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FEMALE LABOR SUPPLY AND MARITAL STATUS DECISIONS: A LIFE CYCLE MODEL

BY

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ABSTRACT

This paper studies the relationship between household structure and female labor supply, through the construction and estimation of a dynamic utility maximization model in which in each period a female simultaneously determines her marital status and work decision. The model is estimated using longitudinal data on women from the Michigan Panel Study of Income Dynamics. The maximum likelihood estimation method employed involves solving a dynamic programming problem. The estimation results indicate that ignoring the endogeneity of marital status decisions will lead to an underestimation of wage effects on female labor supply.

1. Introduction

The American family has undergone a major transformation over the last four decades. This change was characterized by a large increase in the labor force participation rate of married women, a sharp increase in the rate of divorce, a drop in the fertility rate and an increase in the number of female-headed households and never-married men and women. These demographic trends have led to an increased recognition among labor economists of the importance of household structure in the study of individual and family labor supply. In the study of female labor supply, for example, there is growing awareness that both marital status and fertility decisions are strongly interrelated with female labor supply decisions and can therefore no longer be considered exogenous from a life cycle perspective. The presence of children (especially when they are young) is known to have a strong negative effect on the mother's labor supply. Consequently, female wages and labor force experience play an important role in decisions on the timing and number of births.

Female labor force participation decisions are also known to be affected by changes in marital status through income and substitution effects. In addition, economic theories of marriage imply a strong correlation between a female's return in the labor market and her 'return' in the marriage market, measured in terms of utility gains from marriage. For example, according to Becker's (1973,1974) theory of marriage, marital gains can be derived from the specialization of labor within the household, which is found to depend negatively on the ratio of the wife's to the husband's wage rate. Gains from marriage and therefore marital status decisions will thus in general depend on a female's (potential) wage rate. If gains from marriage are greater for low wage women, this will imply higher marriage and lower divorce rates and a resulting self-selection of low wage women into the married state. Decisions to enter or exit the married state, and the timing of entry or exit, are therefore also likely to depend on female wages and previous work experience.

As part of an expanding literature on the timing and spacing of births, several life cycle models have been developed and estimated which have addressed the relation between life cycle fertility and female labor supply (Heckman and Willis [1976], Hotz and Miller [1988] and Moffitt [1984]). The interaction between marital status and labor supply decisions, on the other hand, has been awarded considerably less research effort. Research on the labor supply of single- and multiple-person households has largely ignored the endogeneity of marital status decisions. First, there is a vast empirical literature that examines female labor supply *conditional* on marital status. Typically, an hours function is estimated where both the husband's wage income (possibly as part of the female's nonlabor income) and the marital status of the individual are included as explanatory variables. These studies assume both marital status and the husband's income to be exogenous, which may lead to biased estimates. Second, the same problem arises in the estimation of wage functions where a marital status indicator is included as an exogenous regressor variable (see Nakosteen and Zimmer (1987) who report a strong bias for the case of male wage equations).

In addition, in most studies of household labor supply, both male and female labor supply decisions are determined jointly through maximization of a household utility function or as the outcome of a bargaining game. While the exogeneity assumption on the husband's labor supply and wage income is relaxed, these models still ignore the endogeneity of the household formation process itself. Life cycle models of family labor supply are typically estimated using data on couples who were continuously married throughout the survey period (for example, Heckman and MaCurdy [1980], Altug and Miller [1988]), so that estimates derived for these models potentially suffer from a sample selection bias. Given the sharp rise in the rate of divorce, where currently 44 percent of all marriages of the early seventies either have ended or are predicted to end in divorce, the need to incorporate marital status decisions into life cycle labor supply models is becoming even greater.

Following the innovative work of Becker (1973,1974), the economic literature on marriage and divorce behavior has highlighted several important aspects of marital status decisions. The different potential sources of marital gains and its dependence on individual charateristics has been the main focus in models of optimal sorting or matching (Koopmans and Beckmann [1957], Becker [1981], Lam [1988]). The division of marital gains and its relationship to consumption and time allocation decisions within the household have been studied in recent game-theoretic models of household behavior (McElroy and Horney [1981], Chiappori [1988]) and the uncertainty and dynamic aspects of marital status decisions has played the prominent role in models of marital search and divorce (Becker et al. [1977], Mortensen [1988], Montgomery [1992]).

Even though several studies in this literature have emphasized the strong interactions between marital status and labor supply decisions, and despite the important implications for studies of individual and household labor supply, the only studies which have explicitly modelled both labor supply and marital status or household membership choices have been those by Johnson and Skinner (1986,1988) and Haurin (1989), who analyzed the response of labor supply decisions to a realized or anticipated divorce, and that by McElroy (1985) who studied household membership and market work decisions by young men.

While these studies have led to a better understanding of labor supply decisions, they suffer from the significant shortcoming that they do not capture the true dynamic nature of both marital status (or household membership) and work decisions. Given the nature of marital status decisions, where each decision typically has longterm consequences, the interaction with market work decisions cannot satisfactorily be captured in a static framework. A female might opt for a labor market career and consciously postpone marriage. On the other hand, more work experience generally implies higher wages, which in turn might affect gains from a potential marriage. Interruptions in labor market participation caused by marriages can have long term effects through lower future wages associated with less labor market experience, making the female more economically dependent on the husband. During a marriage the investment and accumulation of marriage specific goods also reduces the probability of a divorce. Alternatively, a higher probability of divorce could give rise to an increase in the female's labor supply when married so as to gain more market experience.

This study represents a first attempt to fill this gap in the labor supply literature by the construction and estimation of a structural dynamic model that explicitly addresses the relation between marital status and labor force participation choices. A simple dynamic utility maximizing framework is specified in which the female simultaneously determines her marital status and work decision in each period, while taking into account the effect of current decisions on future choices. The model incorporates different types of uncertainty such as those associated with marital search, divorce and future wage earnings.

Not only does the structural model enable us to study how both labor supply and marital status decisions may influence each other, it will also allow us to study how these decisions and their interactions depend on certain individual characteristics. In particular, the estimates of the model are used to predict differences in the life cycle patterns of employment and marital status due to differences in education, race, region, the female's (potential) wage rate and expected husband's wage income.

Further, by specifying the expectations formation process, it is possible to evaluate the impact on current choice behavior of changes in future wages, wage returns and marital gains. Only a structural model will allow us to study how much and in what way current choices respond to such changes as increases in (future) wage returns to work experience and the difference in the effects of a permanent and temporary wage change.

Estimation of discrete-time discrete-state dynamic programming models such as the one in this paper has recently received considerable attention (see Eckstein and Wolpin [1989] for a recent review). The maximum likelihood estimation method employed here is most similar to that in Wolpin (1984,1987), Eckstein and Wolpin (1989) and Berkovec and Stern (1988). It is based on a recursive numerical solution of 'reservation values' and expected value functions, from which the choice probabilities in the likelihood function can be calculated. Further, by using a minimum distance estimator, wage data are incorporated here in a computationally simple way that has not been achieved in prior work.

The model is estimated using longitudinal data on women from the Michigan Panel Study of Income Dynamics (PSID). The results indicate that women who are white, with low (potential) wage rates and women with high expected husband earnings are more likely to marry soon after leaving school, are less likely to work in the labor force and are less likely to separate. High wage women, on the other hand, marry only after several years of market work, and are more likely to get a divorce. We also find that our dynamic model provides more plausible predictions of the responses in marriage and labor supply behavior to various changes in wages and wage returns than a static model in which individuals behave myopically.

This paper is organized as follows. The next section presents a simple dynamic model of female labor force participation and marital status decisions. Section 3 discusses the data analyzed in this study and Section 4 deals with the econometric specification and estimation of the model. The estimation results are presented in Section 5 and the model's explanatory power and incorporation of unoberved permanent individual effects are discussed in Section 6. Finally, Section 7 offers concluding comments and suggests some important areas for future research.

2. A Structural Model of Marital Status and Labor Supply Decisions

In addition to the need for a dynamic framework, the economic literature on marriage and divorce has identified several aspects of these decisions that our model should ideally include. The dynamic model presented here incorporates many of these aspects in a explicit way, but others only indirectly. In particular, it will focus primarily on the female's decision process and will assume that every husband always works full time in the labor market. Given that in a typical representative sample, such as the one used in this study, 95 percent of the male population works, this is not a very restrictive assumption. To avoid the complications associated with modelling the choice of husband as a multivariate choice problem, and given the emphasis on female labor supply decisions, each (potential) husband will be characterized solely by his expected wage income. Utility gains associated with marriage and work decisions are however directly modelled and the dynamic nature of both decisions will be represented through several sources of state and duration dependence. Uncertainty and search aspects will further be captured by random arrivals of new preference evaluations of existing and potential spouses and by the randomness of wages.

The model will not explicitly incorporate fertility decisions. It is clear that a more complete model of lifecycle female labor supply should incorporate these decisions as choice variables. To avoid the modelling and estimation complications resulting from an increase in the choice set and dimension of the state space in the model, the focus here will be only on the interaction of marriage, divorce and labor force participation decisions, leaving incorporation of fertility behavior as an important issue for future research.

Starting with the period in which the individual leaves school, in each period an individual is assumed to maximize the present value of utility over a known finite horizon (T) by choosing whether or not to work, whether or not to be married, and how much to consume[1]. The objective of the individual is to maximize

$$E \sum_{t=1}^{T} \delta^{t-1} \left[U(p_t, c_t, m_t; p_{t-1}, m_{t-1}, ten_{t-1}, X_t) + \nu_{p_t m_t t} \right] \qquad [1]$$

by choosing a path $\{(p_t, c_t, m_t), t = 1, ..., T\}$, where p_t represents the labor force participation decision in period t; $p_t = 1$ (participation) or $p_t = 0$ (non-participation) and m_t indicates whether the individual is married at time t ($m_t = 1$) or single ($m_t = 0$). c_t equals the consumption in period t of a composite good or commodity, C, produced in the household according to a production process which will be discussed below. ten_{t-1} refers to the tenure of the current marriage up till the beginning of period t and can be defined as $ten_{t-1} = m_{t-1}[ten_{t-2} + m_{t-1}]$. $\delta \in (0, 1)$ is the subjective discount factor and E is the expectations operator.

