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The Determinants of Birth Interval in Ahvaz-Iran: A Graphical Chain Modelling Approach

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Abstract: Birth interval is a major determinant of the rates of fertility. In this paper a graphical modelling approach is used to study the effect of different socio-economic factors on birth intervals of children in Ahvaz-Iran. This approach provides an easily interpretable empirical description and illustrates explicitly the conditional independence structure between each pair of variables. The interpretation can be read directly from a mathematical graph. Besides examining the direct association of each determinant on birth interval, we also examine the effects of socio-economic determinants on intermediate determinants to understand the pathways through which the socio-economic determinants affect the birth interval. The data analysed come from a sample of women referred to "Health and Medical Centres" during October and November 2002.

Key words: Birth interval, graphical modelling, Iran, mortality.

1. Introduction

Event histories such as birth, pregnancy and marriage have been used by social scientists to study fertility behavior of women. Birth history analysis undoubtedly provides useful information regarding reproduction and family formation. Fertility depends not only on the decisions of couples but also on many socioeconomic, demographic, health-related as well as tradition-related and emotional factors. The factors affecting fertility may have varying effects on child spacing. Thus, birth intervals experienced by women may reveal some insights about their reproduction patterns. Moreover, a detailed analysis of the sequence of steps in the childbearing process could provide a more comprehensive picture of the dynamics of fertility transitions (Hirschman and Rindfuss, 1980).

Bongaart (1978) found that the level of fertility in a group of women depends mainly on four intermediate variables: the proportion that is married, postpartum infecundability, contraception and induced abortion. In other words, differences in exposure to the risk of pregnancy and differences in the length of time between births when women are exposed may contribute to differentials in childbearing levels (Trussell *et al.*, 1985). Whatever the cause, the length of birth intervals may vary from one population of women to another.

Social scientists believe that differences in birth interval lengths are explained by varying breastfeeding patterns, contraceptive use, frequency of intercourse, incidence of abortion and fecundity (Trussell *et al.*, 1985). Differences in other factors such as women's roles and status and the value of children may also influence the birth intervals. There is no doubt that the socioeconomic, demographic, health and cultural background of a country, consequently that of women, affects the above factors.

Women's education and age at marriage are the most widely analysed determinants of birth intervals. The former is found to have a substantial effect on birth interval (Hirschman and Rindfuss, 1980; Rindfuss *et al.*, 1983). However, in a study done in a village of Kerala State in India, Nair (1996) did not find any significant effects in terms of the education of women on the birth intervals. In addition, female education was found to be an insignificant determinant of the risk of pregnancy in Malaysia, Philippines and Indonesia. Nevertheless, male education and occupation were found to be significant determinants of fertility in Indonesia and Philippines (Trussel *et al.*, 1985).

Age at marriage is considered to be an important variable in the fertility process. If couples marry at a very young age, decisions on number of children, use of contraceptives and the like may be formed at a less mature age, consequently affecting the birth interval (Bumpass *et al.*, 1978). Furthermore, since the effect of age at marriage possibly operates through biological and maturational factors rather than with respect to coital frequency (Kallan and Udry, 1986), age at marriage may have a varied effect on different birth intervals. For young women, West (1987) found that the first birth is an important determinant at the transition from parity one to parity two. For older women, he found its importance at the transition from parity two to parity three. Interestingly, his findings also showed that the younger a woman is at first birth, the higher the transition probability. In another study, Abdel-Aziz (1983) concluded that the later a Jordanian girl marries, the swifter she will bear her first child. A similar result was found in Nepal. The women of Tamang ethnicity, who married at age 19 or older, had higher chances of childbirth than those marrying at younger age (Fricke and Teachman, 1993).

A couple's decision on the timing of the first baby or the second or the third may depend on traditional norms and cultural practices as well. Ethnicity was found to be an important determinant of pregnancy in Malaysia (Rindfuss et al., 1983). Nair's (1996) analysis of birth intervals suggested that a significant differential existed between Hindus and Muslims in Kerala for the first and the second intervals, but not for the third birth interval. This suggests that religion is an important factor in the fertility behaviour of women in Asia. Suwal (2001) considered socio-cultural dynamic of birth intervals in Nepal. She found that different births are given varied importance in Nepalese society and first births are much more important than the subsequent births. Rashid Manan (1997) Studied effects of lactation, contraception and other factors on birth intervals in Bangladesh.

This article intends to explore several questions regarding the socioeconomic, demographic, cultural differential and health-related factors on birth intervals, of children in Ahvaz-Iran, using a graphical modelling approach. This approach provides an easily interpretable empirical description and illustrates explicitly the conditional independence structure between each pair of variables. The interpretation can be read directly from a mathematical graph. Besides examining the direct association of each determinant on birth intervals, we also examine the effects of socio-economic determinants on intermediate determinants to understand the pathways through which the socio-economic determinants affect the birth interval.

In the next section we give a brief review of the graphical modelling with the emphasis on graphical chain models and in section 3 we introduce the collected data set, the conceptual framework and model selection procedure. In section 4 we consider results of the different chain graph fitted models including cultural and views model, demographic and socio-economic model and health-related model.

