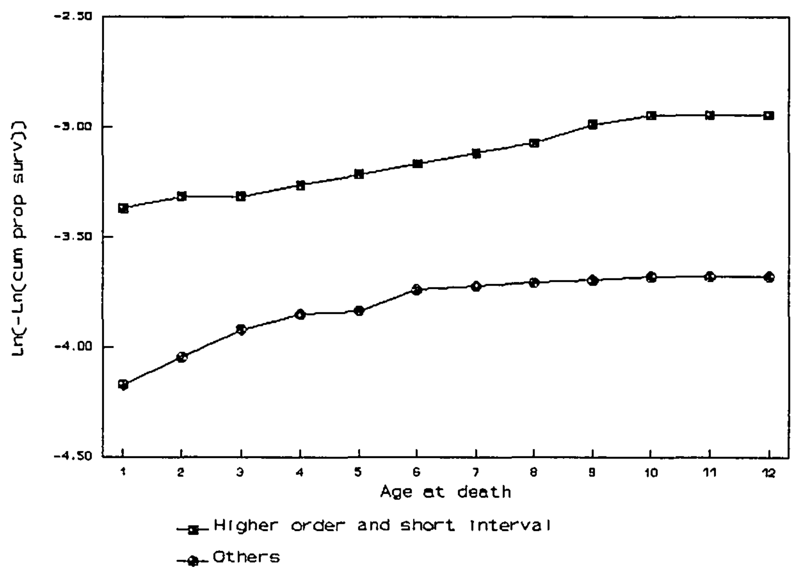

Figure 5.4 Ln(-Ln(S_i(t))) for birth order greater than one with short birth intervals against time t in months

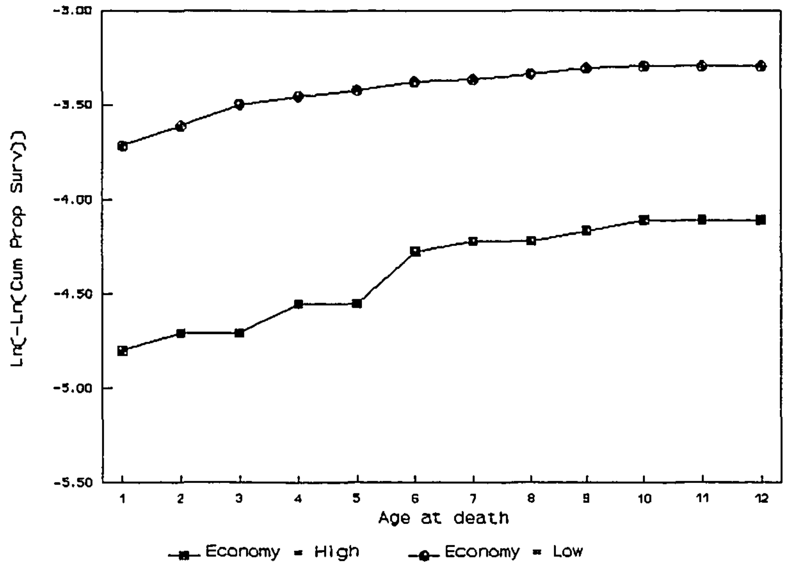

Figure 5.5 $Ln(-Ln(S_i(t)))$ for family economic condition against time t in months

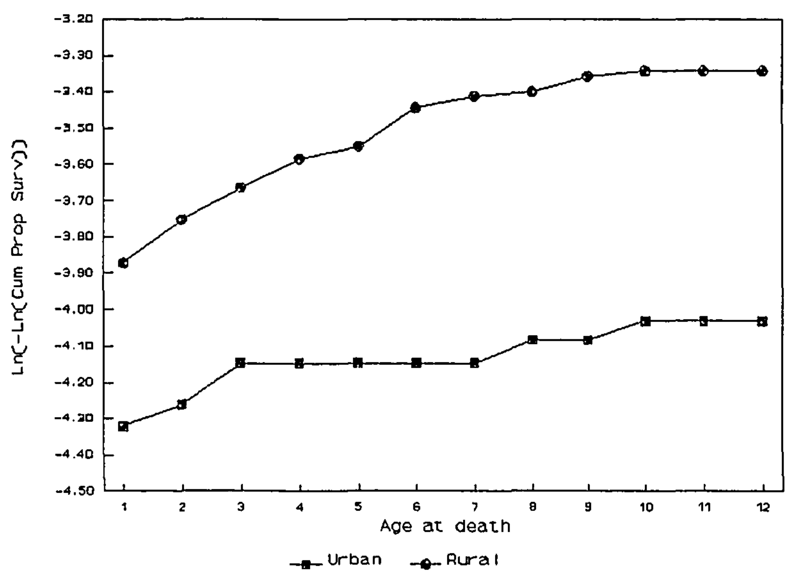

Figure 5.6 $Ln(-Ln(S_i(t)))$ for place of residence against time t in months

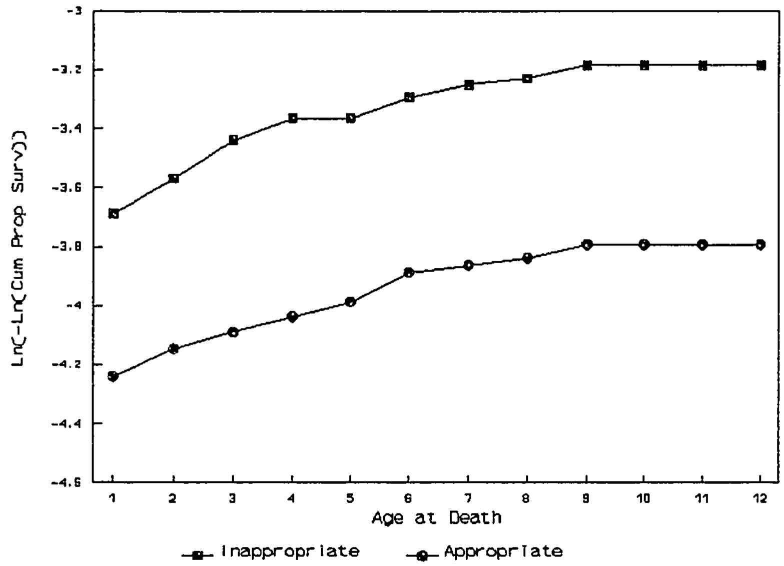

Figure 5.7 Ln(-Ln(S_i(t))) for toilet facility against time t in months

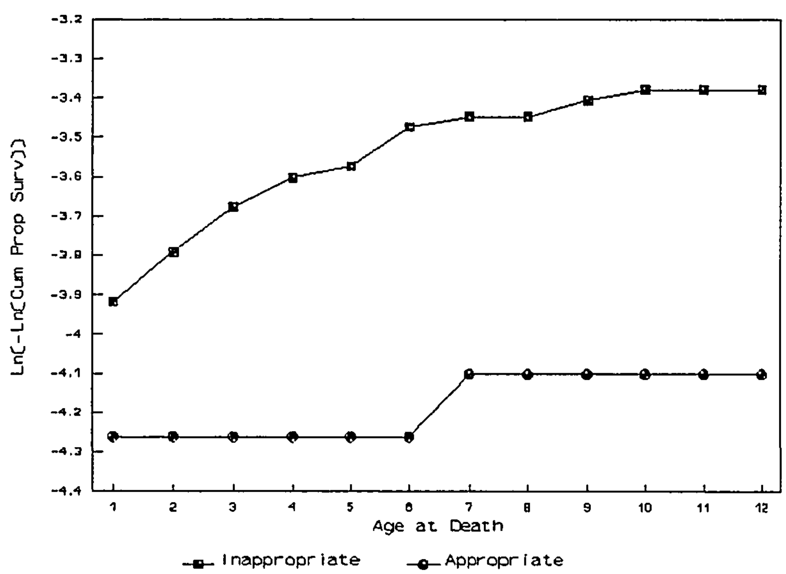

Figure 5.8 Ln(-Ln(S_i(t))) for sources of drinking water against time t in months

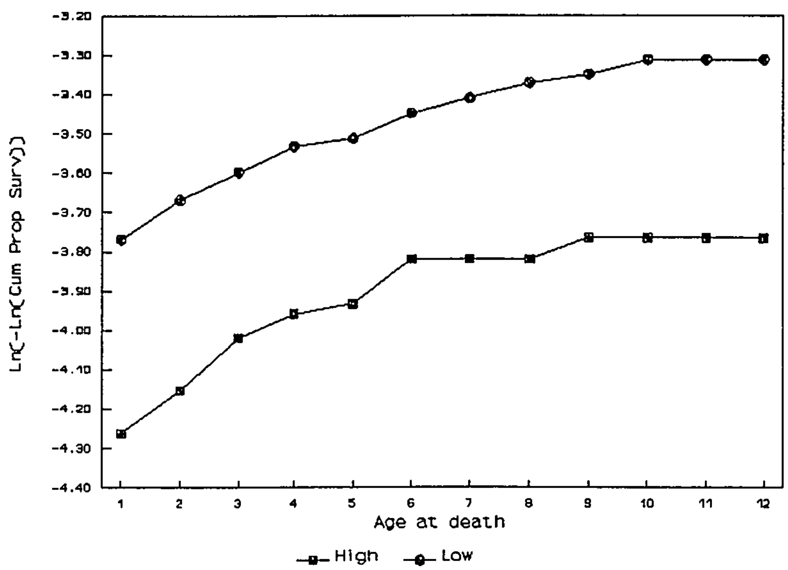

Figure 5.9 Ln(-Ln(S_i(t))) for health care utilization against time t in months

All coefficients of variables estimated by the multiplicative and the additive risk functions are significant, except birth order greater than one. The estimated relative risks associated with each of these variables, except family's economic condition, estimated from both risk functions, are very close, though the multiplicative risk function model yield greater estimated values for all variables (Table 5.2).