The utility function $U(\cdot\cdot)$ is assumed to be decreasing in p_t, reflecting disutility of working, and increasing in c_t. The disutility associated with market work might increase or decrease with previous work experience. Non-market time at adjacent points in the life cycle may be substitutes or complements. A positive effect of the previous period's work decision (p_{t-1}) on the current gains from working may reflect habit formation or complimentarity of non-market time in subsequent periods, while a negative effect may reflect an increasing disutility of working with previous work effort. Utility further depends on the female's marital status, representing factors such as love, companionship and a higher disutility of market work or a higher marginal utility of consumption when the female is married as compared to when she is single. The dependence on the marital status and the duration of the current marriage (when married) at the time of the choice decision (m_{t-1} and ten_{t-1}) represent the utility costs of a divorce. If the female has been married until the previous period, the utility obtained when choosing to separate and become single will reflect the utility costs associated with a divorce. These costs are likely to depend on the duration of the dissolved marriage. As during a typical marriage large joint investments are made into more or less marriage-specific goods, such as housing and children, the longer the duration of the marriage, the greater the costs of a divorce and the less attractive the option to become single. Finally, utility may also depend on individual characteristics, X_t, such the race and education of the female, representing individual differences in tastes.

The composite commodity, C, is assumed to be produced by combining time spent at home and market inputs, e_t. For simplicity time spent at home is defined as the total available time left after doing market work. Given our focus on participation decisions, we basically assume that each female decides about full time market and home work only. The production technology of C is characterized by the function $C(1-p_t, e_t, m_t; p_{t-1}, m_{t-1}, ten_{t-1}, X_t)$ which is increasing in its first two arguments. The dependence on p_{t-1} reflects the possibility that home time in subsequent periods are complements in the production of C. The production technology further depends on the female's marital status. When married, the production function is a joint household production function into which is incorporated the (fixed) husband's home time, defined as the total time left after working full time in the labor market. Through joint production there is scope for efficiency gains through division of labor and economies of scale. These gains may change over time with the duration of the marriage. In addition, the production technology of C could depend on other characteristics of the individual, such as years of education and age.

Of the total amount of commodity C produced in the household in period t, a share $\alpha(m_t)$ will be available for consumption by the female. Consumption by the female in period t equals

$$c_t = \alpha(m_t) \cdot C(1 - p_t, e_t, m_t; p_{t-1}, m_{t-1}, ten_{t-1}, X_t) \qquad [2]$$

In the case when the female chooses to be single ($m_t = 0$), all of the household goods produced will be available for her consumption and $\alpha(0) = 1$. When married however, this share is assumed to be determined through cooperative bargaining between husband and wife. The bargaining outcome will depend, among other things, on both spouses' preferences, the female's current and previous work decision and both her wage income (when she works) and the husband's wage income, representing each spouse's bargaining power and opportunities outside the marriage. Accordingly we assume that the outcome can be described by the function

$$\alpha(1) = f(p_t, w_t, w_t^h, p_{t-1}, m_{t-1}, ten_{t-1}, X_t) \qquad [3]$$

Chiappori (1988) and Browning et al. (1992) have shown that the existence of such a sharing rule follows solely from the assumption of Pareto optimality of the household allocation outcome and egoistic or caring preferences.

Without saving or borrowing, the household buget constraint determines for each choice of p_t and m_t the total amount of market inputs, e_t, the household can purchase. Characterizing the wife's and husband's wage earnings by w_t and w_t^h, respectively, the household budget constraint is

$$w_t p_t + m_t \hat{w}_t^h = e_t + b_1 p_t + b_2 m_t [1 - m_{t-1}] + b_3 (ten_{t-1}) m_{t-1} [1 - m_t] \qquad [4]$$

where b_1 and b_2 are fixed monetary costs associated with market work and getting married and b_3 represents the monetary costs of a divorce. These latter costs are allowed to depend on the tenure of the dissolved marriage, as with the accumulation of more marital specific goods these costs may increase[2].

Note that it is $\hat{w}_t^h$, the *expected* husband's earnings, that enters each period's budget constraint. It is assumed that each female has formed certain expectations about her (potential) future husband's wage earnings which can be described by the "matching equation":[3]

$$\hat{w}_t^h = Z_t'\pi \qquad [5]$$

where Z_t is a vector of characteristics of the female, such as her age, education, race, work experience and local labor market variables. The female's characteristics do not only reflect her expectations and preferences for a particular husband's wage income, but also determine her position in the "marriage market". Each female is assumed to form and update these expectations or projections by evaluating the earnings of husbands of women with characteristics and choice histories that are most similar to hers.

The female's current and future wage earnings are both uncertain and endogenous, because they are likely to depend on the female's previous work decisions. Accordingly, when the female chooses to work, she will receive wage earnings w_t that depend on her personal characteristics (such as education), the previous period's work decision, p_{t-1}, her total work experience, exp_{t-1}, local labor market variables, and a random term u_t, representing random fluctuations in earnings over time. Thus

$$w_t = w(p_{t-1}, exp_{t-1}, X_t) + u_t \qquad [6]$$

where work experience exp_{t-1}, represents the total number of prior years the female worked in the labor force since leaving school and therefore evolves according to $exp_{t-1} = exp_{t-2} + p_{t-1}$, with $exp_1 = 0$. The previous period's work decision is included as a separate variable to allow for a stronger effect of more recent work experience. At the time of the decision the female knows both the current value of w_t and the wage structure in [6], but obviously does not know the future realizations of u_t and w_t.

Uncertainty about the value of the match, about the realization of the husband's wage earnings in each period and uncertainty about other characteristics of the spouse give rise both to marital search and divorces. These sources of uncertainty are represented in the model by a composite error term, $\nu_{p_t m_t t}$, representing the random arrival of new preference valuations of potential partners in each period while single, and of new valuations of existing spouses when married[4]. When currently single, a high value of $\nu_{p_t 1 t}$ can be interpreted as a good first opinion or a higher than expected value of the match associated with the potential husband. To allow for a possible difference in the (expected) compatibility between the husband's and female's work decisions, these preference evaluations may differ in the work and non-work states. When married, $\nu_{p_t 1 t}$ reflects the uncertainty that persists during the marriage about the quality of the match. It may also represent random events that could affect this quality[5].

It is likely that not only the utility of being married but also the current utility of being single varies with the occurrence of random events. The birth of a child when single, for example, might lower the utility of staying single. These types of random shocks are represented by the error term $\nu_{p_t 0 t}$.

Finally, when substituting [2], [3] and [4] into the utility function in [1], the resulting model consists of the wage equation [6] and the following dynamic utility maximization problem:

$$\max_{\{(p_t, m_t), t=1,\ldots,T\}} E \sum_{t=1}^{T} \delta^{t-1} \left[\mathcal{U}(p_t, m_t; p_{t-1}, m_{t-1}, ten_{t-1}, w_t, \hat{w}_t^h, X_t) + \nu_{p_t m_t t}\right] \qquad [7]$$

where $\mathcal{U}$ represents the non-stochastic part of the quasi-indirect utility function.

It is important to discuss in some more detail the various sources of dynamics that are incorporated in this model. First, the dependence of wages on the individual's past work history and of the disutility of working on the previous period's work decision implies that when choosing whether or not to work in period t, the individual will in general not only consider the current utility difference associated with work versus not-work choices, but also the effects of the current work decision on future utility levels and choices through an increase in work experience. In deciding whether or not to work, the individual weighs the advantages of working this year, such as an increase in current and future wage earnings, against its disadvantages, such as the disutility associated with work and a decrease in the time available for home production. The actual outcome depends therefore on the relative magnitudes of the wage, the marginal product of time in home production, the disutility of working, the expected husband's earnings (when married) and also on future returns to work experience and other effects on future utility levels.

Similarly, in the current marital status decision, the individual has to take into account its effect on future utility levels, resulting from the dependence of utility levels and the production of C on the female's marital status in the previous period and, if married, on the duration of the marriage.

While not introduced into the framework to limit the computational costs associated with estimation of the model, it is important to note that the dependence of current indirect utility levels on the marriage and work history is not necessarily confined to the most recent marital status decision, marriage spell and most recent work decision and total work experience[6]. Previous marriages might, for example, affect the utility of remarriage through the presence of children from previous marriages. With time, the utility derived from being single may depend on how long the female has been so until the current period and besides the female's most recent work decision and total work experience, the individual work decisions made two or three periods back might be of separate importance.

3. A Description of the Data

The data used in this study were extracted from the 1985 family-individual tape of the Michigan Panel Study of Income Dynamics (PSID). The PSID started in 1968 with a sample of approximately five thousand households, which included a sample that was representative of all U.S. households in 1968 and a supplementary low-income sample.

Household heads were interviewed annually to obtain fairly detailed information on socio-economic and demographic characteristics and on each member's prior year's earnings and labor force behavior. Further, the 1985 interview included a detailed retrospective marital history of the household head.

The initial sample extract included all females aged 12 to 19 in 1968 (or 29 to 36 in 1985), who were part of the national representative random section of the PSID. This age group was selected so that for each individual a complete work and marital history could be constructed. The first observation year for each female in the sample is the year in which she leaves school, the final observation year will either be 1985 or the year the female dropped out of the sample. For the resulting unbalanced panel, the average number of years available for each female is about 13 years (see Table 1).

For the construction of the marital history both the 1985 retrospective information (if available) and the year by year marital status information were used. Here the retrospective data can add extra information not directly obtainable from the panel data, such as divorces and remarriages that occur within one year, and the starting dates of marriages that started before 1968. A female is defined to be married (MARRIED=1) when she is both legally married and is living with her husband (an exception is made when the husband was in an institution for 1 or 2 years). No distinction is therefore made between divorces and separations. Also this definition of marital status does not include those cohabitating as being married. The decision to cohabitate is quite different from the decision to marry. However, because the available data on cohabitation appeared not very reliable, cohabitation was not included as a separate choice.

For other variables used in the empirical analysis the following definitions apply. A person is defined to participate in the labor force (WORK=1) in a particular year if yearly hours of work exceeded 775[7]. It therefore does not include those who work less than 15 hours a week or those who work less than 20 weeks full time. Work experience (EXP) represents the total number of prior years the person has participated in the labor force. The tenure of the current marriage (TEN) is defined as the duration of the current marriage up till the previous year. It therefore equals zero if the person was not married in the previous period. Average hourly wages (WAGE) are obtained by dividing annual labor income by annual hours of work. Wages are further expressed in real terms and are deflated by the implicit price deflator for personal consumption expenditures, with 1983 as base year. Real husband's wage rates (HWAGE) are obtained in a similar way, by dividing annual labor income by annual hours of work.

Years of education (EDUC) represent the number of years spent in full time education until the first time the person left school. It therefore does not include education obtained later in life (although in our sample very few women do return to school) and may therefore not be a precise measure of the person's human capital. RACE is defined as 0 if the person is white and 1 otherwise. SOUTH is an indicator equal to one if the individual lived in the South during the majority of the years the individual is followed in the sample. The variable MANUFWG is the mean (real) state manufacturing wage earnings, averaged over the years the individual was in the sample. This variable represents a measure of "permanent" or average local labor market demand. In the individual's decision process it is assumed that only these permanent values matter in current and future wages and decisions.