2. Graphical Modelling

Empirical studies typically involve a huge number of variables being collected on the subjects of interest. Although in general the primary research question addresses the explanation of one or more response variables by certain explanatory variables, it is often also of interest to determine the complete association structure among all variables. This cannot be done within most multivariate models. In addition, many models cannot cope with situations in which indirect influences are to be investigated. Besides the fact that the analysis of such high-dimensional data structures is complex and time-consuming by its very nature, an important aspect concerns the representation of the model, which should be comprehensible to the data owner and easy to communicate.

The problems related to modelling and representing complex association structures can be tackled within the framework of graphical models, which have been established, mainly by Darroch, Lauritzen and Speed (1980), Lauritzen and Wermuth (1989), Wermuth and Lauritzen (1990), Cox and Wermuth (1993) and Wermuth, Cox and Pearl (1998). Graphical models combine a statistical model with its representation as a graph, where the underlying key concepts are conditional and marginal independence between the variables incorporated in the analysis. For introductory books in the theoretical methodology of graphical models, see for instance Edwards (2000) and Lauritzen (1996). The book by Cox and Wermuth (1996) additionally provides approaches for model fitting strategies and hints for interpreting graphical models.

2.1 Some basic notations of graphical chain models

For convenience, let us first recall the basic notations and the theoretical background of graphical models with a special focus on graphical chain models. The main idea of graphical models is the graphical representation of a multivariate association structure of a random vector in which marginal or conditional independencies are reflected. For this purpose, it has to be clarified first how to represent a statistical model by a graph and second how to ensure that certain statistical properties may be read off from the graph directly.

Following the terminology introduced by Lauritzen and Wermuth (1989), $X_W = (Y', I')'$ denotes a random vector in which Y consists of r continuous random variables and I of q discrete variables. The realizations of Y are given as $y \in R^r$ and the set of all possible realizations i of I is given as $\mathcal{I}$. Accordingly, the index set W consists of two disjoint subsets Γ and Δ (i.e. $W = \Gamma \cup \Delta, \gamma \cap \Delta = \emptyset$) with Δ denoting the index set of discrete and Γ that of continuous components. The most common and probably the most important family of distributions for such a mixed random vector is the conditional Gaussian (CG-) distribution, which assumes a multivariate normal distribution of Y given $I = i$ (Lauritzen and Wermuth, 1989).

A graph $G = (W, E)$ is now given by a nonempty finite set W of vertices representing the random variables and a set $E \subset W \times W$ of edges representing the associations between pairs of variables. In the graphical representation, we use dots for the discrete and circles for the continuous variables. Undirected edges are drawn as lines, directed edges (a, b) as arrows pointing from a to b, where an undirected edge reflects a symmetric association between X_a and X_b and a directed one an asymmetric association with X_a being regarded as explanatory for X_b.

In general, independencies are represented by missing edges. It is of interest how to interpret missing edges with respect to the underlying family of multivariate distributions. Here, it is necessary to distinguish between directed and undirected graphs, where chain graphs play a special role among the directed graphs. Chain graphs contain both directed and undirected edges. They are based on a partition of W into disjoint chain components (blocks) $B_1, \ldots, B_T$. Edges within one component are always undirected and edges between variables belonging to different components are always directed. Usually, the components are ordered from right to left such that the extreme right box contains pure influence variables and the extreme left box the pure responses. In between, we find all variables, which are simultaneously responses, and explanatory variables, the so-called intermediates (see Cox and Wermuth, 1993). Coming back to the related statistical models, marginal or conditional independencies can be read off from the graph, if the family of distributions fulfills the so-called Markov properties. These properties are the link between graph theoretic concepts like missing edges and statistical concepts such as independencies. In the case of chain graphs, it can be shown that the different kinds of Markov properties are equivalent for CG-distributions (Frydenberg, 1990).

It should be noted that the properties of the graph could not only be used to read off from the graph certain independencies but that they are also very useful concerning the statistical analysis of a multivariate data set as for instance regarding a simplification of the underlying estimation problem.

2.2 Fitting a graphical chain model

The theoretical background for analyzing graphical models is well known but the question arises how these models can be used for practical purposes. Here, the most challenging problem concerns the model fit. In a first step, it has to be decided which type of model is most appropriate to analyze the research question, i.e. among others it has to be decided whether conditional or marginal independencies are to be investigated and whether a directed or an undirected graph is more adequate. In the following, we consider concentration graphs, which model conditional independencies and we focus on the most complex problem of fitting chain graphs. For this purpose, we can make use of the fact that the joint density factorizes into a product of several conditional densities and one marginal density with respect to G as follows

$$f_W = f_{B_T|B_{T-1}\cdots B_1} \cdot f_{B_T|B_{T-2}\cdots B_1} \cdots f_{B_1|B_1} f_{B_1}.$$

Assuming now a conditional CG-distribution for each conditional density, a so-called CG-regression, the joint distribution of X_W is called a recursive multivariate CG-regression (Lauritzen and Wermuth, 1989).