The coefficient and effect of maternal education are also estimated by using the two risk functions. Education is grouped into five categories: no education, one to three years, four years, five to seven years, and more than seven years. The respective relative risk for each educational category is

Table 5.2 Comparison of Coefficients of Covariates, Their Standard Errors, Z-Scores, and Relative Risks Estimated by the Multiplicative and the Additive Risk Functions, Univariate Analysis.

Covariates	Multiplicative				Additive			
	Coefficient	Standard Error	z-score	Relative Risk	Coefficient	Standard Error	z-score	Relative Risk
Mother's education[a]	-0.1789	0.0430	-4.1625	0.4889	-0.1753	0.0266	-6.5782	0.2988
Economic Index	0.8334	0.2443	3.4115	2.3011	0.7175	0.1695	4.2339	1.7175
Residence	0.6775	0.2446	2.7700	1.9689	0.5564	0.1865	2.9828	1.5564
Maternal age	0.8685	0.1998	4.3471	2.3833	1.0428	0.2718	3.8372	2.0428
Sex	0.6561	0.2095	3.1311	1.9273	0.6275	0.1849	3.3943	1.6275
Bint1[b]	0.9292	0.2697	3.4449	2.5522	1.0738	0.3451	3.1114	2.0738
Bint2[c]	0.3382	0.2406	1.4025	1.4061	0.2820	0.1937	1.4559	1.2820
Toilet facility	0.6093	0.1971	3.0904	1.8391	0.6416	0.2120	3.0268	1.6416
Water	0.7139	0.2793	2.5557	1.8373	0.5183	0.1953	2.6538	1.5183
Health care Utilization[d]	0.4512	0.1998	2.2585	1.5702	0.4512	0.1952	2.3117	1.4512

Notes: a = Number of years; relative risk of four years of education against no education.
b = Birth order greater than one and birth interval shorter than 24 months.
c = Birth order greater than one and birth interval is at least 24 months.
d = Health care utilization index.

estimated from each risk function, using the average years of education in each category, and compared to the observed values and their 95% confidence intervals. The no education category is treated as reference category for relative risk estimates. The coefficients of maternal education for each risk function are obtained from Table 5.2.

Table 5.3 shows the observed and expected relative risks estimated from the multiplicative and additive risk functions for each level of maternal education. Apparently, the estimates from the multiplicative risk function are closer to the observed values than those estimated from the additive risk function. The relative risks estimated from the latter are all lower than the observed values and all, except for the one to three years of education category, fall outside 95% confidence intervals of the observed values; two of them are negative (Table 5.3). As mentioned before that the additive risk function can give rise to negative estimates if $1 + \Sigma\beta_i Z_i$ is less than zero. Though the estimates from the multiplicative function are better than those from the additive, none of the estimates are close to the observed values. This is probably due to the fact that the number of samples in each category of education, except for the four year category, is very small.

Table 5.3 Observed and Expected Relative Risks Estimated from the Multiplicative and Additive Risk Functions Under the model with Maternal Education

Education	Number at risk	Number of Deaths	Observed Relative Risks			Estimated RR	
			RR	Confidence interval		Multi-plicative	Addi-tive
				Lower	Upper		
No education	294	13	1			1	1
1 - 3 years	144	8	1.2259	0.524	2.871	0.6722	0.6108
4 years	2117	65	0.6908	0.389	1.226	0.4889	0.2988
5 - 7 years	427	13	0.7017	0.335	1.469	0.3246	-0.1026
Higher than 7	665	4	0.1316	0.043	0.399	0.2040	-0.5567

Note: 1. No education category was used as the reference category.
2. The average year of education for each educational category was used in the estimation of the expected relative risks.

2.2. Multivariate Analyses

Three models of multivariate analyses were carried out to compare the two risk functions. These models are a demographic model and two background models. The covariates included in the demographic model are maternal age at birth, sex of the child, birth order and preceding birth interval. The first background model consists of place of residence and family economic condition, and the second model includes family economic condition and maternal education.

It is speculated that there might be interaction effects among variables in these models, so the interaction terms are added into the models. These terms are the interactions between maternal age and birth order greater than one with short birth interval for the demographic model, place of residence and family economic condition for the first background model and maternal education and family economic condition for the second background model. The effects of these interaction terms are tested, and all, but maternal education and family economic condition, are statistically significant. Therefore, only the interactions between maternal age at birth and birth order greater than one with short preceding birth interval, and place of residence and family economic condition are included in the respective models.

Table 5.4 shows the coefficient estimates, their standard errors, and Z scores, estimated from the multiplicative and additive risk functions under

Table 5.4 Comparison of Coefficients of Covariates Estimated by the Multiplicative And the Additive Risk Functions Under Different Models

Covariates/Model	Multiplicative			Additive		
	Coeffi-ents	SE	Z	Coeffi-ents	SE	Z
<u>Demographic Model</u>						
Maternal Age	0.9635	0.2025	4.7583	0.9863	0.2552	3.8653
Sex	0.6376	0.2096	3.0423	0.4666	0.1659	2.8122
Bint1[a]	1.0900	0.2721	4.0053	1.0421	0.3185	3.2721
Bint2[b]	0.4940	0.2437	2.0274	0.3096	0.1639	1.8893
<u>Background Model</u>						
Place of residence	0.4325	0.2575	1.6799	0.4047	0.1909	2.1198
Economic condition	0.6854	0.2574	2.6630	0.5963	0.1904	3.1324
<u>Background Model</u>						
Maternal Education	-0.1438	0.0473	-3.0389	-0.1344	0.0357	-3.7598
Economic condition	0.5398	0.2595	2.0798	0.4024	0.2071	1.9429

Note: a: BINT1 : Birth order greater than one and birth interval shorter than 24 months.
b: BINT2 : Birth order greater than one and birth interval longer than 24 months.

different models without interaction terms. Under the demographic model, Z statistics are higher for all covariates estimated from the multiplicative risk function, while the additive risk function yield greater Z values for the covariates under the model of place of residence and family economic condition. The estimates from both risk functions under the model with maternal education and family economic condition are close.

Table 5.5 shows the coefficients, their standard errors and levels of significance estimated from the multiplicative and additive risk functions under the demographic and the place of residence and family economic condition models with interaction terms. All coefficients of covariates, except the interaction terms, are statistically significant. Relative risks estimated from these coefficients are compared against the observed values.

Table 5.6 shows the observed and the expected relative risks estimated from the two risk functions under the demographic model. All estimates from the multiplicative risk function fall within 95% confidence intervals of, and are closer to the observed values than those estimated from the additive risk function. Five out of 12 relative risks estimated from the additive risk function fall below the lower bounds of the 95% confidence intervals of the observed values. Notice that the smaller the number of samples, the wider the confidence intervals.

The improvement of the estimated relative risks from the multiplicative

Table 5.5 Comparison of Coefficients of Covariates Estimated by the Multiplicative And the Additive Risk Functions with Interaction terms Under Demographic and Background Models

Covariates/Model	Multiplicative			Additive		
	Coeffi-ents	SE	Z	Coeffi-ents	SE	Z
<u>Demographic Model</u>						
Maternal Age	1.0417	0.2357	4.4195	0.9739	0.2640	3.6885
Sex	0.6375	0.2096	3.0416	0.4884	0.1633	2.9914
Bint1[a]	1.2062	0.3282	3.6746	1.0129	0.3325	3.0465
Bint2[b]	0.5049	0.2444	2.0657	0.3396	0.1595	2.1291
Maternal age x Bint1	-0.3062	0.4683	-0.6539	0.5607	1.0988	0.5103
<u>Background Model</u>						
Place of residence	0.9645	0.4629	2.0447	0.5110	0.2495	2.0481
Economic condition	1.2010	0.4629	2.5946	0.7531	0.3037	2.4794
Residence x Economic	-0.7496	0.5481	-1.3677	-0.2766	0.4150	-0.6666

Note: a: Birth order greater than one and birth interval shorter than 24 months.
b: Birth order greater than one and birth interval longer than 24 months.