After deleting individuals from the sample for whom information on any of the above variables were missing, the resulting sample contains information on 548 females with a total of 7204 person-year observations. The means and standard deviations of the variables are shown in Table 1. [Table 1 here]

In the structural model each female is assumed to have formed certain expectations about her (potential) future husband's wages as described in equation [5]. To calculate the husband's expected (real) wage rate, a logarithmic husband's wage regression was estimated which contained the same explanatory variables that will be included in the female's wage equation: the wife's age, years of education, race, region of residence (SOUTH), work experience, experience squared, the previous period's work decision and MANUFWG. We also included a selection correction term to correct for the fact that the dependent variable was observed for married women only. It is assumed that each female uses this "matching" equation in forecasting current and future husband's wage rates. As reported in Table $A1$ in the Appendix, women who are white and have more years of education marry husbands with, on average, higher wage rates. The female's age and work experience variables serve as proxies for the husband's age or work experience. Husbands' wage rates are further higher in states with higher mean manufacturing wage earnings.

Even though the sample consists of relatively young women, Table 2 shows that most of them have already undergone one or more changes in marital status. Keeping in mind that the survey period is different for each individual, only 123 (22 percent) of the females remained single throughout their observation interval, 81 (15 percent) got married twice, 117 (21 percent) experienced one divorce and 28 (5 percent) two divorces. [Table 2 here]

As a first measure of the relationship between marital status and labor force participation decisions, Table 1 reports a simple cross-tabulation. For the sample of 7204 person-year observations the participation rate for the single state person-year observations is much greater than for the married state observations (respectively 69 percent and 52 percent). Of course, these numbers conceal both differences across individuals as well as differences across time and it will therefore be more instructive to look at these differences separately.

Accordingly, out of the total sample all observations corresponding to the 1984 wave were selected to obtain a 1984 cross-section (many questions in the yearly questionnaire relate to the previous year, so that more information was available for the 1984 wave than for the (last) 1985 wave). Table 3 shows fairly large differences in the mean individual characteristics for the different employment and marital status groups. In particular, married women are more likely to be white, less likely to be working, have on average less work experience and, for those who work, lower average wage rates than their single counterparts. Similarly, comparing non-working and working women, we find that women who participate in the labor force have on average more work experience, more years of education, are less likely to be married and, for those who are married, are married to husbands with average wage rates which are lower than for women who do not work. [Table 3 here]

To study the patterns in marital status and work decisions over time, Figure 1 presents both the percentage of women who are married and who are working in the labor force, for the first 16 years since leaving school (for later years there are very few observations). Within the first five years more than 50 percent of the women get married and by the tenth year the percentage of women who are married has increased to about 70 percent. While the labor force participation rate initially increases to more than 60 percent in the third year since leaving education, it subsequently decreases to about 55 percent in the eighth year since leaving school, after which it slowly starts to increase again. The graph suggests that with more women getting married, the initial growth in the participation rate decreases and then becomes negative. When the percentage of women who are married stabilizes, the participation rate starts to increase again. [Figures 1 and 2 here]

Figure 2 shows the labor force participation rates for single and married women. It is clear that the participation rate for married women is persistently lower than that for single women. Both rates initially increase, possibly reflecting the time it takes to find an acceptable job and persistence in the work decision through accumulation of work experience. While the increase in the participation rate for single women is persistent, however, it is not so for married women. For the later group, the participation rate stabilizes in the third year since leaving school, then falls until year eleven after which it appears to increase again. Of course, it is not possible to tell from Figure 2 to what extent the differences in the participation rates are merely reflecting a self-selection effect into both states and to what extent they are the result of a structural difference in decision behavior associated with being single or married. It should also be kept in mind that the composition of each group of married and single women changes with the time elapsed since leaving school. Because these rates are averages, they conceal the individual transitions between the marital status and employment states. These transitions will be studied in Section 5 with the aid of our economic model.

4. Econometric Specification and Estimation.

The empirical problem is to use the structural model to predict the marital status and work decisions made by each female in the sample. First the functional forms of the indirect utility functions in [7] will be specified. Given these specifications the probability that a female chooses each of the four possible states (single and not working, single and working, married and not working, married and working) can be obtained by solving a dynamic programming problem. Estimates of the structural parameters can then be found by maximum likelihood and minimum distance estimation techniques.

Adopting linear-in-parameters specifications for the nonstochastic indirect utility components in [7], for each of the four states in period t we have:

$$\begin{aligned}
&State1: p_t = 0, m_t = 0 \quad && \mathcal{U}(0,0;p_{t-1},m_{t-1},ten_{t-1},\ 0,\ \ 0,X_t) = X_{1t}'\beta_1 \\
&State2: p_t = 0, m_t = 1 \quad && \mathcal{U}(0,1;p_{t-1},m_{t-1},ten_{t-1},\ 0,\hat{w}_t^h,X_t) = X_{2t}'\beta_2 \\
&State3: p_t = 1, m_t = 0 \quad && \mathcal{U}(1,0;p_{t-1},m_{t-1},ten_{t-1},w_t,\ \ 0,X_t) = X_{1t}'\beta_3 + \alpha_1\, w_t \\
&State4: p_t = 1, m_t = 1 \quad && \mathcal{U}(1,1;p_{t-1},m_{t-1},ten_{t-1},w_t,\hat{w}_t^h,X_t) = X_{2t}'\beta_4 + \alpha_2\, w_t
\end{aligned} \qquad [8]$$

The vector X_{1t} includes both measures of human capital that affect market and household production and taste parameters of the utility function. In our specification X_{1t} contains the variables $p_{t-1}, m_{t-1}, ten_{t-1}$, and the female's age, race, education and region of residence. Note that the variable ten_{t-1} (as well as m_{t-1}) will equal zero if currently single. This implies that the duration of the marriage only affects the utility levels in states 1 and 3 (the *single* states) when the female is married at the time of the current choice decision, representing the possible dependence of divorce costs on the completed duration of the marriage. The vector X_{2t} contains all the variables in X_{1t} but also includes the expected husband's wage rate and w_t represents the logarithm of the female wage rate in period t.

Next the wage equation is specified as

$$w_t = X_{3t}'\gamma_1 + X_{4t}'\gamma_2 + u_t \qquad [9]$$

where X_{3t} represents the subset of human capital measures in X_{1t} affecting market production (p_{t-1}, age, education, race, region) and X_{4t} contains exp_{t-1}, exp_{t-1}^2 and a variable that reflects the average strength of demand in the local labor market[8]. Substituting the wage equation into the indirect utility functions in [7], the resulting utility levels associated with each state $i = 1, ..., 4$ are defined as

$$R_{it}(\mathcal{X}_t) + \epsilon_{it} = \mathcal{X}_t'\lambda_i + \epsilon_{it} \qquad [10]$$

where $\mathcal{X}_t$ consists of all variables in X_{1t}, X_{2t}, X_{3t} and X_{4t} so that given our definitions of X_{2t} and X_{4t} we can define $\mathcal{X}_t = [X_{2t}\ X_{4t}]'$. It is assumed that the transitory unobserved utility effects ϵ_{it} , $i = 1, .., 4$, are independently distributed over time and individuals[9].

Given the functional form specifications above, let $d_i(t) = 1$ if alternative $i \in I = (1, 2, 3, 4)$ is chosen in period t and $d_i(t) = 0$ otherwise. In correspondence with [7], the maximum expected value of utility at time t, $t < T$, is then

$$V_t(\Omega(t)) = \max_{i \in I}[\ R_{it}(\mathcal{X}_t) + \epsilon_{it} + \delta E[V_{t+1}(\Omega(t+1))|d_i(t) = 1, \Omega(t)]\ ] \qquad [11]$$

where $\Omega(t)$ is the relevant information set at t containing the current realizations of the error terms ϵ_{it}, the vector of individual characteristics $\mathcal{X}_t$ in period t (which include measures of the decision history until t) and the functional forms of the R_{it} functions.

It is possible to derive all $V_t(\Omega(t))$ functions $t = 1, .., T$ and to solve for the optimal policy at each t by exploiting the finite horizon nature of the dynamic programming problem. In period T we have $V_T(\Omega(T)) = \max_{j \in I}\ [R_{jT}(\mathcal{X}_T) + \epsilon_{jT}]$. Further, for each period $t < T$ and for each state vector $\mathcal{X}_t$, we can define three values ϵ_{kt}^* such that[10]

$$\begin{aligned} R_{1t}(\mathcal{X}_t) + \delta E[V_{t+1}(\Omega(t+1))|d_1(t) = 1, \mathcal{X}_t] + \epsilon_{kt}^* = \\ R_{kt}(\mathcal{X}_t) + \delta E[V_{t+1}(\Omega(t+1))|d_k(t) = 1, \mathcal{X}_t] \end{aligned} \qquad [12]$$

Then the optimal policy for each information vector $\mathcal{X}_t$ and each $i = 1, .., 4$ can be defined as:

$$\begin{cases} d_i(t) = 1 \\ d_j(t) = 0 \quad , \forall j \neq i \end{cases} \quad iff \quad \epsilon_{it} - \epsilon_{jt} \geq \epsilon^*_{jt}(\mathcal{X}_t) - \epsilon^*_{it}(\mathcal{X}_t) \quad \forall j \in I$$

In each period t, the 3 values ϵ^*_{kt}, $k = 2, 3, 4$ ($\epsilon^*_{1t} = 0$) divide the 4 dimensional space up into regions in each of which one (assuming no ties) of the alternatives is optimal. Given the decision rule in each period and given V_T and [11] it is possible to solve, by backward recursion, for all $V_t(\Omega(t))$ functions and all ϵ^*_{kt} values. Note that this involves the calculation of the expectations $E[V_{t+1}(\Omega(t+1))|d_i(t) = 1, \mathcal{X}_t]$ for each i and t, which itself requires the calculation of the expectations $E[\max \epsilon_{it+1}|d_i(t) = 1, \mathcal{X}_t]$.