In an empirical study, this dependence chain, i.e. the partition of W into the components (blocks) $B_1, \ldots, B_T$, is postulated by the researcher, which then results in the above factorization of the likelihood. Thus, this factorization can also be justified from subject-matter knowledge. These blocks are completely ordered to form a chain. The elements in B_1 are potential causes of the elements in B_2, the elements in B_1 and B_2 are potential causes of the elements in B_3, etc. If there are two or more elements in a block, other than B_1, then they are considered as a multivariate response to the elements in the preceding blocks. Any association between two variables from the same block is assumed to be non-causal and is represented by an undirected edge (line), whereas any association between two variables from different blocks is potentially causal and is represented by a directed edge (arrow). A graphical chain model displays the pairwise independence between variables conditioned on all the other variables in the current and previous blocks. Therefore, the major difference between a graphical model with no directed edges and graphical chain models is that for an undirected graph the independence statements concern a single joint distribution, whereas for a chain graph they concern one marginal distribution and a sequence of conditional distributions (see Cox and Wermuth, 1996).

In the modelling process a series of models is fitted. The first is fitted to the marginal variables in B_1 and is a model for the marginal distribution of these variables. The second is fitted to the marginal variables in B_1 and B_2, and is a model for the conditional distribution of the variables in B_2 given the variables in B_1. The procedure continues by modelling the conditional distribution of the variables in B_i given the variables in $B_1, \ldots, B_{i-1}$, for $i = 2, \ldots, T$. The second and subsequent models contain both explanatory and response variables. When modelling the conditional distribution of the variables in a block given the variables in the pervious blocks all interactions between the explanatory variables are included in the model. Note that depending on the nature of both the explanatory and response variables appropriate regression models can be used to build the graphical chain model, provided that they permit tests of conditional independence to be performed. For example, a log-linear model for discrete variables, a multinomial logistic model, which takes into account ordinal nature of response variable, and a mixture of categorical and continuous explanatory variables, or a linear regression model if the response is continuous.

3. Background and Study Data

As well as major decline in fertility rate, Iran's socio-economic situation has improved substantially. Income and level of education have increased. Basic facilities such as water supply, electricity, sewage, sanitation and health services are now available to a wider population than in past years. These trends will have an indirect effect on the fertility and related factors including birth intervals.

In this study we examine regional and temporal variables as well as some other socio-economic and intermediate factors on birth intervals. The factors are ordered in such a way that the effects of socio-economic factors on intermediate factors can be examined as well as their effects on the birth intervals. This provides direct and indirect pathways from each of the determinants to the birth intervals. The data used in this paper contain a sample of 965 married women aged 18-49 years that referred to "Health and Medical Centres" in Ahvaz city,

Table 1: Description of quantitative variables

Variable	Scale
Women's (men) view about no. of child	Number
Women's(men) view about birth interval (BI)	Month
Women's(men) access to media	Score 4-12
Women's age at 1st marriage	Year
1-st child breast-feeding duration	Month
2-nd child breast-feeding duration	Month
No. of abortion before 1st birth	Number
No. of abortion before 2nd birth	Number
No. of abortion before 3rd birth	Number

Table 2: Description of categorical variables

Variable	Categories
Birth interval	No interval (ref.), $<$ 18 months, 18-35 months, $> 35 months$
Contraceptive use	Natural method (ref.), Supply method, None
Women's (men) sex preference	No preference (ref.), Boy, Girl
Women's occupation	Housewife (ref.), Working
Men's occupation	High class[1](ref.), Middle class[2], Low class[3], Lower class[4]
Women's education level	University (ref.), High school, Secondary, Primary, None
Sex of preceding child	No child (ref.), Boy, Girl
Relative interferences	No(ref), Yes
Women's(men) ethnicity	Persian(ref), Arab, Bakhtiari, Others
Residential home	Owner (ref), Rent, Others
Childbearing method	Normal, Abnormal

[1]Managers, Universsity professors and Doctors
[2]Teachers, Officers and Engineers
[3]Ordinary officers, Employers and Non professional own account workers
[4]Farmers, Fishers and Unskilled workers

the capital of Khuzestan provenance in south west of Iran during October and November 2002. For the collection of data, we used intensively trained and supervised teams of female interviewers. Because of the personal nature of the survey content and cultural situation of region, we used female interviewers for administration. The data consist of birth intervals, couples and their relative's views about child, socio-economic, demographic and health-related variables of couples.

We considered the birth intervals of up to three children and we defined each interval as categorical variable with four categories including a "no interval" category. The categories are "no interval", less than 18 months, 18-35 months and more than 35 months and they have been coded from 0 to 4, respectively. For the first birth interval "no interval" indicates that a couple has no child and for the second birth interval "no interval" shows that a couple has one child and finally, for the third birth interval "no interval" refers to a couple with two children. The "no interval" category will facilitate the use of all data in modelling effects of determinants on birth intervals simultaneously. Tables 1 and 2 present a brief description of quantitative and categorical variables.

3.1 The conceptual framework and model selection

The conceptual framework for this study is as follows: We partitioned the explanatory variables into three sets which are cultural and views variables, demographic and socio-economic variables, and health-related variables. We considered graphical chain model of each set of variables with birth intervals of up to three children. We divided variables of each partition into blocks based on temporal sequence and possible causal direction.

The cultural and views variables are divided in six blocks. There are three variables in the first block: relative interferences, women and men's access to media. Block 2 contains six variables: women and men's view about the number of child, birth intervals and the sex of child. Block 3 contains contraceptive use and blocks 4 to 6 are allocated to first, second and third birth intervals, respectively.