Table 5.6 The Observed and the Expected Relative Risks estimated from the Multiplicative and the Additive Risk Functions under Demographic Model

MA	Sex	Bint1	Bint2	Number at risk	Number of Deaths	Relative Risks				
						Observed	Confidence Interval		Expected	
							Lower	Upper	Multiplicative	Additive
0	0	0	0	460	3	1.0000	1.0000	1.000	1.0000	1.0000
1	0	0	0	205	4	2.9697	0.7658	11.5159	2.6261	1.9863
0	0	1	0	224	7	4.9545	1.5132	16.2218	2.9783	2.0421
1	0	1	0	48	2	6.7727	1.3464	34.0693	7.8109	3.0284
0	0	0	1	683	10	2.3030	0.7483	7.0881	1.6413	1.3096
1	0	0	1	147	8	8.3939	2.6321	26.7690	4.3033	2.2959
0	1	0	0	467	8	2.7576	0.8654	8.7872	1.8913	1.4666
1	1	0	0	226	12	8.1364	2.7220	24.3202	4.9685	2.4529
0	1	1	0	234	12	7.9091	2.6478	23.6251	5.6380	2.5087
1	1	1	0	57	7	19.0606	5.9178	61.3828	14.7783	3.4950
0	1	0	1	726	20	4.2879	1.5159	12.1283	3.0978	1.7762
1	1	0	1	170	10	9.1364	2.9848	27.9661	8.1413	2.7625
Total				3647	103					

Note: MA: 0 = Maternal age 20-34 years; 1 = Maternal age <20 or => 35 Sex: 0 = Female; 1 = Male
Bint1: 1 = Birth order >1 with short birth interval; 0 = All others
Bint2: 1 = Birth order >1 with long birth interval; 0 = All others

risk function are greater than those of the additive one when the interaction between maternal age and BINT1 is added. The five relative risks, estimated from the additive risk function before adding the interaction term that fall below the lower bounds of the 95% confidence intervals of the observed values, are still below the lower bounds (Table 5.7).

The comparisons between the two risk functions are also done via goodness-of-fit test which is derived from the method of Moreau, et al., 1986 (See details in Chapter III). This method concerns only the estimate of number of deaths in each subgroup which are obtained by using the coefficient of covariates in the estimation. Table 5.8 shows the comparison of the observed and the expected number of deaths estimated from both risk functions under the demographic model. Although the estimates from both risk functions are not significantly different from the observed values, the multiplicative risk function gives better estimates than those of the additive model. The overall χ^2 value of the estimates from the multiplicative and the additive risk functions are 1.77 and 6.86, respectively (Table 5.8).

The interaction term, between maternal age at birth and birth order greater than one with short birth intervals, is added into the models to improve the estimates of each risk function. Apparently, the improvements of the estimates of the multiplicative risk function, after the interaction term is added are greater than that of the additive risk function. By adding the interaction

Table 5.7 The Observed and the Expected Relative Risks estimated from the Multiplicative and the Additive Risk Functions under Demographic Model with interaction term

MA	Sex	Bint1	Bint2	Number at risk	Number of Deaths	Relative Risks				
						Observed	Confidence Interval		Expected	
							Lower	Upper	Multiplic@	Additive
0	0	0	0	460	3	1.0000	1.0000	1.000	1.0000	1.0000
1	0	0	0	205	4	2.9697	0.7658	11.5159	2.8340	1.9739
0	0	1	0	224	7	4.9545	1.5132	16.2218	3.3408	2.0129
1	0	1	0	48	2	6.7727	1.3464	34.0693	6.9713	3.5475
0	0	0	1	683	10	2.3030	0.7483	7.0881	1.6568	1.3396
1	0	0	1	147	8	8.3939	2.6321	26.7690	4.6955	2.3135
0	1	0	0	467	8	2.7576	0.8654	8.7872	1.8917	1.4884
1	1	0	0	226	12	8.1364	2.7220	24.3202	5.3613	2.4623
0	1	1	0	234	12	7.9091	2.6478	23.6251	6.3199	2.5013
1	1	1	0	57	7	19.0606	5.9178	61.3828	13.1879	4.0359
0	1	0	1	726	20	4.2879	1.5159	12.1283	3.1343	1.8280
1	1	0	1	170	10	9.1364	2.9848	27.9661	9.1364	2.8019

Note: MA: 0 = Maternal age 20 - 34 years; 1 = Maternal age < 20 or > 34
Bint1: 1 = Birth order >1 with short birth interval; 0 = All others
Bint2: 1 = Birth order >1 with long birth interval; 0 = All others
Sex: 0 = Female; 1 = Male
@ = Multiplicative

term, the overall χ^2 values of the estimates is reduced by 36% for the multiplicative and by 4% for the additive risk functions (Table 5.9).

Under the model of family economic condition and place of residence without the interaction term, the estimated relative risks from the additive risk function are again lower than those of the multiplicative risk function and are all lower than the lower bounds of the 95% confidence intervals of the observed values. Two out of three of the estimates from the multiplicative risk function are below the lower bounds (Table 5.10). These estimates are improved after the interaction term is added into the model. The estimates of the multiplicative risk function show greater improvements and are much closer to the observed values, while all the estimates of the additive risk function are still below the lower bounds of the observed values (Table 5.11).

The comparisons, between the observed and the expected number of deaths under the model with family economic condition and place of residence without interaction term, confirm the results from the comparison of relative risks. Although the model with the multiplicative risk function yield a better overall estimate, the additive risk function gives a better estimate for rural category, disregarding level of economic condition. Nevertheless, when the interaction term is added into the model, the improvement is greater for the multiplicative risk function (Tables 5.12 and 5.13). The number of deaths estimated by the multiplicative risk function for all categories is much closer to

Table 5.8 The Observed and the Expected number of deaths estimated from the Multiplicative and the Additive Risk Functions for the Demographic Covariates

MA	Sex	Bint1	Bint2	Number at risk	Number of Deaths			Moreau's test value $[(O-E)^2/E]$	
					Observed	Expected (Mult)	Expected (Add)	Multiplicative	Additive
0	0	0	0	460	3	3.22	3.71	0.02	0.14
1	0	0	0	205	4	3.78	3.29	0.01	0.15
0	0	1	0	224	7	5.76	6.83	0.27	0.00
1	0	1	0	48	2	3.24	2.17	0.47	0.01
0	0	0	1	683	10	11.51	13.07	0.20	0.72
1	0	0	1	147	8	6.49	4.93	0.35	1.91
0	1	0	0	467	8	8.83	11.06	0.08	0.85
1	1	0	0	226	12	11.17	8.94	0.06	1.05
0	1	1	0	234	12	11.63	14.21	0.01	0.34
1	1	1	0	57	7	7.37	4.79	0.02	1.02
0	1	0	1	726	20	18.57	21.98	0.11	0.18
1	1	0	1	170	10	11.43	8.02	0.18	0.49
Total				3647	103	103.00	103.00	1.77	6.86

Note: For notations see Table 5.6

Table 5.9 The Observed and the Expected number of deaths estimated from the Multiplicative and the Additive Risk Functions for the Demographic Covariates with interaction Term

MA	Sex	Bint1	Bint2	Number at risk	Number of Deaths			Moreau's test value $[(O-E)^2/E]$	
					Observed	Expected (Mult)	Expected (Add)	Multiplicative	Additive
0	0	0	0	460	3	3.09	3.72	0.003	0.141
1	0	0	0	205	4	3.91	3.28	0.002	0.160
0	0	1	0	224	7	6.22	6.53	0.098	0.033
1	0	1	0	48	2	2.78	2.47	0.219	0.088
0	0	0	1	683	10	11.18	13.12	0.125	0.743
1	0	0	1	147	8	6.82	4.88	0.204	2.000
0	1	0	0	467	8	8.43	11.11	0.022	0.869
1	1	0	0	226	12	11.57	8.89	0.016	1.086
0	1	1	0	234	12	12.60	13.64	0.028	0.197
1	1	1	0	57	7	6.40	5.36	0.056	0.501
0	1	0	1	726	20	18.03	22.08	0.215	0.195
1	1	0	1	170	10	11.97	7.92	0.323	0.544
Total				3647	103	103.00	103.00	1.132	6.557

Note: For notations, see table 5.6

Table 5.10 The observed and the expected Relative Risks estimated from the Multiplicative and the Additive Risk Functions for Economic and Place of Residence Variables

Economic status	Place of Residence	Number At risk	Deaths Observed	Relative Risks				
				Observed	Confidence Interval		Expected	
					Lower	Upper	Multiplic@	Additive
High	Urban	748	7	1	1	1	1	1
Low	Urban	448	14	3.3763	2.1322	5.3465	1.9846	1.5963
High	Rural	579	14	2.7634	1.7516	4.3598	1.5411	1.4047
Low	Rural	1769	68	4.0645	2.7355	6.0393	3.0584	2.0010
Total		3647	103					

Note: @ = Multiplicative

the observed values. The total χ^2 values for goodness-of-fit for the multiplicative risk function before and after the introduction of the interaction terms are 1.85 and 0.0016, respectively, while those for the additive risk function are 2.598 and 2.213, respectively. The reductions are almost 100% for the multiplicative and 15% for the additive risk function (Tables 5.12 and 5.13).