Knowing the optimal policy it is possible to calculate for each set $\mathcal{X}_t$ the probability that alternative i is chosen in period t as

$$Pr(d_i(t) = 1|\mathcal{X}_t) = Pr[\epsilon_{it} - \epsilon_{jt} \geq \epsilon^*_{jt}(\mathcal{X}_t) - \epsilon^*_{it}(\mathcal{X}_t) \quad \forall j \in I] \tag{13}$$

In general only numerical solutions for these probabilities and the expected value functions are available. When the errors have an extreme value distribution with variance parameter r, however, the choice probabilities actually do have an analytical solution:

$$\begin{aligned} Pr(d_i(t) = 1|\mathcal{X}_t) = \quad & Pr[\epsilon_{it} - \epsilon_{jt} \geq \epsilon^*_{jt}(\mathcal{X}_t) - \epsilon^*_{it}(\mathcal{X}_t) \quad \forall j \in I] \quad = \quad \frac{exp(\epsilon^*_{it}/r)}{\sum_{j=1}^4 exp(\epsilon^*_{jt}/r)} \\ = & \frac{exp\Big[(R_{it}(\mathcal{X}_t) + \delta E[V_{t+1}(\Omega(t+1))|d_i(t) = 1, \mathcal{X}_t])/r\Big]}{\sum_{j=1}^4 exp\Big[(R_{jt}(\mathcal{X}_t) + \delta E[V_{t+1}(\Omega(t+1))|d_j(t) = 1, \mathcal{X}_t])/r\Big]} \end{aligned} \tag{14}$$

Also, the expected value functions turn out to have a convenient analytical solution in this case[11]. Using the fact that $E[\epsilon_{it}|d_i(t) = 1, \mathcal{X}_t] = -r \; ln\big[Pr(d_i(t) = 1|\mathcal{X}_t)\big]$, it is straightforward to show that

$$\begin{aligned} E[V_t(\Omega(t))|\mathcal{X}_t] =& E\big[\max_i\{R_{it}(\mathcal{X}_t) + \delta E[V_{t+1}(\Omega(t+1))|d_i(t) = 1, \mathcal{X}_t] + \epsilon_{it}\}|\mathcal{X}_t\big] \\ =& \; r \; ln \sum_{j=1}^{4} exp\Big[[R_{jt}(\mathcal{X}_t) + \delta E[V_{t+1}(\Omega(t+1))|d_j(t) = 1, \mathcal{X}_t]/r\Big] \end{aligned}$$

As described in the previous section, our PSID sample constitutes a panel of 548 individuals in which the choice of each alternative i is observed for each individual k for

T_k periods. Let the decision set for individual k be $\underline{d}^k(t) = [d_1^k(t), d_2^k(t), d_3^k(t), d_4^k(t)]$ and $\mathbf{d}^k = [\underline{d}^k(1), ..., \underline{d}^k(T_k)]$ where $d_i^k(t)$ specifies the actual choice of alternative i for individual k at time t. Thus $\underline{d}^k(t)$ is the vector defining the choice of alternative at time t for individual k and $\mathbf{d}^k$ is the vector describing the choice set over the individual's observed sample period.

Our objective is to estimate the structural parameters θ consisting of β_i, $(i = 1, .., 4)$, γ_1, γ_2 and α_1, α_2 in the utility and wage functions ([8] and [9] respectively), the discount factor δ, and the parameter describing the error distributions of the ϵ_{it}'s , r, given the observed data on the individuals' choices and wages.

Focussing first only on the data on the actual choices of the (K=548) individuals and ignoring the wage equations, the (marginal) likelihood function is defined as

$$\begin{aligned} L_1(\lambda) &= \prod_{k=1}^{K} Pr(\mathbf{d}^k|\lambda) \qquad [15] \\ &= \prod_{k=1}^{K} Pr[\underline{d}^k(T_k)|\underline{d}^k(T_k-1), ..., \underline{d}^k(2), \underline{d}^k(1)] \cdots Pr[\underline{d}^k(2)|\underline{d}^k(1)] Pr[\underline{d}^k(1)] \end{aligned}$$

where λ is the vector of 'reduced form' parameters in [10] , that is $\lambda = [\lambda_1, \lambda_2, \lambda_3, \lambda_4, \delta, r]$. Each of the probabilities above is equal to the probability that the chosen alternative is the optimal one, which is equal to the probability that the draw of the $(\epsilon_{it})_{i \in I}$ vector falls in the region of the (ϵ_t) space where the chosen alternative is optimal. In the case of i.i.d. extreme value ϵ's, the likelihood function equals the product of logistic probabilities like [14]. On the other hand, when the errors are i.i.d. normal, each probability involves a numerical evaluation of a trivariate normal integral. Thus an algorithm for estimating the model amounts to calculating these probabilities for each individual and time period. As we saw above, the backward recursive solution to the dynamic programming problem provides us with these probabilities. Note that for each set of parameter values the evaluation of the corresponding likelihood function requires solving the dynamic programming problem for each individual separately. Estimation is therefore not a trivial task and necessitates fairly extensive computer run times[12].

The other data available are the wages in the years each female works. Incorporating this information, the sample likelihood function is

$$L_2(\theta) = \prod_{k=1}^{K} Pr(\mathbf{d}^k, \mathbf{w}^k|\theta) \qquad [16]$$

where the likelihood function can now be expressed in terms of all the structural coefficients θ and where $\mathbf{w}^k = [w_1^k, ..., w_{T_k}^k]$, elements of which will be zero (missing) if in that period the female does not work.

Maximization of the likelihood L_2 is computationally much more cumbersome than maximization of L_1, as the parameter space is much smaller in the latter. Further, L_2 requires a specification of the joint distribution of the error terms. We therefore propose an alternative two-stage estimation procedure.

In the first stage the likelihood function L_1 is maximized to find consistent estimates of the reduced form coefficients λ. We then proceed by using the wage data to estimate the coefficients in the wage equation, $\gamma = [\gamma_1\ \gamma_2]'$, while correcting for the selection bias caused by using data on workers only (see appendix II). In the second stage, given the two sets of consistent estimates from the first round, say $\hat{\lambda}$ and $\hat{\gamma}$ with associated covariance matrices $V_{\hat{\lambda}}$ and $V_{\hat{\gamma}}$, we can obtain consistent estimates of the structural parameters θ by using a minimum distance estimator (MDE) (see Chamberlain [1985]). We define the MDE as

$$\hat{\theta} = \arg_\theta \min \left[\hat{p} - g(\theta)\right]' V^{-1} \left[\hat{p} - g(\theta)\right]$$

where the function g imposes on the reduced form parameters the restrictions specified by the structural model and $\hat{p} = [\hat{\lambda}\ \ \hat{\gamma}]'$. V represents the covariance matrix corresponding to $\hat{p}$ and can be estimated using both the estimates $V_{\hat{\lambda}}, V_{\hat{\gamma}}$ and the outerproduct of the first order conditions (see appendix I).

The resulting estimate of θ, $\hat{\theta} \xrightarrow{a.s.} \theta^\circ$ and

$$\sqrt{N}(\hat{\theta} - \theta^o) \xrightarrow{D} n[0, (H'V^{-1}H)^{-1}] \qquad [17]$$

where $H = \partial g(\hat{\theta})/\partial\theta'$ and θ° is the true value of θ (see Chamberlain [1985]).

Parameter identification is best discussed by studying the two steps in the estimation procedure separately. Starting with the wage equation [9], the coefficients γ_1, γ_2 and the coefficient of the selection bias term are identified by the data on wages, as ten_t and mar_{t-1} do not directly enter the wage equation. In the estimation of the reduced form model in [10], similar to identification in static discrete choice models, a normalization has to be imposed on the coefficients of the variables in $\mathcal{X}_t$ that appear in all four utility specifications. We therefore normalize λ_1 and β_1 to zero. Further, as is the case in a standard discrete choice model, the error variance parameter r is not identified and will be normalized to one, implying that the utility function parameters are only identified relative to each other. The discount factor is in our case identified through the non-linearity of the expected value functions.

Having discussed the identification of the coefficients λ and γ, the identification of the structural utility parameters follows from the minimum distance estimator. In our empirical specification the variables included in Z, used to predict the husband's wage, $\hat{w}_t^h$, are the same as the variables included in the female's wage equation, X_3 and X_4. Further, in our specification, X_4 contains three regressor variables not included in X_1. This implies that the structural utility parameters, α_1, α_2, β_2, β_3 and β_4 are over-identified.

5. Estimates of the Structural Model

Before presenting the estimates of the structural parameters that were obtained in the second stage of the two-stage estimation procedure outlined in section 4, we will briefly discuss the first stage estimation. In the first stage, for the sample of 7204 person-year observations, the likelihood function L_1 was maximized to obtain estimates of the reduced form model as described by [10]. Next, in estimating the wage equation a selectivity bias correction was required to correct for the fact that the wage equation was estimated using data on working women only. We used the first stage estimates of the reduced form parameters to obtain an estimate of the selectivity bias. This term was then included as regressor variable in the wage equation. Lee (1982) derived the appropriate correction term when the error in the selection equation has a nonnormal distribution and when the selection is of the polychotomous-choice type, as is the case here (see appendix *II*).

It is important to point out that this two-stage selection bias correction procedure does not depend on the assumption of normality of the wage equation error u_t. A sufficient assumption is the linearity of the conditional expectation function of u_t. As argued in the previous section, the main advantages of the proposed minimum distance estimator are the reduction in the dimensionality of the parameter vector in the estimation of the dynamic programming model and the fact that we need not specify the complete distribution of the wage error term.

In the empirical specification of the model some structural parameters in the model are overidentified. Instead of discussing the (somewhat harder-to-interpret) reduced form parameter estimates derived in the first stage of the estimation, we therefore proceed directly with the presentation of the minimum distance estimates of the structural parameters. The corresponding estimates of the reduced form parameters λ, and wage equation parameters, γ_1 and γ_2 are presented in Tables $A2$ and $A3$ in the appendix.

Parameter Estimates

The model was estimated for four values of the discount rate, $\delta = 0.00, 0.75, 0.85$ and 0.95 and for two different distributions of the ϵ_{it} error terms, namely the independent extreme value and independent normal distribution[13]. The estimation results for the three positive discount factor values were qualitatively very similar compared to the zero discount factor results, both in terms of explanatory power and in their implications for individual response behavior which will be analyzed below. To limit the number of tables and results, and to focus on the difference between the implications of a dynamic versus a static model, we will therefore only report and compare the $\delta = 0.85$ and $\delta = 0$ estimation results.

Further, the parameter estimates are presented only for the model with extreme value errors. When the disturbances have an independent normal distribution, the estimation results were almost identical to those found for the extreme value distribution[14]. This is perhaps not very surprising since both the normal and logistic distributions are very similar, except in the extreme tails.

Table 4 presents the estimates and asymptotic standard errors of the structural parameters for the two values of the discount factor. The standard errors of the estimates are obtained as in [21], using the estimate of the covariance matrix $\hat{V}$ presented in appendix I. In the case when the discount factor is zero, the model reduces to a static model, while when $\delta = 0.85$ dynamics becomes important as each female takes into account the consequences of current decisions on future wages and utility levels. [Table 4 here]

As the coefficients in the 'single+not-work' state, β_1, were normalized to zero, all coefficients reported in the table represent the effect of each variable on the indirect utility level associated with each choice relative to its effect on the 'single+not-work' utility level.

