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An analysis of reproductive behaviour in Canada: Results from an intertemporal optimizing model

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Abstract. Results based on a sample of Canadian households challenge the findings of most studies which show significant negative effects of schooling on the fertility of women under the age of 45. This is due to the application of methods to an optimization model which distinguish between those households which have completed their reproductive behaviour from those which have not. Completion status and the desired number of children are used to infer characteristics of the optimal programme which are then employed to derive a likelihood function. Traditional demographic methods have so far not fully utilized the distinction between incomplete and completed households in sample surveys. These methods also lead to the conclusion that completed fertility had increased from its all time low in the nineteen seventies.

JEL classification: C24, C25, J13

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1. Introduction

Social scientists, especially demographers, have long been interested in the determinants of family size and this has been the subject of intensive research activity. In particular, much attention has been focused on the statistical analysis of sample surveys. This is important because it attempts to identify, at

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the level of the household, those variables on which individual fertility decisions are based. Canadian researchers have certainly recognized this and have organized large sample surveys and carried out an analysis of the data that they generated. While much has been learned from these studies the statistical methodology has not been directed by a coherent economic theory of reproductive behaviour and has frequently failed to recognize some of the special characteristics of the data.

Perhaps the most fundamental problem with Canadian demographic research is the absence of a clearly articulated model of individual behaviour. In Sect. 3, it is assumed that household reproductive behaviour is determined by maximizing an intertemporal objective function.[1] In this environment decision making is sequential. Individuals are uncertain about the future but make forecasts of the values of economic and social variables that they think will affect them. As new information arrives these forecasts are updated and intentions and sometimes decisions are revised to conform to what is optimal given new information. Some of the characteristics of the optimal solution can be deduced when respondents reveal their desired family sizes and their completion status; that is, whether they intend to have any more children or not. This generates a sample likelihood function which permits the pooling for estimation purposes of households which have completed their reproductive behaviour together with those who have not.

The consequences of modeling reproductive behaviour in this way are substantial. When couples have less than complete control over conceptions the number of births becomes a state variable and the structural equations arising from the optimization problem above involve the desired number of births. Although, the desired number of births may be related to the actual number of births that a couple has had, in an Euler equation for example, it will generally not be correct to model the number of children ever born in a simple regression framework if one wants to capture the idea that reproductive behaviour is driven by intertemporal optimality considerations.

There are also econometric issues. The number of children ever born, or simply the number of births, is an integer valued variable. Yet, this feature is rarely integrated into the statistical analysis of sample survey data on family size. As Winkelmann and Zimmermann (1994, p. 206) point out, the application of least squares to an equation which explains children ever born as a linear function of individual characteristics neglects the discrete non-negative and possibly heteroscadastic and asymmetric nature of the data's distribution. In Sect. 3 models which are discrete analogues of the Probit and Tobit models for continuous data explicitly deal with the integer nature of the data in a framework which recognizes that reproductive decisions are the consequences of the intertemporal maximizing behaviour of households.[2]

The rest of the paper has the following format. The next section reviews the literature on Canadian fertility and other relevant studies. The model is described in Sect. 3 and its parameters estimated using data from Cycle 5 of the 1990 Statistics Canada *General Social Survey* in Sect. 4. A discussion of the results as well as a summary of the main findings is contained in Sect. 5.

2. A review of the literature

In Canada recent research activity has almost exclusively focused on the 1984 *Canadian Fertility Survey* which is a survey of women. Most of the studies using data from this survey are summarized in the recent monograph by Balakrishnan et al. (1993). The methodology is largely that of carefully designed cross-tabulation methods, although some multivariate techniques are used.

In the section employing multivariate methods they report place of residence, religion, religiosity, ethnicity, education, and work status as the significant variables in determining the number of children ever born. In these calculations the authors control for age and age at marriage. They conclude on page 87 that

"Education is one of the most important variables determining fertility in all age cohorts, with β values that are significant at the 0.05 level. The strength of this inverse relationship between education and fertility is evident even when other factors are controlled. Among young women below 30 years of age education makes more of a difference than among older women.... Equally important is the labour force participation of women."