Under the model with maternal education and family economic condition, both risk functions give similar relative risks for education categories of four years or less, disregarding the levels of family economic condition. For education higher than four years, the additive risk function gives poorer estimates and one of them is negative (Table 5.14).

Goodness of fit tests confirm the results from the estimates of the relative risks. The expected number of deaths estimated from the additive risk function for the categories of up to four years of education is closer to the observed values than those estimated from the multiplicative risk function. However, for education greater than four years, the estimates from the additive risk function greatly deviate from the observed ones. The estimates from the additive risk function are significantly different from the observed values. The total χ^2 value with 3 degree of freedom of the goodness-of-fit test for the additive risk function is 21.78 (Table 5.15).

In sum, the effects of the demographic and background covariates under

Table 5.11 The observed and the expected Relative Risks estimated from the Multiplicative and the Additive Risk Functions for Economic and Place of residence with interaction Term

Economic status	Place of Residence	Number At risk	Deaths Observed	Relative Risks				
				Observed	Confidence Interval		Expected	
					Lower	Upper	Multiplic@	Additive
High	Urban	748	7	1	1	1	1	1
Low	Urban	448	14	3.3763	2.1322	5.3465	3.3234	1.7531
High	Rural	579	14	2.7634	1.7516	4.3598	2.5767	1.5110
Low	Rural	1769	68	4.0645	2.7355	6.0393	4.0467	1.9875
Total		3647	103					

Note: @ = Multiplicative

Table 5.12 The Observed and the Expected number of deaths estimated from the Multiplicative and the Additive Risk Functions for Place of Residence and Family Economic Condition Variables

Family Economy	Place of Residence	Number at risk	Number of Deaths			Moreau's test value $[(O-E)^2/E]$	
			Observed	Expected (Mult)	Expected (Add)	Multiplicative	Additive
High	Urban	748	7	9.49	10.62	0.6517	1.2348
Low	Urban	448	14	11.51	10.38	0.5370	1.2637
High	Rural	579	14	11.45	15.11	0.5695	0.0810
Low	Rural	1769	68	70.55	66.89	0.0924	0.0183
Total		3647	103	103.00	103.00	1.8506	2.5980

Table 5.13 The Observed and the Expected number of deaths estimated from the Multiplicative and the Additive Risk Functions for Place of Residence and Family Economic Condition With interaction Term

Economic status	Place of Residence	Number at risk	Number of Deaths			Moreau's test value $[(O-E)^2/E]$	
			Observed	Expected (Mult)	Expected (Add)	Multiplic@	Additive
High	Urban	748	7	6.92	10.13	0.0009	0.9670
Low	Urban	448	14	14.08	10.87	0.0004	0.9011
High	Rural	579	14	13.94	16.11	0.0003	0.2772
Low	Rural	1769	68	68.06	65.89	0.0001	0.0678
Total		3647	103	103.00	103.00	0.0016	2.2132

Note @ = Multiplicative

study on infant mortality in the *1987 Thailand Demographic and Health Survey* data appear to be multiplicative rather than the additive. Most of the estimates obtained from the multiplicative risk function are closer to the observed values than those obtained from the additive risk function, which also give rise to negative estimates.

It is evident that the proportional hazards model with the multiplicative risk function fits the infant mortality data better than the one with the additive risk function. Thus this model is used in the analysis of the relationships between maternal education and other covariates in relation to infant mortality in Thailand during 1982 to 1987. Data, used in this study, is unweighted.

3. Associations Between Maternal Education and Other Variables

To determine the relationship between maternal education and particular types of variables in relation to infant mortality, eight nested hazards models were formulated (See Chapter Three). The percent change of the coefficient of each covariate due to the addition of maternal education is estimated by:

$$\frac{\beta_b - \beta_u}{\beta_u} \times 100 \qquad (5.4)$$

where β_b is the coefficient of the variable estimated from the model including maternal education, and β_u is the coefficient of the respective variable estimated from the model that excludes maternal education.

Table 5.14 The observed and the expected Relative Risks estimated from the Multiplicative and the Additive Risk Functions for Education and Family Economic Condition Variables

Economic status	Avg. yr of Education	Number At risk	Deaths Observed	Relative Risks				
				Observed	Confidence Interval		Expected	
					Lower	Upper	Multiplic@	Additive
High	0	44	2	1.00			1	1
Low	0	250	11	0.91	0.22	3.75	1.706	1.402
High	2.22	20	1	1.01	0.10	10.15	0.727	0.702
Low	2.22	124	7	1.15	0.26	5.04	1.240	1.104
High	4	544	9	0.35	0.08	1.48	0.563	0.462
Low	4	1573	56	0.73	0.20	2.73	0.961	0.865
High	6.29	192	7	0.78	0.18	3.40	0.405	0.155
Low	6.29	235	6	0.53	0.12	2.40	0.691	0.557
High	8.88	548	2	0.07	0.01	0.46	0.279	-0.193
Low	8.88	117	2	0.35	0.05	2.29	0.477	0.209
Total		3647	103					

Note: The relative risks for education were estimated against no education
@ = Multiplicative

Table 5.15 The Observed and the Expected number of deaths estimated from the Multiplicative and the Additive Risk Functions for Maternal Education and Family Economic Condition

Economic status	Average years of Education	Number at risk	Number of Deaths			Moreau's test values $[(O-E)^2/E]$	
			Observed	Expected (Mult)	Expected (Add)	Multiplicative	Additive
High	0	44	2	1.22	1.45	0.51	0.21
Low	0	250	11	11.78	11.55	0.05	0.03
High	2.22	20	1	0.69	0.74	0.14	0.09
Low	2.22	124	7	7.31	7.26	0.01	0.01
High	4	544	9	10.96	10.14	0.35	0.13
Low	4	1573	56	54.04	54.86	0.07	0.02
High	6.29	192	7	4.21	2.40	1.85	8.79
Low	6.29	235	6	8.79	10.60	0.89	1.99
High	8.88	548	2	2.93	5.20	0.30	1.97
Low	8.88	117	2	1.07	-1.20	0.81	-8.54
Total		3647	103	103.00	103.00	4.97	21.78

Table 5.16 shows the coefficients of covariates, degree of freedom (DF) and log likelihood (LL) of each of the eight models. The difference of the log likelihood between two nested models or likelihood ratio indicates the significant contribution of maternal education to the infant mortality.

From this Table, Model 1 shows that all demographic covariates had significant effects on infant mortality; and their coefficients are minimally affected by the addition of maternal education, except for BINT2 whose coefficient is reduced by 35% and becomes nonsignificant (Model 2). Among all demographic covariates, only the coefficient of duration of breastfeeding increase, but only to a small extent, when maternal education is added. The difference between the log likelihood of Model 1 and Model 2 indicates that maternal education contributed significantly to the model. One year of maternal education reduces infant mortality by 16%, controlling for all demographic covariates under study.

Model 3 shows that none of the environmental and health care factors has significant effects on infant mortality. Nevertheless, the coefficients of toilet facilities and health care utilization are reduced by 55% and 27%, respectively, when maternal education is added into the model (Model 4).

Models 5 and 6 indicate that, without controlling for other types of covariates, the effect of the family economic condition on infant mortality is substantially affected by the inclusion of maternal education. Its coefficient is

Table 5.16 Coefficients of Covariates for Different Models

Covariates	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Education		-0.1764***		-0.15**		-0.1342**		-0.1022*
Residence					0.4325	0.3100	0.5574	0.4838
Economic					0.6854**	0.4508	0.7480**	0.5776*
Maternal age	1.0068***	0.8227***					0.7901***	0.7330***
Bint1	1.1218***	0.9307***					0.9172***	0.8497**
Bint2	0.6951**	0.4527					0.5080*	0.4005
Sex	0.6002**	0.5620**					0.5171**	0.5014**
Toilet			0.4271	0.1909			0.1246	0.0626
Water			0.3751	0.4366			0.3736	0.4131
Health			0.2739	0.1997			0.3981	0.3616
Breastfeeding	-2.9001***	-3.056***					-3.3288***	-3.3365***
BFT	0.5659***	0.5610***					0.5501***	0.5496***
DF	6	7	3	4	2	3	11	12
LL	-769.2341	-759.08	-833.91	-828.63	-832.95	-829.12	-748.41	-746.0507

Note: * = p<.05 ** = p<.01 *** = p<.001
BINT1 = Birth order greater than one with birth interval shorter than 24 months
BINT2 = Birth order greater than one with birth interval at least than 24 months
BFT = Breastfeeding x age

reduced by 34% when maternal education is added while that of place of residence decreases by 28%.

In Model 7, all covariates, except maternal education, are included. All demographic covariates have significant effects on infant mortality. Among the background, environmental and health care factors, only family economic condition still has significant effect on infant mortality. Its effect decreases by 23% when maternal education is added. The toilet facility variable does not have any significant effect on mortality; however, its effect declines by about half when maternal education is added. As in Models 1 and 2, the effect of BINT2 is no longer significant when maternal education is added (Model 8).