First of all, in both specifications the estimates of the wage coefficients are similar to the ones found in many other studies. Next to the expected positive experience and education effects, we find slightly lower wage earnings for non-whites and for those living in the South, and somewhat higher average wages for those living in states with higher mean manufacturing wages (measuring greater local labor demand). In addition, a strong separate positive effect is found of the previous period's work decision, indicating that more recent work experience has a higher wage return than earlier work experience. Age has the expected negative sign, picking up the depreciation of human capital with time spend out of the labor force.

Concerning the utility parameters, the most important findings can be summarized as follows:

(1) A higher female wage rate has a positive and significant effect on the utility associated with working (and thus on the probability of working) in both specifications ($\alpha_1 > 0, \alpha_2 > 0$). For working women, or conditional on the decision to work, a higher wage has a negative significant effect on the utility gains from marriage in the zero discount factor case ($\alpha_2 - \alpha_1 < 0$), but not in the positive discount case ($\alpha_2 - \alpha_1 = 0$) (asymptotic

T-statistics for differences in the structural parameters are reported in Table A4). The total impact of a higher wage rate on the utility gains from a marriage is not directly obvious and will depend on its separate effects on utility in the two working states. This issue will be discussed in more detail below.

(2) Higher husband's wage earnings decrease the gain in utility derived from working when married ($\beta_{47} - \beta_{27} < 0$), increase the gains from marriage when not working ($\beta_{27} > 0$) but have an insignificant effect ($\beta_{47} = 0$) on these gains when working. The total effect of a higher husband's wage rate on marital gains is therefore positive.

(3) Non-whites receive lower utility gains or a greater disutility of working when single ($\beta_{34} < 0$) and (although somewhat less so) when married ($\beta_{44} - \beta_{24} \leq 0$). In total, the utility gains from working are smaller for non-whites. Not-working white women receive significantly higher utility gains from marriage than non-white women ($\beta_{24} < 0$) in the zero discount factor case, but not in the positive discount factor case ($\beta_{24} = 0$). To evaluate the total impact of race on both the work and marriage decisions, next to these direct utility effects also the indirect effects through race differentials in the female's and her (potential) husband's wage rates should be incorporated.

(4) More years of education decrease the utility gains from working, or increase the disutility of working for single women ($\beta_{32} < 0$) only when $\delta = 0$. The same is true for married women ($\beta_{42} - \beta_{22} < 0$), but for them it does so significantly for both values of the discount factor. This last result was also obtained by Eckstein and Wolpin (1989). Schooling does not have any significant effect on utility gains from marriage both when working and not working ($\beta_{42} - \beta_{32} = 0$, $\beta_{22} = 0$). Again this is a partial effect, keeping all wages constant.

(5) Older women who do not work have lower utility gains from being married than younger women who do not work ($\beta_{23} < 0$). Age has no effect on marital gains for working women ($\beta_{43} - \beta_{33} = 0$). Gains from working increase with age for married women in the positive discount factor case ($\beta_{43} - \beta_{23} > 0$), but not for single women ($\beta_{33} = 0$). This

might reflect the fact that a mother's disutility of work falls when children grow older.

(6) Women living in the South obtain greater utility gains from marriage if not working ($\beta_{25} > 0$), and (slightly less so) when working ($\beta_{45} - \beta_{35} \geq 0$). When single they have slightly larger utility gains from working ($\beta_{35} \geq 0$), but no effect is found when married ($\beta_{45} - \beta_{25} = 0$). These results might reflect differences in cultural and religious backgrounds.

(7) The fixed utility ~~losses associated with a divorce~~, β_{29} and ($\beta_{49} - \beta_{38}$), are both large and positive significant. A chi-square test does reject the hypothesis that they are the same for both working and non-working wives, with the latter being significantly larger. These utility losses do appear to depend quite strongly on the duration of the dissolved marriage for working women ($\beta_{48} - \beta_{37} > 0$), although only significantly so in the zero discount factor case. For non-working women, the duration effect is not significantly different from zero ($\beta_{28} = 0$) in either specification. This result is surprising as one would expect the costs of a divorce to increase with the accumulation of marital specific capital both for working and non-working women.

(8) Comparing the utility derived from working and not working when single, the disutility of work decreases (or utility gains increase) with the amount of prior work ($\beta_{36} > 0$), which could reflect habit persistence. Increasing utility gains from working might also be the result of improving non-pecuniary job characteristics with the accumulation of more work experience. For married women the same is true and even to a larger extent than for single women ($(\beta_{46} - \beta_{26}) - \beta_{36} > 0$). Also, the utility gains from marriage are greater if the individual worked in the previous period (keeping wages constant).

(9) Although perhaps not immediately obvious from the table, the estimates for the static model with $\delta = 0$ are quite different from those of the dynamic model with $\delta = 0.85$. Unfortunately, it is not possible to test one discount factor value specification against the other, as they are not nested. By studying the differences in the implications of the static and dynamic model, however, we will find below that both models imply very different

optimal choice behavior.

Own and Husband's Wage Effects

To understand the implications of these estimates for individual behavior patterns, it will be useful to analyze in more detail the influence of some of the variables and in particular the female's wage rate and the (expected) husband's wage earnings on the work and marital status decisions made over the life cycle, as implied by the parameter estimates.

Table 5 reports, for both values of the discount factor, the impact of changes in some of the variables on the decision to work and to be married for a female of fairly representative characteristics at two different points in her lifetime[15]. The first column reports responses in marriage and work decisions of an 18 year old single female who has just left school. The second and third columns give similar responses later in life, at age 25, when the female has been married for the last three years. The second column corresponds to the case where the female has never worked in the labor force since leaving school, while in the third column she has accumulated five years of work experience and is currently (at the time of the current choice decision) working.

Considering first the relationship between the female's wage rate and the participation decision, two types of wage changes are considered. The first one represents a permanent increase in the hourly wage rate of $1 where the wage growth rate in subsequent periods, due to increasing work experience and age, is applied to the increased current wage rate. The second is a temporary increase in the wage rate of $1 which applies only in the current year with next year's wage rate back at the level it would have been without the current period's wage change.

According to Table 5, for the dynamic specification, a one dollar permanent increase in the female's real hourly wage rate increases the probability of working in the three cases by respectively 21, 18 and 8 percentage points. For a temporary change, these increments are only 12, 7 and 4 percentage points. One might have expected a greater effect of a temporary wage change than a permanent wage change, reflecting a strong intertemporal substitution effect[16]. However, both human capital accumulation in the form of work experience and forward looking behavior by the individual leads to the opposite result as the expected future wage returns to current work effort are much smaller in case of a temporary change, outweighting an intertemporal substitution effect. The static model can not distinguish between permanent and temporary changes and provides equal estimates of 25, 12 and 7 percentage points for both. Thus, myopic and forward looking behavior have very different implications for individual labor supply responses to alternative types of wage changes.

The $\delta = 0.85$ estimates further imply that similar increases in the (expected) husband's wage rate reduce the probability of working by about 9, 6 and 13 percent for a permanent increase and 2, 3 and 5 for a temporary increase, by increasing the probability that the single female at age 18 will choose to get married (and choose the married-non-work option) and through a negative income effect when the 25 year old female is married. In the static model temporary and permanent changes again have identical effects and in the three cases here imply reductions in the probability of working of 4, 4 and 6 percentage points.

Considering the effect of both wages on marital status decisions, for the $\delta = 0.85$ case, the probability that the 18 year old single female chooses to get married increases by about 13 and 4 percentage points with a permanent and temporary one dollar increase in the (expected) husband's wage rate and decreases by 7 and 2 percentage points with similar one dollar increments in her own wage. The myopic model instead predicts an increase of 8 and a drop of 5 percentage points in the probability of marriage for both types of increases in the husband's wage and own wage rate.

Similar results are found when the female is 25 years old and currently married. The female's own wage has a positive effect on the probability of divorce, which is somewhat bigger for the female without work experience. An increase in the husband's wage rate, on the other hand, leads to a decrease in the probability of divorce. These results appear consistent with Becker's specialization of labor argument, which predicts greater marital gains when the ratio of the wife's over the husband's wage is smaller. According to Becker's theory, women with higher earnings gain less from marriage than other women because higher earnings reduce the demand for children and the advantages of the sexual division of labor in marriage (Becker[1981], p.231). While a higher husband's wage rate, through its income effect, reduces the probability of working, a rise in the female's wage rate may increase her work effort, leading to a reduction in the gains derived from specialization of labor, and with that in the utility gains derived from being married.

Concerning the responses to the other variables, Table 5 shows that for both discount factor values one extra year of education increases the probability of working in all three cases, but only because of the associated increases in her wage rate. The increase in education slightly increases the probability of getting or staying married. Combined with its effect on the two wage rates however, education has, besides its direct effect on delaying the timing of the first marital status decision, basically no effect on the marital status decision. The gains from marriage are greater for women living in the South, leading to higher marriage and lower divorce probabilities. These women are also somewhat more likely to work at age 18, but less (sligtly more) likely to work at age 25 in the positive (zero) discount factor case. Non-white women have lower wages and a higher disutility of work, leading to lower probabilities of working. They also face on average lower marital gains, leading to a lower probability of marriage and a much higher probability of divorce.

The results above showed that the difference in ability to distinguish between temporary and permanent wage changes will result in important differences in behavioral implications of the dynamic and static model of utility maximization. Further, even though the direction of the responses are almost always the same, the magnitude often differs considerably. To study this issue in more detail, it may be more interesting to consider longer term responses in marriage, divorce and work behavior. Accordingly, for the same representative single, 18 year old female yearly choice probabilities were predicted by simulating 1000000 choice sequences from age 18 to age 35, using the parameter estimates from Table 4. The yearly choice probabilities were then obtained by averaging these simulated choice paths. Corresponding probabilities of being employed and conditional probabilites of entering into marriage, conditional on having been single until that year (ie. the "hazard rate" or marriage rate), are shown in Figures 3 and 4, labelled "baseline" predictions.