In an earlier paper, Grindstaff et al. (1991), noted a strong inverse relationship between age at first birth and completed fertility. While one should be very wary of such results because of the statistical problems involved there is an important issue here. There is a selection problem caused by the exclusion of individuals with zero births as well as a simultaneity problem because both variables are endogenous. On which aspects of reproductive behaviour should we, as social scientists, concentrate our research efforts? This study analyses the number of children ever born to both men and women. Of the individuals answering the question on whether they had completed their family size 19.6% had no children, 20.2% had one child; 40.2 had two children; and 20.0% had three or more. The largest number of children was 9. This distribution has sufficient variation to justify the study of actual births. On the other hand, the parents ages at which children are born also exhibit considerable variation across individual characteristics and these should occupy our research interests as well. These are complimentary and not competing problems and the best way to deal with these different but related dimensions of behaviour is to build models which consider the simultaneous determination of both the timing and the number of births.

Questions concerning the timing and spacing of births are beyond the scope of this project. However, there are a number of papers which deal with these problems; see, for example, Heckman and Walker (1990) and Taşiran (1995) for a survey of Swedish and American results.

There are a number of recent studies based on American data which examine the determinants of children ever born. Three papers which are particularly relevant here are Calhoun (1989), Caudill and Mixon (1995), and Famoye and Wang (1997). All of these papers, in addition to offering explanations of children ever born, attempt to address some of the problems raised in the introduction. As one would expect since the two countries are so similar in so many respects, the results that Balakrishnan et al. (1992) found do not differ significantly from those based on US data. Without exception all of these studies find strong significant negative effects of education and female work status on the number the reported number of births. However, the first two of these studies also show that when information on completion status and desired family sizes is utilized there are quite dramatic changes in the results.

3. An optimization model

This section begins by looking at economic models of the household and how they can be used to formulate consistent hypotheses about behaviour. A number of authors have developed intertemporal optimization models to describe reproductive behaviour in an uncertain environment. These include McIntosh (1983), Wolpin (1984), Vijverberg (1984), Rosenzweig and Schultz (1995), Newman (1988), Hotz and Miller (1988), and Leung (1991). While all of these models have their distinguishing features, they share a common modelling approach, which is now described. The problem to be solved is defined by the following value function

$$V(b_t, x_t) = \underset{\{d_\tau \tau = t, \ldots T\}}{Max} \; E_t\left[\sum_{\tau=t}^{T} \delta^{(\tau-t)} U(d_\tau, b_\tau, x_\tau, w_\tau) \middle| \Omega_t\right] \quad (1)$$

subject to

$$x_t = g(d_{t-1}, b_{t-1}, X_{t-1}, w_t). \quad (2)$$

In equation (1), $U(d_t, b_t, x_t, w_t)$ represents the household's per period utility function, net of costs, which depends on a vector of decision variables, d_t, the cumulative number of births, b_t, a vector of other 'state variables', x_t, and a set of exogenous shocks, w_t. Utility is discounted at rate δ and the state variables evolve according to the difference equations defined by (2) which depend on the histories of the state variables at the end of the previous period, X_{t-1}, and w_t. Expectations are conditioned on the information available at time t which is contained in the information set, Ω_t. There is uncertainty because agents do not know the future values of w and are not sure whether they will have a birth in some future period.

In equation (1), b_t is regarded as a state variable because of the uncertainty associated the birth of a child.[3] If a household decides in period t that it wants to have an additional child it sets the relevant decision variables at the appropriate values and this will lead to a birth at some future data with positive probability. The other state variables are of two types. The first includes household specific variables such as the composition of the household, the ages of its members, levels of education, income and wealth levels. These evolve in response to changes in exogenous variables, random components and decision variables. Other state variables are exogenous to the household and their evolution is not affected by anything that happens within the household. Typical examples are tax rates, the performance of the economy, and the prices of goods and services.