The demographic and socio-economic variables are partitioned into six blocks. The variables in first block are women and men's ethnicity and those in block 2 are couple's education levels. Block 3 contains four variables: age of women at first marriage, job category of women and men and residential home category. Blocks 4 to 6 are allocated to first, second and third birth intervals, respectively.

Finally, the health-related variables are divided into six blocks. The first block contains the number of abortions and contraceptive use before the first birth. In the second block there are four variables, related to the first child: sex, breast-feeding duration, birth interval and childbearing method. The third block contains number of abortions and contraceptive use before the second birth. In the forth block there are four variables, related to the second child: sex, breast-feeding duration, birth interval and childbearing method. The number of abortions and contraceptive use before the third birth are given in the fifth block and the sixth block is allocated to the third birth interval.

In practice fitting a graphical model to a high-dimensional data is currently still rather cumbersome since mixed data with a large number of variables cannot be handled easily. Therefore, in this study we have used a heuristic strategy introduced by Cox and Wermuth (1996) for each partition. This strategy is mainly based on the calculation of univariate regression models where it is roughly divided in two steps. First, a screening is performed regarding possible second order interaction and non-linear relations. The screening for interactions and non-linearities is performed separately for each chain and involves all the variables. Only those interactions and non-linear relations showing statistical relevance are selected. The screening tests (Cox and Wermuth, 1994) are based on testing the systematic departure from multivariate normality. To detect significant cross-product terms, the t-values from trivariate linear regressions, such as that of a response variable on X_i and X_j and $X_i * X + j$, are examined. In absence of interactions, for large sample sizes, the studentized t-statistics approximately follows a standard normal distribution. The screening for non-linearities proceeds likewise. Quadratic terms only are included since Taylor expansions up to the second order are a good approximation tool of non-linear dependency in a large framework. Normal probability plots are drawn to find out eventual departure points denoting significant quadratic effects.

The second step consists of forward and backward regressions depending on the scale of the response variable. This step consists in investigating the form of the conditional distributions by means of separate regression analyses. A system of univariate regressions is performed for each chain component. The model type is related to the scale of the selected response variables, according to the postulated chain.

4. Findings

In this section we discuss how, starting from both statistical as well as sociological considerations, it is possible to investigate and visualize through the final chains the determinants of birth intervals. We analyzed the data with the aid of the framework introduced above for each partition.

For the first two partitions, we started from first block (right box) and a log linear model is fitted to the marginal variables in this block. Then the marginal variables in first and second blocks are selected and each variable in the second block modeled against variables in first block and the remaining variables in the second block. In the next step, the same procedure was repeated for each variable in third block as the response variable against the variables in previous blocks and the remaining variables in third block. Then we fitted a logistic regression model for multinomial response (see Agresti, 2002) to the variable in the block 4 (1-st birth interval) versus variables in previous blocks. The same models were fitted for the variables (2nd and 3rd birth intervals) in blocks 5 and 6. The procedure for the third partition (Health-related model) is slightly different due to the order of 1-st and 2-nd birth intervals in the blocks. In this case the 1-st and 2-nd birth intervals are in the second and forth blocks, respectively. Therefore, the model for 1-st birth contains the variables of the first block and the remaining variables of the second block. Furthermore, the model for 2nd birth interval also contains the variables of the previous blocks and the other variables in 4-th block.

Due to limitation of space in the next sections we only present the final chain graph of each partition and tables of the results of modelling birth intervals as response variables against the significant explanatory variables. This includes the estimated log odd-ratios for the direct associations between each interval and significant explanatory variables. The data were analysed using the GraphFitI Statistical package (see, Blauth *et al.*, 2000).

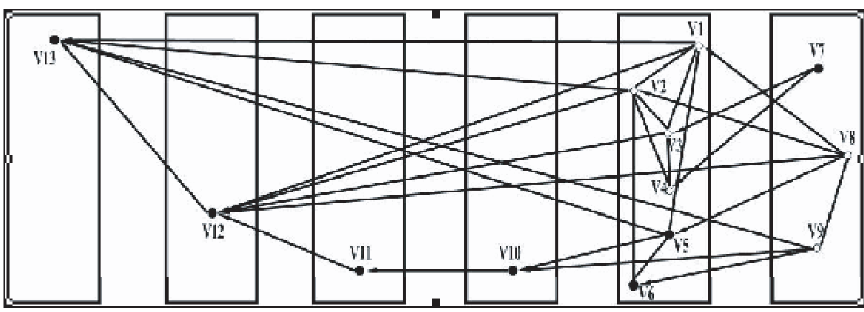

Figure 1: Chain graph of birth intervals, cultural and views variables
V1: Women's view about no. of child; V2: Men's view about no. of child ; V3: Women's view about birth intervals ; V4: Men's view about birth intervals ; V5: Women's sex preference; V6: Men's sex preference; V7: Relative interferences; V8: Women's access to media ; V9: Men's access to media ; V10: Contraceptive use; V11: 1-st birth interval; V12: 2-nd birth interval ; V13: 3-rd birth interval.

4.1 Cultural and views model

The chain graph presented in Figure 1 shows the direct and indirect associations of cultural and views variables with birth intervals. Estimated coefficients for the direct associations between each interval and the other variables are given in Tables 3-5. These coefficients are the log-odds ratio of significant explanatory variables (with significant level 0.05) on birth intervals with "no interval" as reference category from a multinomial logistic regression model. It should be remember that, to keep down the size of tables, the no interval category columns are not given in the tables of this section and the next sections.