Dynamic and Myopic Response Behavior

To illustrate the differences in myopic and forward looking behavior, the responses to two different changes in individual characteristics were studied. The first one concerns an increase in the wage returns to work experience. The second represents a 10 percent increase in the fixed (non-duration dependent) utility losses incurred by a divorce. Responses in work probabilities and marriage rates to an increase in wage returns are shown in Figures 3 and 4. Here, the coefficient of work experience (EXP) in the wage equation γ_{21} was increased by 25 percent, increasing by a constant amount the returns at each experience level. It is clear that an increase in wage returns has very different impacts in both discount factor value cases. In the static model this change will only start to affect the probability of working several years later, while in the dynamic model, with forward looking behavior, the increase in this probability is immediate and becomes more pronounced over the years. The same is true in Figure 4. While in the static model effects only become apparent at older ages, in the dynamic case a greater rate of return to work experience also lead to a reduction in the marriage rate at younger ages, where the female who faces a steeper wage profile is less likely to marry at each age. Forward looking behavior leads to a greater investment into human capital or work experience through higher participation rates and also leads to lower expected future gains from marriage, causing both a delay of entry into marriage and somewhat lower probabilities of ever marrying.

Figures 5 and 6 show how both patterns are affected by a 10 percent increase in the fixed utility costs of a divorce, that is, both β_{29} and $\beta_{49}-\beta_{38}$ were increased by 10 percent. In our model β_{29} and $\beta_{49}-\beta_{38}$ represent the non-stochastic fixed (non-tenure dependent) utility losses of non-working and working women when deciding to divorce. These utility losses (or gains) include the direct costs of a divorce (monetary and non-monetary) and the extra utility gains accumulated after the first year of marriage (the "returns to marriage" received after the first year of marriage), which are lost upon a divorce. Therefore in our model, in which the utility parameters in the single-not working utility function are not identified and normalized to zero, this increment corresponds to both an increase in these returns to marriage and an increase in the direct costs of a divorce.

Again, the dynamic and static model differ sharply in their predictions. In the dynamic model the change has a direct impact on the choice behavior of the single non-working female. In anticipation of greater utility gains after the first year of marriage, the overall (expected) utility gains from marriage and thus the probability of marriage increase sharply leading to an immediate reduction in the probability of working and a stronger temporary decline in the 20 to 25 age range. According to the static model, the increase in divorce costs and returns to marriage will only affect work choices later in life, once the individual is actually married. Thus marriage rates are unaffected in the myopic model, while they respond more according to expectations in the dynamic model. Once married, the increase in the divorce costs will reduce the divorce rate and the probability of working in both discount factor cases. Higher divorce costs imply more stable marriages and with that more specialization of labor and a greater investment in marriage specific capital, partly explaining the lower divorce rates and work probabilities.

An important question at this point is: How much do the wage elasticities of female labor supply change when marital status is included as an endogenous rather than an exogenous regressor variable? In particular, for the model estimated here, how do wage elasticities conditional on marital status compare to the unconditional ones? Unfortunately, because of the discrete nature of our labor supply measure, it is not possible to derive conventional wage elasticities of labor supply. It is however possible to use the estimates to decompose the total change in the participation probability due to a one dollar increase in the wage rate into two parts. The first part measures its direct effect on the probability of working, while keeping the *probability* of choosing to be married in the current period constant. The second represents an indirect wage effect on the labor force participation probability caused by a change in the probability of choosing the married state when the wage increases (see Appendix *III*).

To illustrate this decomposition, predicted wage effects were calculated for all observations in our sample that were part of the 1984 wave, forming a 1984 cross section. The average total change in the probability of working caused by a one dollar (permanent) increase in each female's wage rate and in all husbands' wage rates was, respectively 9.56 percentage points (about 15 percent) and 4.77 percentage points (7 percent). The indirect effects accounted for 3 percent of the total wage effect and 13 percent of the total husband's wage effect. When comparing the individual decompositions, we found that the indirect effects are greatest (in both percentage and absolute terms) at younger ages when the female has not yet married, where both indirect effects account for 8 percent and 43 percent of the total wage effects. For these women, a higher wage rate implies lower gains from marriage, reducing the tendency to get married which then leads to an increase in the probability of working. For married women the indirect effect is much smaller. For example, for a 25 year old married woman, the indirect effect accounts for only 2 percent and 4 percent of the total own and husband's wage effect.

These predictions imply that the total effect of a wage change will be underestimated by up to 3 percent if one ignores the endogneity of marital status decisions. Similarly, the negative effect of an increase in the expected husband's wage rate will be underestimated by 13 percent if one does not take account of the fact that greater expected husband's wage rates reduce the probability of a divorce and increase the probability of marriage. Even though we can not use our estimates to calculate wage elasticities of hours of work, these results do suggest that wage elasticities are likely to be (slightly) underestimated in traditional labor supply models which condition on marital status, especially if the sample includes a relatively large number of single women.

6. Explanatory Power and Unobserved Individual Effects

To analyze the predictive power of the model, Table 6 compares the proportions of women choosing each of the four states as predicted by our model to the actual proportions for each year since leaving school. Except perhaps for the first and the last few years, the predicted trend in the proportion of women who are married is very close to the actually observed trend as seen in Figure 1. Also the predicted trend in the labor force participation rate seems to capture the actual trend reasonably well, except perhaps in the first and last few years (the imprecision in the last few years is partly due to the small number of individuals in the sample who we observe for 16 years or more). It seems to predict the drop in the participation rate that occurs after the fifth year and the subsequent increase in later years, though often with a lag of about one year (see Figure 1). This might indicate that the model is not completely successful in picking up the observed state dependence in labor force participation behavior. One possible explanation is the presence of unobserved heterogeneity, which will be studied below.

Disaggregating the participation rate by marital status, Figure 2 shows that the model captures the major trends in the labor force participation rate fairly well. However, for single women the model is not able to explain the sharp drop in the 13th year since leaving school. This drop appears to be related to a reduction in the sample size of single women, as more than 60 women whose work decisions were observed in the 12th year are no longer in the sample in the 13th (see Table 6). For married women the predictions in the first two and last year are quite far below the actual rates. For these years, however, there are relatively few observations available. A more problematic area where the predicted values deviate from actual values is the region between the 6th and 11th year. These are most probably the years in which women withdraw from the labor force to look after young children at home. Given that information on births of children was not incorporated into this analysis, it is not surprising that the model there overestimates the participation rate. It is reasonable to assume that the incorporation of fertility decisions will considerably improve the fit of the model in this region. Because those decisions are clearly endogenous within such a model, incorporating them is not a simple task.

It must be stressed however, that overall the model does surprisingly well in predicting both the year by year choices and most life cycle patterns: predicting the much higher labor force participation rates at all age levels for single women as compared to married women and predicting the sharp rise, flattening and eventual decline of the labor force participation rates for single women. It also predicts the increasing labor force participation rate of married women at later ages (as compared to a decline for single women), the rapid increase in the proportion of women who are married in the years just after leaving school and also the eventual stabilization of the labor force participation rate at around 70 percent. Similar predictions based on the static model were almost identical to the ones above and are therefore not shown here.

The assumption of identically independently distributed errors ϵ_{it} in the indirect utility functions, might be a strong and unrealistic one. It assumes that the errors are independently distributed across choices and time, which in a static (but not in a dynamic) framework would imply the well known independence of irrelevant alternatives property.

To allow for one specific kind of correlation over time and choices, a simple permanent-transitory scheme with $\epsilon_{it} = \mu_i + \sigma_{it}, \quad i = 1,..,4$ was adopted in [10], where μ_i are individual specific taste parameters associated with state i, that are known to the individual in the initial period, but unobserved by the econometrician. The σ_{it} now represent the purely transitory unobserved utility effects. By redefining the $R_{it}(\mathcal{X}_t)$ functions to be $R_{it}(\mathcal{X}_t) = \mathcal{X}_t{}'\lambda_i + \mu_i$, $i = 1,...,4$, a similar specification is obtained as in [10]. In this case, the likelihood functions defined in [15] and [16] are conditional likelihoods where the conditioning (though omitted there) is on the set of errors $\mu = [\mu_1,..,\mu_4]'$. By integrating over the distribution of μ, we can remove the conditioning on μ to obtain the sample likelihood function $\mathcal{L}_1$ defined as

$$\mathcal{L}_1(\lambda) = \prod_{k=1}^{K} \int Pr(\mathrm{d}^k|\lambda,\mu)dF(\mu) \qquad [18]$$

where F is the distribution of μ.

Instead of specifying F a nonparametric approach was adopted which was proposed by Heckman and Singer (1984). Suppose there are N types of individuals ($N < K$) with permanent taste components equal to $\mu^1, ..., \mu^N$, where $\mu^s = [\mu_1^s, ..., \mu_4^s]'$, and comprising $q^1, ..., q^N$ proportions of the population, respectively. Then for each type μ^s the contribution to the likelihood function $Pr(\mathrm{d}^k|\lambda, \mu^s)$ can be calculated. The likelihood contribution of an individual k will then equal the weighted average of these terms, where the weights are the sample fractions $q^1, ..., q^N$. The distribution of the unobservable can be estimated along with the parameters.

In the following estimations, it was assumed that there are four types of individuals who differ according to their attitude towards working in the labor market and marriage: they can either have a relatively low or high desire for marriage and working[17]. Individuals can therefore be divided into 4 groups (types), with population proportions $q^1, ..., q^4$. The first type has a (relatively) low preference for both marriage and work. The second also has a low preference for work, but has a high preference for marriage, in that this type of individual receives ρ^1 more utility units when married than type 1. The third group has a low preference for marriage, but a high preference for work. Individuals of this type receive ρ^2 extra utility units when working. Finally, type 4 individuals receive higher utility both from marriage and from working. To allow those with a preference for work to have different increments in the utility level depending on whether they are married or single, the increase ρ^3 for married women is allowed to be different from the increase ρ^2 for single women. Thus the utility levels for each type are defined as:

$$Type1 : R_{it}(\mathcal{X}_t) = \mathcal{X}_t'\lambda_i \quad (\mu_i^1 = 0) \quad i = 1, ..., 4$$

$$Type2 : R_{it}(\mathcal{X}_t) = \mathcal{X}_t'\lambda_i \quad (\mu_i^2 = 0) \quad i = 1, 3 \qquad R_{it}(\mathcal{X}_t) = \mathcal{X}_t'\lambda_i + \rho^1 \quad (\mu_i^2 = \rho^1) \quad i = 2, 4$$

$$Type3 : R_{it}(\mathcal{X}_t) = \mathcal{X}_t'\lambda_i \quad (\mu_i^3 = 0) \quad i = 1, 2 \qquad R_{it}(\mathcal{X}_t) = \mathcal{X}_t'\lambda_i + \rho^2 \quad (\mu_i^3 = \rho^2) \quad i = 3, 4$$

$$Type4 : R_{1t}(\mathcal{X}_t) = \mathcal{X}_t'\lambda_1 \quad (\mu_1^4 = 0) \qquad R_{2t}(\mathcal{X}_t) = \mathcal{X}_t'\lambda_2 + \rho^1 \quad (\mu_2^4 = \rho^1)$$

$$R_{3t}(\mathcal{X}_t) = \mathcal{X}_t'\lambda_3 + \rho^3 \quad (\mu_3^4 = \rho^3) \qquad R_{4t}(\mathcal{X}_t) = \mathcal{X}_t'\lambda_4 + \rho^1 + \rho^3 \quad (\mu_4^4 = \rho^1 + \rho^3)$$

Estimates of the model with $\delta = 0.85$ are reported in the first column of Table 7. Most of the parameter estimates, especially the significant ones, are very similar to those in Table 4. Some parameter values do change however, especially those of the variables that remain constant over time, such as RACE, SOUTH and EDUC and also the coefficient of the duration of the current marriage, TEN, which becomes smaller and insignificant, but rarely by more than one standard deviation. Overall the qualitative results are very similar to those of Table 4.