Although there is some variation across models in terms of predictions there are plausible sets of assumptions which predict a positive effect of income and a negative effect of the level of education the number of births. And Leung (1991, p. 1074) also finds that "the larger the number of children, the lower will be the probability of a birth in the next period". In general, however, unambiguous results and analytical solutions to this type of model are very difficult to obtain.

On the other hand, it is possible to derive some of the characteristics of the solution and these will turn out to be useful in constructing a sample likelihood function. To see exactly what this means consider the following definition that arises from the value function in period t. Define the integer, b_t^*, by the condition: $V(b_t^*, x_t) \geq V(b_t, x_t)$ for all integer values of b_t. It is difficult to say very much about the properties of b_t^* since the functional form V is unknown. In principle, this problem could be solved analytically given explicit assumptions on the functional forms for U and g. In practice, however, this is not an easy task; consequently, my approach is to adopt reduced form methods which preserve as much of the intertemporal characteristics of the problem as possible. This is accomplished by treating b_t^* as a non-negative an integer-valued random variable with a cumulative distribution function defined by

$$Pr\{b_t^* \leq z\} = F_a(z, x_t, \beta), \tag{3}$$

where (β, a) is a vector of parameters to be estimated. The parameter 'a' measures dispersion.

If there is enough information available to specify the relation between b_t and b_t^* then it is possible to estimate (β, a). At the time of the sample survey used in this study respondents stated whether they intend to have any more children or not. Those who said that they intended to have more children said how many they wanted. Unfortunately, those households which reported no desire for more children were recorded as having $b_t^* = b_t$. This is not really correct; not only is it possible for households not to want any more children, they could also regret having the number they actually had, in which case $b_t^* < b_t$. Rosenzweig and Schultz (1985, p. 1013) noted that in *National Fertility Survey* "27% of the couples reported that they had one or more unwanted children by 1975". For these households, the appropriate contribution to the likelihood function is $F_a(b_t, x_t, \beta)$ and not the density function $f_a(b_t^*, x_t, \beta)$. On the other hand, for households which intend to have more children, $b_t < b_t^*$ and the density function is the appropriate contribution. The resulting likelihood function for the sample is, therefore,

$$L_{b^*}(\beta, a) = \prod_{i \in I} f_a(b_{it}^*, x_t, \beta) \prod_{i \in C} F_a(b_{it}, x_t, \beta), \tag{4}$$

where I and C are the sets of households with incomplete and completed family sizes, respectively and i is the household indicator.

Some researchers have been reluctant to draw inferences from the desired number of children that a woman would like to have because of the inherent speculative nature of these responses. Even when the information on desired family sizes is not reliable, if one has confidence in the completion status data this can be used to construct the likelihood function

$$L_c(\beta, a) = \prod_{i \in C} F_a(b_{it}, x_t, \beta) \prod_{i \in I} [1 - F_a(b_{it} + 1, x_t, \beta)] \tag{5}$$

which reflects the completion status of the sample. Readers familiar with the literature on binary choice models will recognize that this is the discrete analogue to the standard Probit model.

For comparative purposes and to create a benchmark a likelihood function for the analogue to the regression model is required. Here no account is taken of completion status. It is just the product of the density function for all members of the sample which is

$$L_b(\beta, a) = \prod_{i \in C \cup I} f_a(b_{it}, x_t, \beta). \tag{6}$$

Calhoun (1989) appears to be the first researcher to incorporate the consequences of unwanted children into an estimation procedure. While he allows for the possibility of $b_t^* < b_t$ for households that have completed their families, b_t is not considered as a state variable and is, therefore, not included as a regressor in the equation explaining the desired number of births. He also recognized the discrete nature of births and modeled this by using an ordered probability model. Because of the necessity of estimating extra threshold parameters his estimates are less efficient than those obtained by using a discrete distribution. Caudill and Mixon (1995) recognize both problems, however, their censoring is based on age as a proxy for completion. They assume that all women over the age of 40 have completed their families. While this is a very reasonable assumption to make, there are many women below the age of 40 who also do not intend to have any more children. Consequently, age is not a very good proxy for completion status.