As expected, maternal education still has a significant effect on infant mortality even when all other covariates are included in the model. An increase of one year of maternal education reduces the risk of infant mortality by 10%. Among all covariates under study, breastfeeding has the greatest effect on infant mortality; if an infant is considered to have had long breastfeeding, its risk of mortality during the first month of life is 94 percent $(1-e^{-3.3365+.5496})$ less than those who have short breastfeeding. However, this positive effect of breastfeeding is reduced as the child aged. Maternal age at birth, birth order greater than one with a short birth interval, and sex of the child also have significant effects on infant mortality. Infants born to very young (less than 20 years) or very old (35 years or older) mothers have a risk of mortality 2.1 times higher than others. Infants of birth order greater than one with short birth intervals have 2.3 times higher risk of mortality than others, and male infants have 1.9 times higher risk of mortality during the first year of life than females. Infant born into low socioeconomic families, have mortality risks 1.8 times higher than those born into higher socioeconomic families.

It was expected that place of residence and environmental and health care factors would have significant effects on infant mortality. However, results from the analysis does not support these hypotheses. This will be discussed later in the next chapter.

It is evident that maternal education has strong associations with family economic condition, place of residence, and toilet facilities. Its relationships with the demographic covariates, except BINT2, in relation to infant mortality are weak.

The above section provides the information about how strongly maternal education is associated with other variables. In the next section, the modifying effect of maternal education on the relationships between demographic, other socioeconomic, environmental and health care factors and infant mortality will be investigated and discussed.

4. Infant Mortality by Maternal Education Categories

To investigate the modifying effects of maternal education on the relationships between other variables and infant mortality, education is categorized into two groups: four years or less and higher than four years. The interaction terms between maternal education and demographic, socioeconomic and health care factors are added into the full model (model 8). Effects of these interaction terms are tested for statistical significance. The differences between cross-classified categories of each interaction term are tested as follows:

For the interaction between maternal education and place of residence, for example, there are two categories for maternal education: high and low; and two for place of residence: rural and urban. Denoting place of residence as R and maternal education as E,

R = 0 = urban; 1 = rural

E = 0 = high education; 1 = low education

We thus have

rural, low (R = 1, E = 1) and $\lambda(t) = \bar{\lambda}(t)e^{a+b+c+T}$

rural, high (R = 1, E = 0) and $\lambda(t) = \bar{\lambda}(t)e^{a+T}$

urban, low (R = 0, E = 1) and $\lambda(t) = \bar{\lambda}(t)e^{b+T}$

urban, high (R= 0, E = 0) and $\lambda(t) = \bar{\lambda}(t)e^{T}$

The coefficients of place of residence, education, and interaction term are a, b, and c, respectively. T is the combination of coefficients of other covariates in the model.

If the coefficients of these three covariates have the same sign, the largest relative difference should be between rural, low and urban, high:

$$\frac{\lambda_{1,1}(t)}{\lambda_{0,0}(t)} = \frac{\bar{\lambda}(t)e^{a+b+c+T}}{\bar{\lambda}(t)e^{T}} \qquad (5.5)$$

$$= e^{a+b+c}$$

Each of these effects is tested by using Z statistics.

Table 5.17 shows coefficients of covariates and the estimated effects for different cross-classified categories of each interaction term.

Table 5.18 shows relative risk associated with each covariate by maternal education categories. Results from this table indicate that risk of mortality among infants of mothers with low education who are exposed to socioeconomic, demographic and health care factors presented in this table are higher than those born to mothers with higher education.

When risks of mortality of being exposed to these factors are compared between infants born to mothers with low education to those of mothers with high education, it is evident that risks of infant mortality of the latter group are

Table 5.17 Coefficients and Effects of the Interactions Under Full Model With Interactions

Variables	Coefficient (S.E)	Effect
Education X Family Economic	-0.0702(0.6293)	
Education (E)	1.6368(0.9752)	$e^{1.6368-0.0702I}$
Economic (I)	0.6259(0.5387)	$e^{0.6259-0.0702E}$
Education X Residence	1.4739(0.6605)	
Education (E)	1.6368(0.9752)	$e^{1.6368+1.4739R}$
Residence (R)	-0.5382(0.5427)	$e^{-0.5382+1.4739E}$
Education X Maternal age	-0.8605(0.5663)	
Education (E)	1.6368(0.9752)	$e^{1.6368-0.8605M}$
Maternal age at birth (M)	1.5210(0.5202)	$e^{1.1521-0.8605E}$
Education X Sex	-0.7909(0.6180)	
Education (E)	1.6368(0.9572)	$e^{1.6368-0.7909S}$
Sex (S)	1.1722(0.5750)	$e^{1.1722-0.7909E}$
Education X Bint1	0.4182(0.7523)	
Education (E)	1.6368(0.9572)	$e^{1.6368+0.4182B1}$
Bint1 (B1)	1.5210(0.6843)	$e^{1.5210+0.4182E}$
Education X Bint2	-0.2383(0.6572)	
Education (E)	1.6368(0.9572)	$e^{1.6368-0.2383B2}$
Bint2 (B2)	0.6346(0.5925)	$e^{0.6346-0.2383E}$
Education X Health care Use	0.5579(0.5930)	
Education (E)	1.6368(0.9572)	$e^{1.6368+0.5579H}$
Health care use (H)	-0.1186(0.5461)	$e^{-0.1186+0.5379E}$

much lower than the former ones, given that they are exposed to the same risk factors. However, these differences are significant only for place of residence, birth order greater than one with short preceding birth interval, and health care utilization.

Infants born to mothers with low education, living in rural areas, have risk of mortality 13 times higher than those born to mothers with high education, living in urban areas. Among infants who were born to mothers living in rural areas, those of mothers with high education have risk of mortality about 95% less than those born to mothers with low education.

Infants of birth order greater than one with preceding birth interval shorter than 24 months, born to mothers with lower education, have risk of mortality about 13 times higher than those who are first birth, born to mothers with high education. Among infants of birth order greater than one with short preceding birth intervals, those who were born to mothers with low education have risk of mortality about 7.8 times higher than those born to mothers with high education.

Risk of mortality among infants born to mothers with low education who use health care services less frequently is about 8 times higher than those born to mothers with high education who use health care services more frequently. Among infants born to mothers who use health care services less frequently, risk of mortality among those born to mothers with high education is about 89% less than those born to mothers with low education.

The above results suggest that maternal education can modify risk of mortality associated with living in rural areas, birth order greater than one with short preceding birth intervals and using health care services less frequently.

It is surprising that the interaction effects between maternal education and the environmental factors: toilet facilities and sources of drinking water, are not significant. This will be discussed in the next chapter.

Results from the above analyses show that maternal education strongly correlated with maternal family economic condition, place of residence, the toilet facilities, and Bint2. It is also found that infant mortality associated with socioeconomic, demographic, and health care factors are modified by maternal education. However, in only three of these risk factors, place of residence, Bint1, and health care service utilization, risk of mortality are significantly reduced by increasing education of mothers from less than secondary to secondary level or higher.

The analysis was also carried out for rural and urban areas to investigate the differentials effects of each covariate in these areas.

5. <u>Infant Mortality by Place of Residence</u>

Table 5.19 shows the coefficients of covariates for infant mortality by

Table 5.18 The Relative Risks Associated with Each Covariate[a] by Maternal Education, Under Full Model with Interactions.

Variables	Maternal Education	
	Secondary or higher	Less than Secondary
Family Economic Condition	1.86	8.96
Place of residence	0.58	13.10*
Maternal age at birth	4.58	9.95
Bint1	1.64	12.84*
Bint2	1.89	7.64
Sex	3.23	7.52
Health care Utilization	0.89	7.97*

Note a = Only the covariates that have significant interaction effects with maternal education that are included in this table

* = Significant difference ($p < .05$) between high and low education categories

place of residence. The effect of maternal education is stronger and significant in rural areas, where one year of education reduces infant mortality by 13%. The effects of maternal age at birth and Bint1 are also significant in rural areas. Infants born to rural mothers who are very young (less than 20 years) or very old (35 years or older) had a risk of mortality 2.4 times higher than others, and those of birth order greater than one with short birth interval had a risk of death 2.4 times higher than others (Table 5.19).

Only family economic condition, sex of the infant and, surprisingly, sources of drinking water had significant effects on infant mortality in urban areas. In this area, infants born to families of low economic condition or to families with unsanitary sources of drinking water had a risk of death 4 and 4.3 times higher, respectively, than others, while male infants had a risk of death 3 times higher than females. In this analysis, breastfeeding was not included because it could not be incorporated in the analysis for urban area due to lack of variation of the variable when it was ordered by time to event.

6. <u>Infant mortality by Family Economic Condition</u>

It is speculated that the covariates under study may affect infant mortality differently between those who are economically advantaged and those who are economically disadvantaged. Therefore, the full model has been stratified by family economic category. Table 5.20 showed the coefficients of covariates by family economic condition. The effect of maternal education is no longer significant for infants of both low and high economic families. Maternal age at birth and breastfeeding are significant for both low and high economic classes while birth order greater than one with short birth intervals and sex of the child are significant for infants born into families with low economic condition. Birth order greater than one with long birth intervals is significant for those born into families with high economic condition.