Looking at the heterogeneity distribution, we find that the largest groups in the population are the 47 percent females of type 2 (with a high preference for marriage but a low one for working) and 33 percent of type 4 (high preference for both). The remaining 20 percent have a relatively high preference to remain single. The population appears to be randomly distributed into these 4 categories with the probability of having a high preference for marriage being independent of the probability of having a high preference for work. Random assignment implies that $q^1 \cdot q^4 = q^2 \cdot q^3$. Here we find 0.0392 and 0.0368 for both expressions and we cannot statistically reject their equality. Further, the difference in the estimates of μ^2 and μ^3 is not statistically significant, indicating that those who prefer work do so to the same extent, irrespective of their marital status.

The introduction of this type of unobserved heterogeneity reduces the likelihood value of the first stage maximum likelihood estimation by 18 points. Given that 6 extra parameters were estimated, this improvement in the likelihood is statistically significant at the 95 percent level ($-2 \cdot Loglik = 36.2$ while $\chi(6, 0.95) = 14.4$). The estimates of the distribution parameters imply that the assumption of i.i.d. extreme value may be too restrictive in that they do not allow for either non-zero serial correlation over time or dependence between the current period's alternative-specific utility error terms. On the other hand, the results show that the qualitative estimation results do not change very much when these restrictions are relaxed, giving an increased confidence in the validity of the main results.

7. Conclusion

This paper has been concerned with the construction and estimation of a structural dynamic model of marital status and labor force participation decisions that a woman makes over her lifetime. The individual's optimization problem was modelled as a dynamic programming problem that can be solved by backward induction. To estimate the model a two stage procedure was proposed which allows, in addition to data on work and marital status choices, for the incorporation of wage data in a computationally simple way.

The results showed, first, that work and marital status decisions are strongly related and indicated that the way in which participation decisions are affected by variables such as race, education and wages is different for single and married women. This implies that a simple marital status dummy variable that is typically included in empirical studies of female labor supply can not satisfactory capture these differences in the participation decision process.

Second, and more importantly, the results showed that marital status decisions strongly depend on various characteristics of the female which also affect her labor supply decisions. This implies that a female's marital status cannot be considered exogenous with respect to the participation decision. A higher wage rate, for example, increases the probability that the female will work but also decreases the gains from marriage leading to both lower marriage rates and higher divorce rates among high-wage women. Higher expected husband's wage rates increase the probability of getting married and decrease the probability that married women work. Ignoring the endogeneity of marital status decisions leads to an underestimation of the magnitude of the response of female labor force participation to these wage effects. Third, the results indicate that dynamics play an important role in female labor supply and marital status decisions. The dynamic model studied here has more plausible implications for the response behavior to changes in wage returns to work experience and changes in divorce costs, than a static model.

The results indicate that the estimates of our model are robust to the incorporation of one particular form of unobserved time-invariant heterogeneity. However, more general forms of serial correlation in the error terms and less restrictive assumptions concerning the within-period correlation between choice specific errors should be explored. Also, more research is required to investigate the estimation problems encountered in several studies, including this one, when trying to estimate the discount factor. In the model presented here, the discount factor is identified solely through the non-linearity of the value function and is therefore, if estimable, sensitive to alternative functional form specifications of the indirect utility function.

Finally, this study's finding of a strong relationship between returns in the labor and marriage market has important policy implications. Any policy program aimed at influencing female or male labor supply behavior may have important effects on marriage and divorce behavior, which could affect the ultimate outcome of the program. Ignoring these marital status effects may therefore lead to incorrect policy evaluations. To date studies on the individual and family welfare implications of welfare programs have considered either only the work (dis)incentives of welfare programs, such as AFDC, or only their effect on marriage and divorce decisions. A study of both incentive effects together will be of considerable importance given the strong interdependence between work and marital status decisions.

Endnotes

[1]We assume the existence of a market of available husbands in each period.

[2]Note that in this specification, as in [1], I have for simplicity restricted the costs of a divorce to affect utility levels in the current period only.

[3]I also adopt the assumption that the husband's *actual* earnings, when married, are realized only after the female's choice decision is made, so that only *expected* earnings matter in the marriage and work decision both when married and single.

[4]The strong separability assumption in [1] is made for computational convenience only. Although computationally more burdensome, it is conceptually straightforward to solve the maximization problem when interactions of the error term with any of the arguments in the utility function are included.

[5]Learning about this quality can be modelled in much the same way as in the worker-firm model of Jovanovic (1979), in which individuals learn about a time-invariant "true" value of a match. Given the nature of marriages where the value of the marriage is likely to change over time with the births of children, for example, this is not a reasonable assumption. A more general learning scheme however would require a too simplistic specification of the model to be worthwhile.

[6]Introducing more variables to characterize the choice history leads to an increase in the state space of the dynamic programming problem described in section 4.

[7]In the first year, when the female leaves school, the cut-off level is defined to be 600 hours. I found that the estimation results did not change very much when cutoff points of 500 and 1000 hours were used instead of 775.

[8]This specification is based on the assumption that while wages earned today depend both on recent and earlier work history (through total work experience), the disutility of working today is likely to depend primarily on the most recent work effort, that is on p_{t-1}.

[9]Unobserved persistent individual effects will be introduced in section 5.

[10]Note that conditioning on the information set $\Omega(t)$ in the expected value function of $t+1$ is equivalent to conditioning on $\mathcal{X}_t$ as the errors are assumed to be serially uncorrelated. Allowing for non-zero serial correlation will in general greatly complicate the estimation as the relevant information set in each period will contain all past error realizations.

[11]Because of this property, the extreme value error specification has been quite popular in the estimation of dynamic programming models (see, for example, Berkovec and Stern [1985], Hotz and Miller [1989] and Rust [1988]).

[12] A single iteration for the model estimated and presented in Table 4 took approximately 7 minutes CPU time on an IBM 3090 mainframe.

[13] Attempts to estimate the discount factor were not successful. When iterating on δ, the estimates do not converge. The discount factor becomes negative and the likelihood surface appears very flat in that region. Eckstein and Wolpin (1989) and Berkovec and Stern (1991) reported similar problems in estimating δ.

[14] Estimation results for the $\delta = 0.75$, $\delta = 0.95$ and independent normal error cases are available on request from the author.

[15] The representative female is white, does not live in the South, has 13 years of schooling and lives in a state with mean manufacturing wages equal to $336.29.

[16] The effects on the work probabilities in subsequent periods are presented in Van der Klaauw (1992).

[17] The computational cost of introducing this type of unobserved heterogeneity is about four times bigger than for the original model.

Table 1: Descriptive Statistics

Variable	Mean	Standard Deviation
Sample of 548 individuals		
Years in Sample	13.146	4.179
Age in 1st period	18.380	1.942
EDUC	12.971	2.176
MANUFWG	336.287	48.618
Sample of 7204 person-year observations		
AGE	24.976	4.711
EXP	3.880	3.700
TEN	2.759	3.805
WAGE	6.849	3.170
HWAGE	9.900	4.882

Sample Frequencies

Variable	Frequency	Total
RACE	97	548
SOUTH	159	548
WORK	4305	7204
MARRIED	3952	7204
Working+Single	2240	7204
Working+Married	2065	7204
Not-working+Single	1012	7204
Not-working+Married	1887	7204
Part. Rate - Single	0.69	3252
Part. Rate - Married	0.52	3952
Part. Rate - Total	0.60	7204

Hourly wage rates, WAGE, are calculated for the sample of workers with non-missing wage information. The hourly husband wage rates, HWAGE, are calculated for married women who did report their husband's wage earnings. Both rates are in 1983 dollars. See Table 3 for definitions of other acronyms.

Table 2: Frequencies of observed marital status sequences

Mar. Status Sequence	Number of Observations	Mar. Status Sequence	Number of Observations
S	123	M	19
SM	258	MS	3
SMS	53	MSM	1
SMSM	60		
SMSMS	20		
SMSMSM	8		
SMSMSMS	3		

Total number of first marriages:	425
Total number of remarriages:	103
Total number of divorces:	181
Individuals with 1 divorce:	117
Individuals with 2 divorces:	28

Each letter represents a spell occurring over one or more years. M stands for Married, S for Single. Observed sequences end either at the end of the sample period (1985) or when the individual is dropped from the sample due to non-response. The first spell starts in the year the individual leaves school.

Table 3: Variable Means for 1984 Cross-section

Variable	Total	Marital Status Single	Married	Employment Status Not-working	Working
AGE	31.12	30.86	31.25	30.96	31.20
EXP	7.51	8.06	7.24	5.04	8.75
TEN	5.55	0.45	8.08	6.68	4.98
EDUC	13.22	13.21	13.23	12.77	13.45
RACE	0.13	0.22	0.08	0.12	0.13
SOUTH	0.28	0.28	0.28	0.28	0.28
MANUFWG	337.03	336.92	337.08	338.18	336.44
MARRIED	0.67	0.00	1.00	0.79	0.61
WORK	0.67	0.79	0.61	0.00	1.00
HWAGE	11.26	-.-	11.26	13.32	9.91
WAGE	7.67	8.57	7.14	-.-	7.67
Number of observations	437	145	292	146	291

Cross-sectional data from the 1984 wave of the PSID. The sample consists of females with ages between 28 and 35 years. The average wage rates are calculated using information on the women and husbands who work only.

The variables are defined as follows. AGE, EXP and TEN represent the individual's age, total work experience and the tenure or duration of the current marriage in years. EDUC represents the number of years of schooling. RACE is a dummy variable equal to zero if the person is white and one if not. SOUTH is an indicator variable equal to one if the person lived in the South during the majority of the years in the sample. MANUFWG represents the mean (real) state manufacturing wage earnings averaged over the years the individual was in the sample. MARRIED and WORK are indicators of the individual's marital status and labor force participation decision, with MARRIED equal to one if the person was married (zero if not) and WORK equal to one if the person worked more than 775 hours (zero if not). HWAGE and WAGE are the female's and husband's average hourly wage rates in 1983 dollars.