As mentioned in the introduction, the solutions to these problems are derived sequentially; as new information becomes available expectations are revised and the solution is recomputed. In period t a household determines whether it has enough children. However, it should be clearly understood that this decision is conditional on the information available at period t and may be revised at a later date if the household experienced a fundamental change in its circumstances. For example, a respondent who reported an intention not to have any more children at the time the survey was carried out could easily change his or her mind if, subsequent to the survey, a child died or he or she received a large, but unexpected, bequest. Another consequence of the model is that some of the x_t variables can be period t variables like income or whether the woman was working in period t. This is quite legitimate, in spite of the fact that some of the household's children may have been born many periods before, because it is the information set at t which determines the relationship between b_t and b_t^*.

In should also be understood that the model does not explain the number of births that a respondent has had and, consequently, why b_t is a state variable. Households have children for a variety of reasons and these decisions are based on the information available to the household prior to the birth of the child in question. Most retrospective surveys do not attempt to elicit this type of information so the researcher is usually unable to explain the household's fertility. What the model does do, however, is relate the number of births to an idealized number, b_t^*, by using the information that the household provides on completion status and its desired number of children. It is then possible using the data in the sample survey to establish which variables determine b_t^*.

4. Data and estimation

The data used in this analysis comes from *The General Social Survey* which was carried out by Statistics Canada in 1990. A stratified random sample of

Table 1. Summary statistics: Women and men

Variable	Symbol	Women	Men
Births	b	1.21	1.29
		(1.11)	(1.13)
Desired births	b^*	2.48	2.64
		(1.36)	(1.55)
Percent complete	c	0.39	0.41
		(0.48)	(0.49)
Education	x_1	13.45	13.33
		(2.17)	(2.50)
Spouse's education	x_2	12.65	12.58
		(3.52)	(3.11)
Age	x_3	30.81	32.32
		(5.77)	(5.47)
Age at marriage	x_4	23.74	25.58
		(3.98)	(4.09)
Working	x_5	0.62	0.64
		(0.48)	(0.48)
Divorced	x_6	0.05	0.06
		(0.23)	(0.24)
Household income	x_7	41707	46464
		(26183)	(25266)
Sample size		955	772

Standard deviations are in brackets.

the population was contacted by telephone and asked a series of questions about their individual characteristics as well as their attitudes towards and opinions on a wide variety of subjects. On the demographic side the methodology was retrospective in the sense that one adult household member, who could have been either male or female, was asked to recall their age at marriage, when their children were born, their level and their spouse's level of education, etc. On the other hand, only current values of important economic variables such as income or employment status were collected. The sample employed here consists of respondents who are currently married, divorced or separated, have been married only once, and are of age forty-five or younger. Summary statistics of the female and male samples are contained in Table 1.[4]

The parameter vector, (β, a), can be estimated once $F_a(b, x_t, \beta)$ is specified. Results are presented here for the generalized Poisson probability density function of Famoye (1993) whose formula is given by

$$f_a(b_t, x_t, \beta) = [\mu/(1 + a\mu)]^{b_t}[1 + ab_t]^{b_t - 1}\, exp[-\mu(1 + ab_t)/(1 + a\mu)]/b_t!, \quad (7)$$

where, as is commonly assumed, the conditional mean is defined by

$$\mu(x_t, \beta) = exp(x_t\beta). \quad (8)$$

The Poisson density function arises as a special case when the parameter 'a' is equal to zero. This distribution also has the attractive property that both under and over-dispersion can be accommodated. Although this specification makes the conditional mean non-linear in both the parameters and the co-