A glance at the Figure 1 and results given in the Tables 3-5 show that 1-st birth interval is only directly affected by contraceptive use and some of the other variables including couple's access to media have indirect effect on 1-st birth interval through this variable. However, 2-nd and 3-rd birth intervals have direct and indirect association with more variables.

Table 3: Estimated log-odd ratios of cultural and views variables on 1-st birth interval

Variable	1-st birth interval (months)		
	< 18	18-35	> 35
Constant	1.3	1.002	-0.73
Contraceptive use			
Supply method	0.89	0.70	1.26
None	2.17	1.31	2.11
Natural method (ref.[1])	-	-	-

[1]Reference category

The 2-nd birth interval has direct relation with 1-st birth interval, women and men's views about number of child, women's view about birth interval and access to media. The variables, contraceptive use, relative interferences (no, yes), men's view about birth interval and access to media and women and men's sex preference have indirect association with 2-nd birth interval.

The 3-rd birth interval has direct relation with 2-nd birth interval, men's access to media, women and men's views about number of child and women's sex preference. The variables, contraceptive use, women and men's views about birth interval, men's sex preference, relative interferences and women's access to media have indirect effect on 3rd birth interval.

The estimated log-odd ratios in Table 3 show that comparing with those using natural method, couples using supply method have more chance of longer 1-st birth interval. Different results can be drive from Table 4. Among those we can refer to the reciprocal effect of women's access to media and view about number of child on the 2-nd birth interval. Furthermore, couples with the longer 1-st birth interval have more chance of long 2-nd birth interval.

Table 4: Estimated log-odd ratios of 1-st birth interval, cultural & views variables on 2-nd birth interval

Variable (main effects)	1-st birth interval (months)		
	< 18	18-35	> 35
Constant	−19.76	−19.34	−19.18
1-st birth interval			
< 18 months	15.95	17.06	15.85
18-35 months	18.54	16.92	16.70
> 35 months	12.11	20.59	18.16
No interval (ref.)	–	–	–
Women's view no. of childen	−0.024	−0.11	−0.001
Women's view about BI	0.004	−0.17	0.012
Women's asses to media	−0.84	−0.77	−0.91
Men's view no. of children	0.43	0.44	0.41
Variable (interactions)	**1-st birth interval (months)**		
	< 18	18-35	> 35
1-st BI*Women's view about no. of child			
< 18 * No. of child	1.25	1.02	0.75
18-35 * No. of child	0.65	0.93	0.53
> 35 * No. of child	1.23	0.27	0.26
1-st BI * Women's access to media			
< 18 * access to media	0.68	0.74	1.01
18-35 * access to media	0.47	0.76	0.92
No. of children			
Women's view * Men's view	−0.17	−0.18	−0.27

The estimated log-odd ratios in Table 5 indicate that couples with the longer 2-nd birth interval have more chance of the shorter 3-rd birth interval. Women's sex preference, views of women and men about the number of child and men's access to media have reverse relation with 3-rd birth interval. Women's view about the number of child has more effect on 3-rd birth interval than men's view. The interaction between 1-st birth interval and women's view about the number of child indicates that with the exceed of number of child, women with short 1-st birth interval have more chance of short 3-rd birth interval, while those with long 1st birth interval have less chance of short 3-rd birth interval. It should be mention that couple's view about birth intervals are measured according to year and couple's access to media are measured with Guttman scale (score 4-12).

Table 5: Estimated log-odd ratios of previous birth intervals, cultural and views variables on 3-rd birth interval

Variable (main effects)	1-st birth interval (months)		
	< 18	18-35	> 35
Constant	−21.03	−20.99	−20.91
2-nd birth interval			
< 18 months	22.26	17.94	20.61
18-35 months	19.11	19.12	17.67
> 35 months	19.44	18.34	17.13
No interval (ref.)	–	–	–
Women's view no. of childen	−0.46	−0.45	−0.43
Men's view no. of children	−0.24	−0.23	−0.26
Women's sex preference			
Boy	−0.31	−0.43	−0.91
Girl	−1.41	−1.43	−1.13
No preference (ref.)	–	–	–
Men's access to media	−0.79	−0.80	−0.80
Variable (interactions)	**3-rd birth interval (months)**		
	< 18	18-35	> 35
1-st BI*Women's view about no. of child			
< 18 * No. of child	0.81	0.89	0.36
18-35 * No. of child	0.83	0.81	1.15
> 35 * No. of child	0.60	0.64	1.45
< 18 * Boy preference	0.25	0.29	0.22
18-35 * Girl preference	0.24	0.84	0.89
> 35 * No preference	0.72	0.69	0.89
1-st BI * Men's view			
< 18 * No. of child	0.92	0.88	0.47
18-35 * No. of child	0.65	0.69	0.50
> 35 * No. of child	0.42	0.44	0.42

4.2 Demographic and socio-economic model

The chain graph presented in Figure 2 shows the direct and indirect associations of demographic and socio-economic variables with birth intervals. Estimated log odd-ratios for the direct associations between each interval and significant explanatory variables (with significant level 0.05) are given in Tables 6-8.