Since factors affecting infant mortality during the first month and the later period of life differ (Stockwell, et al., 1987), the analyses were to carried out separately for neonatal and post neonatal mortality. However, due to the small number of deaths during the post neonatal period, the stratified analysis by neonatal and post-neonatal mortality could not be performed.

7. <u>Summary</u>

7.1. The Comparison of the Multiplicative and Additive Risk Function

The comparison between the multiplicative and additive risk functions showed that for all models, the multiplicative risk function gave the estimates that were closer to the observed values. The additive risk function, for the models that involved maternal education, gave rise to negative estimates.

Table 5.19 Coefficients of Covariates and Associated Relative Risks by Place of Residence

Covariates	Place of residence							
	Rural				Urban			
	Coefficients	RR	SE	p	Coefficients	RR	SE	p
Education	-0.1337	0.87	0.0542	<.05	0.0423	1.04	0.0999	NS
Economic	0.0756	1.08	0.3451	NS	1.3832	3.98	0.5047	<.01
Maternal age	0.8566	2.36	0.2277	<.001	0.5709	1.77	0.5078	NS
Bint1[a]	0.8802	2.41	0.3201	<.05	1.0353	2.82	0.5616	NS
Bint2[b]	0.3242	1.38	0.2833	NS	0.1672	1.18	0.5680	NS
Sex	0.5045	1.66	0.2318	NS	1.1064	3.02	0.5124	<.05
Toilet facility	0.2220	1.25	0.2660	NS	-1.3635	0.26	1.0562	NS
Water	-0.4700	0.62	0.3672	NS	1.4622	4.32	0.4870	<.01
Health care	-0.0485	0.95	0.2456	NS	0.5575	1.75	0.4477	NS
LL	-615.9209				-133.4538			

Note: a = Birth order greater than one with short preceding birth interval
b = Birth order greater than one with long preceding birth interval

Table 5.20 Coefficients of Covariates and Associated Relative Risks by Family Economic Status

Covariates	Family Economy Conditions							
	Low				High			
	Coefficients	RR	SE	p	Coefficients	RR	SE	p
Education	-0.0692	0.93	0.0555	NS	-0.0951	0.91	0.0903	NS
Residence	0.3326	1.39	0.3588	NS	0.8354	2.31	0.5448	NS
Maternal age	0.5697	1.76	0.231	<.01	1.425	4.15	0.4709	<.001
Bint1[a]	0.7274	2.06	0.3073	<.01	1.1725	2.23	0.6797	NS
Bint2[b]	0.2399	1.27	0.2791	NS	1.1831	3.26	0.5986	<.05
Sex	0.6054	1.83	0.2444	<.01	0.0898	1.09	0.4408	NS
Toilet facility	0.1043	1.11	0.2564	NS	0.2103	1.23	0.6868	NS
Water	0.3502	1.42	0.398	NS	0.3942	1.48	0.5822	NS
Health care	0.3761	1.46	0.2413	NS	0.4423	1.56	0.4719	NS
Breastfeeding(BF)	-3.3787	0.03	0.4202	<.0001	-3.3924	0.03	1.2241	<.01
BFT	0.5229	1.69	0.1561	<.0001	0.7325	2.08	0.3042	<.01
LL	-556.9565				-130.1824			

Note: a = Birth order greater than one with short birth interval
b = Birth order greater than one with long birth interval
BFT = Breastfeeding x Age

Data investigation showed the effects of the covariates under study were more than additive. Thus, the interaction terms were added into the models. The improvement of the estimates of the multiplicative risk function due to the inclusion of the interaction terms were greater than those of the additive one.

It can thus be concluded that the multiplicative risk function was more suitable for the study of infant mortality in the Thailand Demographic and Health Survey, 1987.

7.2. Relationship between Maternal Education and other Covariates

The results from applying the hazards model with multiplicative risk function to infant mortality data from Thailand to determine the relationship between maternal education and other covariates indicated that maternal education had a significant effect on infant mortality. Its effect was still significant even when other covariates under study were included in the model. It was evident that maternal education had strong correlations with family economic condition, place of residence, the availability of sanitary toilet facilities in the households, and birth order greater than one with long birth intervals. The coefficients of these covariates decreased markedly when maternal education was added into the model.

There were also indications of the modifying effects of maternal education on risks of mortality associated with family economic condition, place of residence, maternal age at birth, birth order greater than one with short preceding birth intervals, birth order greater than one with long preceding birth intervals, sex of the child, and health care service utilization. Effects of these covariates on infant mortality among mothers with high education were all less than half of those among mothers with low education. However, only the modifying effects of maternal education on risks of mortality due to place of residence, birth of order greater than one with short preceding birth intervals, and health care service utilization were statistically significant.

The stratification of the full model by place of residence suggested different factors affecting infant mortality differently in rural and urban areas. In rural areas, the factors that significantly affected infant mortality were maternal education, maternal age at birth, and birth order greater than one with short preceding birth intervals; while family economic condition, sex of the child, and sources of drinking water significantly affected infant mortality in urban areas.

The effect of maternal education was no longer significant when the full model was stratified by the family economic condition. Both maternal age at birth and breastfeeding were significant across the strata of the family economic conditions. Among infants of families with low economic condition, their mortality was also significantly determined by the birth order greater than one with short preceding birth intervals and sex of the child; while birth order greater than one with long preceding birth intervals was the other infant mortality determinant among those of the families with high economic condition. The results of these analyses will be discussed in the next chapter.

CHAPTER VI

SUMMARY AND DISCUSSION

1. Summary

Infant mortality is regarded as an indicator of the level of socioeconomic and health care development of a country, and at the individual level it has been found to have significant relationships with socioeconomic, demographic, environmental and health care factors. Among all socioeconomic factors, maternal education, has been found to have a significant association with infant mortality in both developed and developing countries.

Naturally, education does not affect mortality directly. Even though there has been evidence indicating the relationships between maternal education and other variables that are more directly related to infant mortality, such as knowledge, skills, and practice in disease prevention and control, and other health behaviors affecting the well-being of the fetus and the infant, there are no conclusive results about how maternal education operates to reduce infant mortality. This is due to the lack of detailed information and because of the inconsistent and inconclusive results from previous studies.

It was speculated that the relationships between maternal education and reproductive and other health behavior might be influenced by such factors as culture, tradition, beliefs, etc., as well as the quality of health care services in that area. As such, the generalization about the roles of maternal education in determining infant mortality from the experiences of other countries could be misleading. It is, therefore, important for any country, developing or otherwise, to clearly understand how maternal education operates to reduce infant mortality in its own society. This will be valuable information for any plan intending to reduce infant mortality.

In the study of infant mortality determinants, a statistical method is needed that makes use of the information of all infant subjects one year of age, either alive or deceased, and takes the ages at death of the subjects into account in the process of estimation. One such statistical method is the proportional hazards model introduced by D.R. Cox in 1972. This model assumes that the individual variable affects the baseline hazard in the multiplicative manner. This assumption has been challenged by some researchers who argued that the multiplicative risk function may not be appropriate for some biological data, such as dose-response type, and, in terms of a public health intervention, may obscure the real magnitude of the problem. New functional forms of the proportional hazards model have been introduced, and among them, the one with the additive risk function has received recognition.

The comparisons between the original functional form of the proportional hazards models and the one with the additive risk function were carried out, but the results suggested no significant differences between the two. In the past, the comparison studies were confined to dose-response type of data. It is, therefore, worthwhile to compare these two functional forms by using other types of data.

Thailand, as in many other developing countries, lacks not only understanding of the role of maternal education in determining infant mortality, but also multivariate analyses of the determinants of infant mortality at the individual level, due to the lack of appropriate data and statistical techniques. Only recently have both pregnancy history data and statistical packages for complicated multivariate analyses been made available for the study of infant mortality. This study, realizing the importance of understanding the role of maternal education in reducing infant mortality, as well as the importance of using the appropriate statistical model to arrive at the unbiased results of the analyses, focuses, therefore, on two main objectives.

The first objective is to compare the performances of the proportional hazards model with the multiplicative risk function to the one with the additive risk function, using infant mortality data from the 1987 TDHS. The second objective is to investigate the association between maternal education and other socioeconomic (place of residence, family's economic condition), demographic, environmental and health care factors in relation to infant mortality by using the proportional hazards model with the risk function that fits the 1987 TDHS. Results from this study will provide insight into which risk function is more appropriate for infant mortality data in Thailand. It will also provide the valuable information for the planning of intersectoral cooperation to reduce infant mortality.

The comparison between the two proportional hazards models were carried out for both univariate and multivariate analyses. The relative risks and the number of deaths estimated from each model were then compared. The goodness-of-fit statistics proposed by Moreau and colleagues was applied to compare the fit of both functional forms. Eight nested models were formulated to investigate the association between maternal education and other variables in relation to infant mortality. To measure the interaction or the modification effects of maternal education on other variables, education was categorized into two categories: four years of education or less and more than four years. The interaction terms between maternal education and the socioeconomic, demographic, environmental, and health care factors were incorporated into the full model. The effects of cross-classified categories of each interaction term were then tested for significance. Due to the small number of deaths during the post neonatal period, the analyses by neonatal and post neonatal mortality were not performed.