Table 2. Parameter estimates

Associated variable	Parameter	$L = L_b$	$L = L_c$	$L = L_{b^*}$
Constant term	β_0	0.329* (0.17)	2.689* (0.49)	1.147* (0.12)
Male education	β_1	−0.018* (0.006)	0.027 (0.01)	0.019* (0.005)
Female education	β_2	−0.013* (0.007)	0.035* (0.015)	0.012* (0.006)
Age	β_3	0.062* (0.003)	−0.158* (0.02)	−0.075* (0.004)
Age at marriage	β_4	−0.062* (0.005)	0.091* (0.02)	0.049* (0.005)
Working	β_5	−0.498* (0.04)	−0.043 (0.07)	−0.044 (0.03)
Divorced	β_6	0.129 (0.08)	−0.104 (0.15)	−0.062 (0.07)
Household income	β_7	0.001 (0.001)	−0.001 (0.001)	0.001 (0.001)
Dispersion	a	−0.081* (0.007)	0.065 (0.06)	−0.095* (0.007)
log-likelihood		−2171.28	−667.15	−1797.04

Notes: Standard errors are in brackets. *indicates significant at $\alpha = 0.05$

variates its derivative with respect to a variable has the same sign as the coefficient of that variable. Parameter estimates for a pooled sample of men and women are shown for all three likelihood functions in Table 2.[5]

5. Comments and discussion

The estimated coefficients in Table 2 reveal patterns of behaviour which are quite different from those reported in the studies reviewed in Sect. 2. The first column of Table 2 demonstrates what happens when conventional methods are applied to the data on actual births for the whole sample without regard to completion status. While the density function is the generalized Poisson, taking account of the integer values of the dependent variable, the results are the same as those of Balakrishnan et al. (1992) using the linear regression model. The education variables, age at marriage, and work status all have a significant negative effect on the number of recorded births. Age representing a cohort or trend effect has a negative impact indicating declining fertility across cohorts or a downward trend in births. Very similar results were found by Famoye and Wang (1997) using data obtained in 1989 on women aged between 18 and 40, by Caudill and Mixon (1995, Table 2, column 2), and by Calhoun (1989, Table 1, Version 1). In fact, these results are what researchers in this area usually find.

When the desired number of births is used instead of actual births taking into account completion status the results change dramatically. The parameter estimates in the second and third columns of Table 2 confirm this.

The highly significant negative coefficient of the age variable shows that cohort fertility has actually increased over the period 1975 to 1990 and this increase is large enough to suggest that the 'baby bust' of the nineteen seventies has finally come to an end. For women in the age group 25–30 who claim to have completed their families the reported mean number of children ever born is 1.96 whereas the mean for the age group 40–45 is 1.76. While one should interpret this result with some caution because the sample sizes are quite small, it is an important finding and it demonstrates the benefits of being able to include young households which have not completed their fertility.

Contrary to conventional results, the effects of education, beyond those which cause a delay in marriage or a delay in completing fertility, are small but positive. Women with higher levels of education take longer to complete their families but have slightly more children. These results are different from what others have found because the estimation procedure distinguishes between incomplete and completed families and uses the data on the desired number of births rather than actual births.

Conventional results are obtained by treating all women as having completed their reproductive activities and using actual births. These are displayed in column 1 of Table 2 and are based on the likelihood function described in equation 6. Clearly, mispecifying the likelihood function by ignoring an observable difference across individuals leads to an erroneous conclusion concerning the role of education in fertility behaviour.

This is not to suggest that education has no effect on fertility decisions. So far this relationship has been considered in terms of the attributes of the individuals who are making the decision. There is another dimension to the problem where education may be important and that is in the determination of the cost of raising children. Education is an expensive commodity to buy and the higher the quality or the level the more expensive it is. This well understood by parents, most of whom also know that educational attainment is much more important in determining the life-time opportunities of their children than it was for them. Required educational levels have risen for reasons that have to do with the workings of the labour market. Parents have recognized this and responded with better educated children but fewer of them because of the higher costs, a result which is consistent with the type of model employed here.