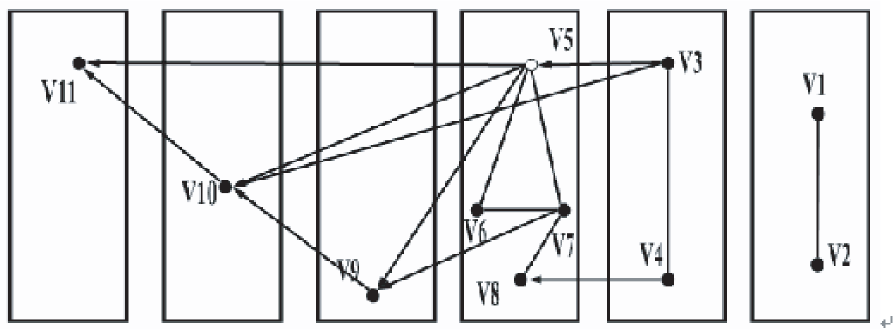

Figure 2: Chain graph of birth intervals, demographic and socio-economic variables
V1: Women's ethnicity; V2: Men's ethnicity; V3 Women's education level; V4: Men's education level; V5: Women's age at 1st marriage; V6: Residential home; V7: Women's occupation; V8: Men's occupation; V9: 1st birth interval; V10: 2nd birth interval; V11: 3rd birth interval.

Table 6: Estimated log-odd ratios of demographic and socio-economic variables on 1-st birth interval

Variable (main effects)	1-st birth interval (months)		
	< 18	18-35	> 35
Constant	3.51	3.46	3.53
Women's age at 1-st marriage (year)	−0.046	−0.086	−0.15
Women's occupation			
Housewife (ref.)	–	–	–
Working	−1.28	−1.17	−0.75
Women's age * Women's occupation	0.16	0.17	0.27

From Figure 2 we find out that only women's age at 1-st marriage and women's occupation have direct effect on 1-st birth interval. The women and men's education level, men's occupation and place of residence have indirect association with 1-st birth interval. The 2-nd birth interval is directly affected by 1-st birth interval, women's education level and women's age at 1-st marriage. The variables men's education level, place of residence and couple's occupation have indirect association with 2-nd birth interval. The 3-rd birth interval is directly related with 2nd birth interval and women's age at 1st marriage. The other variables have indirect relation with 3-rd birth interval mainly through previous birth intervals. The main ethnic categories in Ahvaz are known as Arab, Persian and Bakhtiari. However, we found no relation between ethnicity and birth intervals.

Table 7: Estimated log-odd ratios of 1-st birth interval, demographic and socio-economic variables on 2-nd birth interval

Variable (main effects)	2-ndt birth interval (months)		
	< 18	18-35	> 35
Constant	-17.14	-16.92	-14.53
1-st birth interval			
< 18 months	15.79	16.37	15.14
18-35 months	15.76	17.47	15.95
> 35 months	12.87	15.93	15.92
No interval (ref.)	-	-	-
Women's age at 1-st marrige	-0.45	-0.46	-0.53
Women's educational level			
None	2.07	1.77	-1.21
Primary	1.82	1.13	-0.63
Secondary	0.38	0.82	-0.31
High school	0.18	0.35	-0.56
University (ref.)	-	-	-
Variable (interactions)	**2-nd birth interval (months)**		
	< 18	18-35	> 35
1-st BI* Women's age at 1-st marrage			
< 18 * Women's age	0.42	0.42	0.50
18-35 * Women's age	0.40	0.36	0.44
> 35 * Women's age	0.52	0.43	0.40

The results in Table 6 suggest that working women have less chance of having 1-st birth in any intervals than housewife women. Furthermore, the chance of short 1-st birth interval will decline in working women. The odds of 2-nd birth before 35 month interval, in higher level educated women are less than lower level educated women (Table7). Finally, women's age at 1st marriage have decreasing effect on birth intervals and reduces the chance of births (Tables 6-8).

Table 8: Estimated log-odd ratios of previous birth intervals, demographic and socio-economic variables on 3-rd birth interval

Variable (main effects)	2-nd birth interval (months)		
	< 18	18-35	> 35
Constant	-19.11	-19.11	-19.11
2-nd birth interval			
< 18 months	23.31	21.46	19.79
18-35 months	21.80	19.89	20.32
> 35 months	18.34	17.12	20.10
No interval (ref.)	–	–	–
Women's age at 1−st marrige	-0.48	-0.48	-0.47
Variable (interactions)	**3-rd birth interval (months)**		
	< 18	18-35	> 35
2-nd BI* Women's age at 1-st marrage			
< 18 * Women's age	0.27	0.35	0.45
18-35 * Women's age	0.30	0.40	0.38
> 35 * Women's age	0.38	0.47	0.35

4.3 Health-related model

The order of blocks in health-related model is slightly different from previous models. In this case the 1-st and 2-nd birth intervals appear in second and forth blocks and so it could have casual effect on the variables in the next blocks.

The chain graph presented in Figure 3 shows the direct and indirect associations of health-related variables with birth intervals. Estimated coefficients for the direct associations between each interval and significant explanatory variables (with significant level 0.05) are given in Tables 9-10.