Results from this study suggested that the proportional hazards model with the multiplicative risk function was more appropriate for the infant mortality data of the 1987 TDHS than the additive type and was, therefore, used to investigate the relationships between maternal education and other socioeconomic, demographic, environmental and health care factors in relation to infant mortality.

It appeared that maternal education had a significant effect on infant mortality even when all variables under study were controlled for. The relative risk estimated from the coefficient of each variable indicated that breastfeeding had a strong, negative effect on infant mortality; however, its effect declined as the child aged. The effects of environmental and health care factors were weak and became nonsignificant when other variables were controlled for. Among other socioeconomic variables, which included place of residence and family economic condition, only the family economic condition still had a significant effect on mortality after controlling for other variables in the model.

It has been found that maternal education had strong associations with other socioeconomic and environmental factors. The effects of most demographic factors on infant mortality were minimally affected when maternal education was controlled. There were indications, however, of the interaction effects between maternal education and family economic condition, place of residence, maternal age at birth, sex of the child, birth order greater than one and short preceding birth intervals, and health care service utilization. Risks of being exposed to these factors were lower among mothers with high education than those with low education. Yet, only the effects of place of residence, birth order greater than one with short preceding birth intervals, and health care utilization were significantly reduced by changing maternal education from low education (less than secondary level) to high education (secondary level or higher). As expected, the effect of maternal education was stronger in the rural area; but its effect was no longer significant when the analysis was stratified by the family economic condition. The following sections will discuss the results from this study in more detail.

2. Discussion

2.1. Comparison of the Multiplicative and Additive Relative Risk

The proportional hazards model with multiplicative risk function assumed that the covariates affect the baseline hazard rate in a multiplicative manner, while the model with an additive risk function assumed that the risk associated with a covariate was to add to the baseline hazard rate. Results from the comparisons between these two risk functions showed that socioeconomic and demographic factors acted multiplicatively on infant mortality data in the *1987 Thailand Demographic and Health Survey*.

In the univariate analyses, the coefficients of dichotomous variables with mean value or a probability of being in category of one (p) less than 0.3077, estimated by the multiplicative risk function, had smaller standard deviation and higher level of significance than those estimated by the additive risk function. The opposite was true for those with a probability of being in one (p) greater than 0.5. Disregarding the levels of the significance of their coefficient estimates, relative risks estimated from the multiplicative risk function were closer to the observed values and were all higher than those estimated from the additive risk function. It was also true for the multivariate analyses.

Previous studies found that the multiplicative risk function could underestimate the rates of the events when the true relationship was linear and the events were low (Greenland, 1979; Thomas, 1981; Breslow and Storer, 1985). It has been noticed from this study that all the estimates for the baseline categories of the additive risk function (when all covariates had values of zero) were higher than both the observed values and those estimated from the multiplicative risk function. This could possibly cause the lower relative risk estimates for the additive risk function. A different statistical method was needed to arrive at unbiased results that could be generalized to other circumstances.

The additive risk function gave rise to negative estimates as well, particularly when the estimates involved maternal education. The problem of having negative estimates from the additive risk function was also experienced by others (Walter and Holford, 1978; Saseini, 1992). In this study, the problem was perhaps caused by the low level of mortality which caused to be $1 + \Sigma\beta_i z_i$ less than zero. In addition, one restriction in estimation by using the additive risk was that the baseline category must be the one with the lowest risk, so that the estimates would not be negative. In the case of maternal education, the degree of risk proved to be the opposite. The higher the education, the lower the risk. This, together with low mortality rate, could give rise to negative estimates.

One difficulty in fitting the additive risk function to infant mortality data was the number of covariates included in the model. While the multiplicative risk function could give estimates for all combination of variables, the additive risk function could not handle many variables in the model, especially when maternal education and maternal age at birth were in the same model with other variables. This could be due to the fact that the number of deaths was too small to make the likelihood of the additive risk function reasonably approximate by a quadratic function over the range of plausible β values (Walter and Holford, 1978; Prentice and Mason, 1985). This problem was also experienced by others (Walter and Holford, 1978, Sankrithi, Emmanuel, and Van Belle, 1991; Saiseini, 1992).

When the data were broken down into many categories and the number of samples and failures for each category was small, the relative risk and the goodness-of-fit may not be a good choice in the comparison study. The reason was that the confidence intervals for relative risks would be extremely wide, as in the case of demographic model, where 95% confidence intervals of the observed relative risks were remarkably wide. For the goodness-of-fit test, when the number in any category was less than five, the test was not reliable.

Results from this study were different from those of Thomas (1981) and Breslow and Storer (1985), which found the additive risk function fit their data better than the multiplicative one. Their studies and this study differed in the type of data and the explanatory variables under study. The distributions of the response in the dose-response data were generally linear: the response increased with dose and time. The distribution of mortality rates during the first year of life, however, was basically non-linear: high during the first month, then dropped and leveled off. The additive risk function was probably not appropriate for this type of data. Moreover, rates of response in their studies were much higher than the mortality rate in this study. Rates of response in the study of Breslow and Storer, for example, ranged from 155/1,00 population to 206/1,000 population, while mortality rate in this study was 29/1,000 live births (Breslow and Storer, 1985). If the mortality rates were moderate, the additive risk function was probably applicable.

2.2. The Relationships Between Maternal Education and Other Variables

This study focused on the association between maternal education and other socioeconomic, demographic, environmental, and health care factors in relation to infant mortality. It also focused on investigating the modifying effect of maternal education on the above variables in relation to infant mortality, so that the target population could be effectively identified and planned interventions to reduce infant mortality could be made accordingly.

Results from this study showed that maternal education played an important role in reducing infant mortality in Thailand, even when all other socioeconomic, demographic, environmental and health care factors were controlled for. The increase in one year of maternal education, controlling for all variables in the model, could reduce risk of infant mortality by 10%.

It was expected that the effects of the other more proximate variables, such as maternal age at birth, birth intervals, birth order, environmental and health care factors on infant mortality, would be modified by maternal education. The relative risks associated with these factors should be weaker for mothers with higher education, since it was assumed that maternal education was related with socioeconomic status, higher standard of living and appropriate health behaviors that contributed to the survivorship of the infants.

Results from this study suggested that maternal education was correlated with family economic condition, place of residence, birth order greater than one with long birth intervals (at least 24 months) and toilet facilities in relation to infant mortality. There was evidence of the interactions between maternal education and family economic condition, place of residence, maternal age at birth, short preceding birth intervals, sex of the child, and health care utilization. These relationships will be discussed in the following sections.

a. Maternal Education and the Family Economic Condition

This study did not assume a causal relationship between maternal education and the family economic condition since the causal relationship could be in either direction. It was possible that mothers with higher education came from wealthy families or that education enabled mothers to acquire higher economic status, such as having a better paying job or having a well-to-do husband (Ware, 1984).

Results from this study showed that maternal education had a close relationship with the family economic condition. It also modified the effects of family economic condition, though this modifying effect was not statistically significant. In general, mothers with higher education had higher economic scores. As a result, mothers with higher education were able to enjoy higher standards of living and healthier lives which could be reflected in maternal nutritional status. This, in turn, contributed to the healthy biological growth and development of the fetus and infant. Table 4.5 in Chapter 4 showed that the effect of the family economic condition was stronger during the neonatal than the post-neonatal period, supporting this notion.

The effect of the family economic condition on infant mortality was reduced substantially when maternal education was controlled for, implying high correlation between this variable and maternal education. As expected, the effect of the latter variable was stronger among mothers with low education. Among infants born to families of low economic condition, those who were born to mothers with higher education had risk of mortality 79% less than those born to mothers with low education. This suggested that education could modify the negative effect of economic disadvantages on the survivorship of the infants, possibly due to the skills and knowledge of educated mothers on disease causation and prevention (Fosu, 1981; Caldwell, 1979).

b. Maternal Education and Place of Residence

In this sample, mothers with high education were more likely to live in the urban areas than those with low education. Although the effect of place of residence on infant mortality was not significant when all other variables were controlled for, there was evidence of interaction between this variable and maternal education. Not surprisingly, among mothers with higher education, those who lived in rural areas had a risk of infant mortality 59% less than those who lived in urban areas, though the effect was not significant. It was also evident in the stratified analysis by place of residence that, for those who lived in rural areas, a one year increase in mothers' education reduced infant mortality by 13%, while the effect of education in the urban areas was almost nil.

In rural areas, post-neonatal mortality is substantial, but in urban areas most infant mortality is concentrated in the neonatal period. This was evident from this study that among mothers with high education in urban areas, 90% of infant deaths occurred during neonatal period compared to 43% of neonatal deaths among infants born to mothers with high education in rural areas. Because knowledge and child care behavior that may be altered by mother's education are likely to have larger impact during post-neonatal period. It is thus not surprising that the effect of mother's education is higher in rural than in urban areas.