The significance of a strong negative effect on fertility of age at marriage is result found in most studies of reproductive behaviour. Sometimes mariage duration is included as an explanitory variable. However, all three age variables can not be included as regressors because marriage duration = age − age at marriage. This is not the case in this sample; β_4, the coefficient of age at marriage is significantly positive but rather small. Household income was also not significant and this is consistent with what Balakrishnan et al. found.

The marital status variable was not significant. However, some caution should be exercised in interpreting this result. Since only 5.3% of the sample was separated or divorced it is probably not representative of the population as a whole with respect to marital dissolution.

One rather surprising result is the positive sign of β_b. This says that the more children that the respondent has the more he or she wants. This is not what the theory predicts. Although this is large and very significant dropping it does not change any of the results except that in the absence of b_t the working dummy becomes significant.

Table 3. Goodness of fit statistics

Case	Percentage of correct predictions
$b_t^* = 0$	2.4
$b_t^* = 1$	47.0
$b_t^* = 2$	62.3
$b_t^* = 3$	27.5
$b_t^* = 4$	0.6
Complete: $b_t^* \leq b_t$	54.5
Incomplete: $b_t^* > b_t$	94.2

The model used to explain 'desired fertility' is based on the idea that households, rather than individuals, make family decisions. This sample survey yields responses from both women and men. It is, therefore, possible to see if the parameter estimates based on each gender are consistent with each other. A likelihood ratio test could not reject the hypothesis that the coefficients for each gender were equal. The sign and significance pattern is the same for both genders. The should be taken as convincing evidence in favour of consistent behaviour since age and age at marriage are likely to be highly correlated across gender and the working variable for men refers to his wife's employment status.

As stated earlier, the results of positive education effects on fertility have been found by both Calhoun (1989) and Caudill and Moxon (1995) in the versions of their models which take some account of completion status.

Turning to the goodness of fit of the model, its ability to predict is summarized in Table 3. In predicting individual desired family sizes among those women who have not finished having children the model does poorly except for those men and women who say that they intend to have two children. The model's inability to explain the extremes is not terribly surprising since this type of choice reflects deviations in personal preferences that are probably not captured by the data in the sample survey. On the other hand, completion status is reasonably well explained.

In summary, desired family size within married couples depends largely on the number of births that the couple has already had, age, and age at marriage. Education has a small positive effect on desired family size. Couples appear to agree on the number of children they want. These results are due to the new statistical methods employed. These methods also reveal an important reversal in the trend of completed fertility. By 1990 completed household fertility was well above the lows of the nineteen-seventies and may have reached replacement levels.

Endnotes

1 There is nothing novel in this approach. In fact, there is a well established literature on dynamic microeconomic models of fertility choice. An excellent review of it may be found in Arroyo and Zhang (1997).

2 Some of the problems aluded to above have been recognized by other contributors. See the important contributions of Calhoun (1989) and Caudill and Mixon (1995). These papers are discussed in detail in Sect. 3.

[3] Disregarding mortality and multiple births, $b_{it} = b_{i,t-1}$ or $b_{i,t-1} + 1$ depending on whether household i had a child in period $t - 1$. Households do not control b_t; all they they can do is either try to have a child or try not to have a child.

[4] The same information is available for the over forty-fives. However, this group displayed much higher completed fertility and is, therefore, less representative of contemporary Canadian reproductive behaviour. It was not possible to include respondents living under a common law arrangement, the never married or those who had remarried after a divorce due to the absence of information on completion status. It should also be noted that the variable 'working' is a dummy variable taking on the value one for women if they were working. For men, however, it indicates whether his wife was working or not.

[5] There are other possible distributions like the generalized event count model of King (1989) and Winkelmann and Zimmermann (1994) which can also deal with under-dispersion in the data. The programming for the generalized Poisson is somewhat easier and that motivated the choice. Notice that when 'a' is negative there are two non-negativity constraints that have to be satisfied for each observation: $1 + a\mu_i \geq 0$ and $1 + ab_{it} \geq 0$.

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