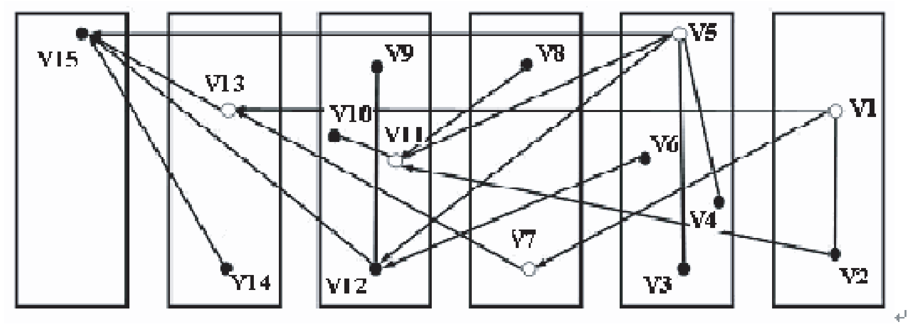

Figure 3: Chain graph of health-related variables and birth intervals
V1: No. of abortion before 1-st birth; V2: Contraceptive use in 1-st BI; V3: Sex of 1st child; V4: 1st childbearing method; V5: 1st child breast feeding duration; V6: 1-st birth interval; V7: No. of abortion before 2-nd birth; V8: Contraceptive use in 2-nd birth interval; V9: Sex of 2-nd child; V10: 2nd childbearing method; V11: 2-nd child breast feeding duration; V12: 2nd birth interval; V13: No. of abortion before 3-rd birth; V14: Contraceptive use in 3-rd BI; V15: 3-rd birth interval.

Inspection of the graph in Figure 3 reveals that there is no path from health-related variables to 1-st birth interval, while 1-st birth interval and 1-st child breast-feeding duration (month) have direct relation with 2-nd birth interval. The sex of 2-nd child has non-causal relation with 2-nd birth interval. The 3-rd birth interval has direct association with 1-st child breast-feeding duration, 2-nd birth interval, number of abortions and contraceptive use in 3-rd birth interval. Numbers of abortions in 1-st and 2-nd birth intervals have indirect relation with 3-rd birth interval. From Table 9 we realise that apart from the length of 1-st birth interval, there is more chance of having 2-nd birth in short interval. The number of abortions have decreased the length of first two birth intervals while have increased the length of 3-rd birth interval.

5. Conclusions

There are two major advantages of using graphical models in analysing birth interval data. First, all the results can be displayed in a simple mathematical graph. From this graph the structure of the association for the whole system under study can be ascertained very easily. We believe that a chain graph is a very powerful tool for displaying the results of the analysis, since it is more straightforward to read than results presented in tables. Second, using graphical chain models, the variables are partitioned into several blocks. This enables us to carry out analyses for each block and to assess the associations between all the variables in the study. The linking of these blocks into a chain graph then gives

Table 9: Estimated log-odd ratios of 1st birth interval & health-related variables on 2nd birth interval

Variable (main effects)	2-nd birth interval (months)		
	< 18	18-35	> 35
Constant	−43.10	−39.13	−39.58
1-st birth interval			
< 18 months	21.37	18.44	19.15
18-35 months	20.46	18.21	17.78
> 35 months	21.37	19.22	18.62
No interval (ref.)	–	–	–
Sex of 2-nd child			
Boy	22.98	22.68	21.00
Girl	23.79	22.78	22.13
No child (ref.)	–	–	–
1-st child breast-feeding duration	−2.18	−3.92	−3.62
Variable (interactions)	**2-nd birth interval (months)**		
	< 18	18-35	> 35
Sex of 2-nd child * 1st child breast-feeding duration			
Boy * Duration	1.13	1.66	2.40
Girl * Duration	0.82	1.72	1.99
1-st BI * 1st child breast-feeding duration			
< 18 * Duration	0.28	1.86	1.36
18-35 * Duration	0.73	1.96	1.92
> 35 * Duration	0.08	1.49	1.24

direct and indirect pathways between any variable and its potential determinants.

In this paper we examined the direct and indirect associations between birth intervals with demographic, socio-economic, family views and health-related determinants in Ahvaz-Iran. We found that there are direct associations between birth intervals and some of the above determinants. The 1-st birth interval has direct relation with contraceptive use, women's age at 1-st marriage and women's occupation. The 2-nd birth interval has direct relation with 1-st birth interval, women and men's views about number of child, women's view about birth interval, access to media, women's education level, women's age at 1-st marriage and 1-st child breast feeding duration. The 3-rd birth interval has direct association

Table 10: Estimated log-odd ratios of previous birth intervals & health-related variables on 3-rd birth interval

Variable (main effects)	3-rd birth interval (months)		
	< 18	18-35	> 35
Constant	−25.78	−25.8	−25.82
2-nd birth interval			
< 18 months	13.75	13.92	13.46
18-35 months	13.11	12.95	13.72
> 35 months	11.43	11.70	11.85
No interval (ref.)	–	–	–
No. of abortions in 3-rd BI	−4.04	−5.43	8.18
Contraceptive use in 3-rd BI			
Supply method	12.58	12.77	12.92
None	13.12	12.75	13.41
Natural method (ref.)	–	–	–
1-st child breast-feeding duration	−0.97	−0.96	−0.95
Variable (interactions)	**3-rd birth interval (months)**		
	< 18	18-35	> 35
No. of abortions in 3-rd BI * Contraceptive use			
No. of abortions * Supply method	−20.36	−19.8	0.74
No. of abortions * None	3.12	−18.44	0.55
No. of abortions * Natural method	0	0	0
2-nd BI* 1st child breast-feeding duration			
< 18 * Duration	0.74	0.37	0.71
18-35 * Duration	0.64	0.64	0.26
> 35 * Duration	0.51	0.57	0.73

with 2-nd birth interval, men's access to media, women and men's views about number of child, women's sex preference, women's age at 1-st marriage, 1-st child breast-feeding duration, number of abortions and contraceptive use in 3-rd birth interval.