A study in Liberia found infant mortality was lower in rural than in urban areas. The authors had attributed this phenomenon to the effects of pollution and poor sanitation in urban areas which could have negative effects on the survivorship of small children (Ahmad, et al., 1991).

c. Maternal Education and Demographic Factors

It was speculated that being in school would postpone the age at first marriage of a woman; therefore, age at first marriage should be positively related to mother's educational levels. Results from this study showed that age at first marriage and age at first birth were weakly linearly related to maternal education. Only mothers with education higher than secondary level that were married for the first time and had first baby noticeably later than others. Ages at first marriage were 18.4, 19.4, 20.7 and 24.9 years for mothers with no education, primary, secondary and higher education, respectively; while ages at first birth for the respective mothers were 20.5, 21.1, 22.4 and 26.6 years.

On the average, the interval between the first marriage and the first birth among women in this sample was about two years. Nonetheless, comparing the average birth intervals and number of children ever born to mothers with higher education to that of mothers with lower education, it appeared that mothers with higher education were more likely to have children within a certain age span and stopped having children earlier. Evidently, the effect of maternal education on reproductive behavior was small. This could be due to the fact that the Thai government has made an effort to provide family planning services to all areas in the country since the 1970s, which might have had more impact on the reproductive behavior of the women than the level of education. The results were consistent with the study of Cleland and van Ginneken, which found no effect of maternal education on reproductive behavior of mothers (Cleland and van Ginneken, 1988).

From the multivariate analyses, the results from the full model indicated that the effects of the demographic factors on infant mortality, except for Bint2 (birth order greater than one with long birth intervals), were minimally affected by maternal education. The coefficient of birth order greater than one with long birth intervals became non-significant when maternal education was controlled for. This implied that the high risk of mortality of this variable was probably due to exogenous factors, such as crowding, family economic disadvantage, or domestic child care, which exposed children to nutritional deficiencies and infectious diseases.

There was evidence of interaction between maternal education and maternal age at birth, birth order, preceding birth intervals, and sex of the child. Risks of mortality were highest among infants born to mothers with low education, having inappropriate reproductive behavior, such as having birth at very young (less than 20 years) or very old (35 years or older) ages, having more births with short birth intervals; and they were lowest among those who were born to mothers with high education who had appropriate reproductive behavior. This was consistent with the study of Pebley and Stupp (1987) which found the effect of maternal age and preceding birth interval were strong among mothers with lower education (Pebley and Stupp, 1987). On the other hand, studies in Korea and Thailand found the effect of maternal education was modified by preceding birth intervals (Park, 1986; Park. et al., 1994). Though the reduction of risks of mortality associated with demographic factors due to maternal education ranged from 54% for maternal age to 87% for Bint1, only the reduction for Bint1 was statistically significant.

Results from this study implied that, except for birth order greater than one with short preceding birth intervals, only when mothers with high education have appropriate reproductive behaviors, their risk of having infant mortality would be significantly lower than that of mothers with low education, having inappropriate reproductive behavior.

d. Maternal Education and Environmental Factors

It was found from this study that more than 90 percent of people living in rural areas did not have access to safe drinking water, despite tremendous resources and efforts by the Thai government to supply safe water to rural areas from 1976 to 1986 (Porapakkham, 1986). There was indication of a relationship between maternal education and the availability of toilet facilities and sources of drinking water. About 88% of mothers with higher education had access to a sanitary toilet, while only 47% of mothers with low education did. For sources of drinking water, sad to say, only 59% mothers with higher education drank water from proper sources: tap water--private or public, and only 19% of those with lower education did. While other studies found significant effect of sanitary toilets and piped water on infant mortality (Patel, 1980; Martin, et al., 1983; Trussell, 1983; Crognier, 1987; Holian, 1988; Barbieri, 1990), this study, however, found that the effects of these two factors on infant mortality were weak and not significant when other variables under study were controlled for. The insignificance of these two factors was probably due to their high correlations with other variables in the model, such as maternal education, place of residence, and family economic condition. The poor distribution of sources of drinking water possibly contributed to the insignificance as well. Another possible reason for the insignificance of the toilet facilities, particularly in the rural areas, was those who had the toilets may not use them. This problem was especially serious in the rural northeast region where water resources were scarce. Though the coefficient of toilet facilities was reduced markedly when controlling for maternal education, its interaction with maternal education was not significant.

e. Maternal Education and Health Care Utilization

There was an indication of an association between maternal education and health care service utilization. The proportion of mothers with higher education who frequently use health care services was larger than that of mothers with lower education. This was consistent with the studies of Sullivan, Caldwell and colleague, Tekce and Shorter, Benyoussef and Wessen, which found positive correlations between maternal education and the use of health care services in Taiwan, India, Jordan and Tunisia, respectively (Benyoussef and Wessen, 1974; Sullivan, 1975; Caldwell, et al., 1983; Tekce and Shorter, 1984). In this study, health care service utilization did not have any significant effect on infant mortality after controlling for other variables under study, which was different from previous studies that found significant effects of health care service on infant mortality in both developed and developing countries (Shapiro, et al., 1965; Silva Aycaguer and Denan Macho, 1990; Macdorman and Rosenberg, 1991; Frankenberg, 1992).

The lack of significant effect in this study was possibly due to the fact that only the quantity but not the quality of services were taken into account. In rural areas, especially, this problem may be more serious. This was also evident on Table 5.19 that showed those living in rural areas who used health care services less frequently had lower infant mortality. It possibly reflected the inferior quality of health care services in rural areas or it could be the fact that those who used services more frequently had ill health or, in the case of pregnant women, had serious complications that needed special care.

Orubuloye and Caldwell found in Nigeria that the effect of maternal education on mortality of young children was stronger in the areas that had access to health care facilities (Orubuloye and Caldwell, 1975). On the other hand, Rozenzweig and Schultz found the effect of maternal education on child mortality attenuated in the areas where efficient health care programs were available (Rozenzweig and Schultz, 1982). In this study, there was evidence of the interaction between maternal education and health care service utilization. The relative risk associated with this variable was stronger among mothers with lower education and risks of mortality would be significantly reduced only if mothers with high education use health care services more frequently.

3. Conclusion

Mensch and others have emphasized the importance of the role of maternal education in reducing infant mortality in developing countries (Mensch, et al., 1983). Results from this study suggested that, in Thailand, maternal education, having a close relationship with the family economic condition, was an important factor in reducing infant mortality. Without any interaction with other variables under study, it could reduce infant mortality by 10%. The mortality reduction was even greater when education interacted with other socioeconomic, demographic, and health care factors. If mothers with secondary or higher education had the appropriate reproductive behavior, infant mortality would be significantly lower than those with education less than secondary level who had inappropriate reproductive behavior.

It was found that education could modify the negative effects of place of residence, high birth order and short birth intervals, and health care use. The results also suggested that mothers with higher education probably used health care services more efficiently than those with lower education.

As a result of this study, the following suggestions are offered as ways to reduce infant mortality in Thailand:

3.1. It was found that though only 8% of the women in this sample had no formal education, yet about 40% of them either could not read or had difficulties reading. Since reading could expand the knowledge and deepen the perspective of a person, the government should ensure that all those graduating from school could read with comprehension, thus, the quality of education should be strengthened and controlled.

3.2. Since it was evident from this study that the relationships between the socioeconomic and demographic factors in relation to infant mortality were complicated, a combined effort among different governmental departments, such as education, public health, economic, community development and community participation was needed to reduce infant mortality in Thailand.

3.3. Programs providing and maintaining safe drinking water supplies should be launched and carried out by local authorities. A more serious effort should be made in rural areas, where safe drinking water tends to be a major problem.

3.4. It was found from this study that the more education a mother had, the shorter she breastfed her child. This was applicable to all educated women, working or not. Since it was shown that breastfeeding had the greatest effect on infant mortality, health personnel or anyone responsible should encourage mothers to breastfeed their children longer. Special programs should be initiated so that working mothers could be encouraged to nurse their children during working hours.

3.5. Those who lived in urban areas where safe water supplies were not available or accessible should receive more attention from local health personnel.

There are some questions that could not be answered by this study due to the lack of information, such as the relationships between maternal education and other factors such as skills and knowledge about disease causation, prevention and control, self confidence, and power in making decisions. The questions were also raised whether mothers with higher education delivered healthier babies than mothers with lower education. Results from this study showed that the majority of infant deaths among mothers with higher education occurred during neonatal period. This could be caused by genetic factors or birth injuries or maternal conditions, etc.

A further study should be conducted with more detailed information on factors such as domestic child care, quality of health care services in the areas, the infant's birth weight, causes of infant death, nutritional status of mothers, etc., to get clearer answers. A case-control study with in-depth interviews is recommended to elicit the above information for a better understanding of the role of mother's education in reducing infant mortality. The links between birth and death certificates may have to be carried out to obtain an accurate information on birth weights and causes of death.

The results of this study have contributed towards understanding the role of maternal education in reducing infant mortality in Thailand. It has shown that maternal education is able to modify the negative effects of some risk factors. The identification of the target groups and means to reduce infant mortality can be made more effectively by applying the results from this study.

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