The findings from this study indicate that encouraging women for higher education and giving opportunity to women in employment may be the influential way of slowing down fertility in this city. Women with lower age at 1-st marriage were found to delay their 1-st births. This is an important finding as well. Because if 1-st births are delayed, subsequent births will naturally come later than in the case when 1st births come earlier. This will certainly affect the total fertility of women.

Finally, contrary to the findings from other developing countries (see, Rindfuss *et al.*, 1983 and Nair, 1996) ethnicity has no association with birth intervals. It is worth to note that despite different ethnicity, people in this city have the same religion.

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References

Abdel-Aziz, A. (1983). A study of birth intervals in Jordan. Scientific Report No. 46, Netherland: World Fertility Survey.

Agresti, A. (2002). *Categorical Data Analysis*. Wiley.

Blauth, A., Pigeot, I. and Bry, F. (2000). Interactive analysis of high-dimensional association structures with graphical models. *Metrika* **51**, 53-65.

Bongaarts, J. (1978). A framework for analyzing the proximate determinants of fertility. *Population and Development Review* **4**, 105-132.

Bumpass, L., Rindfuss, R. and Hanosik, R. B. (1978). Age and marital status at first birth and the pace of subsequent fertility. *Demography* **15**, 75-86.

Cox, D. R., and Wermuth, N. (1993). Linear dependencies represented by chain graphs (with discussion). *Statistical Science* **8**, 204-283.

Cox, D. R., and Wermuth, N. (1994). Tests of linearity, multivariate normality and adequacy of linear scores. *Appl. Statist.* **43**, 347-355.

Cox, D. R. and Wermuth, N. (1996). *Multivariate Dependencies*. Chapman and Hall.

Darroch, J. N., Lauritzen, S. L. and Speed, T. P. (1980). Markov fields and log-linear interaction models for contingency tables. *Annals of Statistics* **8**, 522-539.

Edwards, D. (2000). *Introduction to Graphical Modelling*. Springer-Verlag.

Fricke, T. and Teachman, J. D. (1993). Writing the names: Marriage style, Living arrangements, and first birth interval in a Nepali society. *Demography* **30**, 175-188.

Frydenberg, M. (1990). The chain graph Markov property. *Scandinavian J. Statist.* **17**, 333-353.

Hirschman, C. and Rindfuss, R. (1980). Social, cultural and economic determinants of age at birth of first child in Peninsular Malaysia. *Population Studies* **34**, 507-518.

Kallan, J. and Udry, J. R. (1986). The determinants of effective fecundability based on the first birth interval. *Demography* **23**, 53-66.

Lauritzen, S. L. (1996). *Graphical Models*. Oxford University Press.

Lauritzen, S. L. and Wermuth, N. (1989). Graphical models for associations between variables, some of which are qualitative and some quantitative. *Annals of Statistics* **17**, 31-57.

Nair, S. N. (1996). Determinants of birth intervals in Kerala: An application of Cox's hazard model. *Genus* **LII**, 47-65.

Rashid Manan, H. (1997). Effects of lactation, contraception and other factor on birth intervals in Bangladesh: Evidence from the 1989 BFS. *Genus* **LIII**, 145-157.

Rindfuss, R., Parnell, A. and Hirschman, C. (1983). The timing of entry into motherhood in Asia: A comparative perspective. *Population Studies* **37**, 253-272.

Suwal, J. V. (2001). Social-cultural dynamics of birth intervals in Nepal. *Contribution to Nepalese Studies (CNAS) Journal* **28**, 11-33.

Trussell, J., Martin, L. G., Feldman, R., Palmore, J. A., Concepcion, M. and Abu Bajer, D. N. (1985). Determinants of birth interval length in the Philippines, Malaysia and Indonesia: A hazard model analysis. *Demography* **22**, 145-168.

Wermuth, N. (1976). Analogies between multiplicative models in contingency tables and covariance selection. *Biometrics* **32**, 95-108.

Wermuth, N., and Lauritzen, S. L. (1990). On substantive research hypotheses, conditional independence graphs and graphical chain models (with discussion). *Journal of the Royal Statistical Society, Series B* **52**, 21-72.

Wermuth N., Cox D. R., and Pearl J. (1998). Explanations for multivariate structures derived from univariate recursive structures. Technical Report, Johannes Gutenberg University, Mainz.

West, K. K. (1987). Education, age at marriage or first birth and labour force participation as predictors of parity transition: An application of discrete multivariate analysis to the study of conditional life table probabilities. *Canadian Studies in Population* **14**, 89-109.

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