Table 4: Minimum Distance Estimates of Life Cycle Model

	Variable	Estimate	SDE	Estimate	SDE
	Married+NotWork				
β_{21}	constant	-8.778*	1.343	-7.967*	0.607
β_{22}	EDUC	-0.003	0.048	0.019	0.022
β_{23}	AGE	-0.131*	0.035	-0.062*	0.014
β_{24}	RACE	-0.500*	0.253	-0.160	0.104
β_{25}	SOUTH	0.692*	0.173	0.332*	0.077
β_{26}	WORK_{t-1}	0.517*	0.153	0.375*	0.124
β_{27}	log-HWAGE	4.860*	1.121	2.500*	0.482
β_{28}	TEN	0.018	0.040	-0.003	0.009
β_{29}	MARRIED_{t-1}	4.759*	0.242	4.710*	0.244
	Single+Work				
β_{31}	constant	-4.438*	0.638	-4.268*	0.327
β_{32}	EDUC	-0.180*	0.075	-0.052	0.038
β_{33}	AGE	-0.041	0.022	-0.011	0.011
β_{34}	RACE	-0.475*	0.229	-0.299*	0.108
β_{35}	SOUTH	0.377	0.196	0.190*	0.095
β_{36}	WORK_{t-1}	0.760*	0.237	1.456*	0.154
β_{37}	TEN	-0.045	0.047	-0.020	0.048
β_{38}	MARRIED_{t-1}	0.316	0.293	0.224	0.290
α_1	log-WAGE	5.146*	0.712	2.369*	0.356
	Married+Work				
β_{41}	constant	-8.205*	1.549	-8.896*	0.733
β_{42}	EDUC	-0.133*	0.062	-0.046	0.034
β_{43}	AGE	-0.098*	0.035	-0.010	0.014
β_{44}	RACE	-0.452	0.272	-0.302*	0.122
β_{45}	SOUTH	0.765*	0.188	0.274*	0.093
β_{46}	WORK_{t-1}	2.142*	0.273	2.289*	0.180
β_{47}	log-HWAGE	2.025	1.259	0.112	0.540
β_{48}	TEN	0.072	0.039	0.027*	0.008
β_{49}	MARRIED_{t-1}	4.350*	0.267	4.277*	0.271
α_2	log-WAGE	3.497*	0.630	2.081*	0.350

Continued on next page

Table 4 Continued

	Variable	Estimate	SDE	Estimate	SDE
	Wage Equation				
γ_{11}	constant	0.382*	0.136	0.293*	0.133
γ_{12}	EDUC	0.099*	0.007	0.098*	0.007
γ_{13}	AGE	-0.012*	0.005	-0.012*	0.005
γ_{14}	RACE	-0.015	0.040	-0.011	0.040
γ_{15}	SOUTH	-0.048	0.035	-0.028	0.036
γ_{16}	WORK_{t-1}	0.201*	0.022	0.206*	0.022
γ_{21}	EXP	0.051*	0.008	0.046*	0.008
γ_{22}	EXP-sq/100	-0.006	0.040	0.024	0.041
γ_{23}	MANUFWG	0.004	0.020	0.033	0.021
δ	discount factor	0.000		0.850	
	Log-likh L_1	-5368.7		-5376.5	
	Distance	4.114		2.547	

*: significant at 5 percent level.

The decision horizon, T, at the time of leaving school was fixed at 45 years minus the age at leaving school. In the estimation MANUFWG was divided by 100. For definition of acronyms, see Table 3.

Table 5: Predicted Effects of Variables on Choice Probabilities:

$\delta = 0.85$ Case

	Age 18, single Work	Married	Age 25, Exp=0 Work	Married	Age 25, Exp=5 Work	Married
Probability	0.462	0.157	0.151	0.957	0.806	0.940
HWAGE (perm)	-0.094	0.126	-0.061	0.021	-0.133	0.020
HWAGE (temp)	-0.018	0.035	-0.033	0.010	-0.049	0.004
WAGE (perm)	0.211	-0.069	0.175	-0.034	0.082	-0.018
WAGE (temp)	0.121	-0.020	0.065	-0.007	0.041	-0.004
EDUC.1	-0.032	0.017	-0.017	0.004	-0.026	0.004
EDUC.2	0.066	-0.004	0.019	0.002	0.021	-0.004
SOUTH	0.014	0.086	-0.015	0.019	-0.025	0.018
RACE	-0.122	-0.001	-0.038	-0.006	-0.063	0.003

$\delta = 0.00$ Case

	Age 18, single Work	Married	Age 25, Exp=0 Work	Married	Age 25, Exp=5 Work	Married
Probability	0.462	0.157	0.151	0.957	0.806	0.940
HWAGE (perm)	-0.094	0.126	-0.061	0.021	-0.133	0.020
HWAGE (temp)	-0.018	0.035	-0.033	0.010	-0.049	0.004
WAGE (perm)	0.211	-0.069	0.175	-0.034	0.082	-0.018
WAGE (temp)	0.121	-0.020	0.065	-0.007	0.041	-0.004
EDUC.1	-0.032	0.017	-0.017	0.004	-0.026	0.004
EDUC.2	0.066	-0.004	0.019	0.002	0.021	-0.004
SOUTH	0.014	0.086	-0.015	0.019	-0.025	0.018
RACE	-0.122	-0.001	-0.038	-0.006	-0.063	0.003

Each entry represents the change in probability corresponding to a one unit increase in each variable, such as a one dollar increase in the (expected) husband's wage or the female's real wage rate and a one year increase in education. 1: effect of education when keeping the wage and expected husband's wage constant, 2: total effect of an increase in education. The entries corresponding to SOUTH and RACE represent the changes in probabilities when the female lives in the South or is non-white instead and both are total effects (they include the indirect effects through wages).

Table 6: Predicted Choice Probabilities

Year	Single Not-Work Actual	Single Not-Work Pred.	Married Not-Work Actual	Married Not-Work Pred.	Single Work Actual	Single Work Pred.	Married Work Actual	Married Work Pred.	Obs.
0	0.471	0.443	0.026	0.119	0.487	0.402	0.016	0.037	548
1	0.275	0.282	0.136	0.092	0.476	0.526	0.113	0.101	538
2	0.190	0.195	0.209	0.180	0.412	0.449	0.190	0.177	527
3	0.136	0.149	0.236	0.239	0.379	0.382	0.249	0.230	522
4	0.131	0.123	0.262	0.263	0.326	0.342	0.281	0.272	519
5	0.099	0.110	0.275	0.285	0.321	0.308	0.306	0.297	517
6	0.089	0.093	0.309	0.291	0.278	0.294	0.325	0.322	508
7	0.079	0.083	0.338	0.312	0.259	0.264	0.324	0.340	491
8	0.078	0.080	0.368	0.331	0.256	0.244	0.298	0.346	476
9	0.070	0.077	0.350	0.344	0.248	0.241	0.332	0.339	455
10	0.065	0.071	0.361	0.340	0.245	0.231	0.329	0.358	429
11	0.057	0.074	0.327	0.330	0.232	0.233	0.384	0.363	404
12	0.068	0.064	0.316	0.322	0.214	0.216	0.402	0.398	351
13	0.115	0.077	0.286	0.318	0.192	0.200	0.408	0.405	287
14	0.087	0.092	0.266	0.278	0.218	0.207	0.429	0.423	229
15	0.082	0.077	0.254	0.262	0.213	0.201	0.450	0.459	169
16	0.095	0.102	0.207	0.266	0.198	0.214	0.500	0.418	116
17	0.089	0.088	0.190	0.231	0.215	0.237	0.506	0.444	79
18	0.091	0.082	0.242	0.237	0.212	0.200	0.455	0.482	33
19	0.000	0.034	0.250	0.269	0.250	0.238	0.500	0.460	4
20	0.000	0.050	0.000	0.138	0.500	0.423	0.500	0.389	2
all	0.141	0.141	0.262	0.261	0.311	0.311	0.287	0.287	7204

Table 7: Minimum Distance Estimates of Life Cycle Model with Unobserved Permanent Individual Effects

	Variable	Estimate	SDE	Estimate	SDE
	Married+NotWork				
β_{21}	constant	-7.967*	0.607	-9.462*	0.744
β_{22}	EDUC	0.019	0.022	-0.015	0.028
β_{23}	AGE	-0.062*	0.014	-0.069*	0.017
β_{24}	RACE	-0.160	0.104	-0.150	0.134
β_{25}	SOUTH	0.332*	0.077	0.460*	0.103
β_{26}	WORK_{t-1}	0.375*	0.124	0.429*	0.125
β_{27}	log-HWAGE	2.500*	0.482	3.255*	0.604
β_{28}	TEN	-0.003	0.009	-0.013	0.009
β_{29}	MARRIED_{t-1}	4.710*	0.244	4.679*	0.248
	Single+Work				
β_{31}	constant	-4.268*	0.327	-4.740*	0.342
β_{32}	EDUC	-0.052	0.038	-0.004	0.039
β_{33}	AGE	-0.011	0.011	0.001	0.011
β_{34}	RACE	-0.299*	0.108	-0.354*	0.113
β_{35}	SOUTH	0.190*	0.095	0.183	0.103
β_{36}	WORK_{t-1}	1.456*	0.154	1.449*	0.155
β_{37}	TEN	-0.020	0.048	-0.027	0.049
β_{38}	MARRIED_{t-1}	0.224	0.290	0.262	0.294
α_1	log-WAGE	2.369*	0.356	2.051*	0.354
	Married+Work				
β_{41}	constant	-8.896*	0.733	-10.691*	1.020
β_{42}	EDUC	-0.046	0.034	0.015	0.035
β_{43}	AGE	-0.010	0.014	0.007	0.018
β_{44}	RACE	-0.302*	0.122	-0.354*	0.158
β_{45}	SOUTH	0.274*	0.093	0.357*	0.119
β_{46}	WORK_{t-1}	2.289*	0.180	2.369*	0.196
β_{47}	log-HWAGE	0.112	0.540	0.605	0.805
β_{48}	TEN	0.027*	0.008	0.012	0.009
β_{49}	MARRIED_{t-1}	4.277*	0.271	4.229*	0.276
α_2	log-WAGE	2.081*	0.350	1.405*	0.347

Continued on next page

Table 7 Continued

	Variable	Estimate	SDE	Estimate	SDE
	Wage Equation				
γ_{11}	constant	0.293*	0.133	0.252	0.150
γ_{12}	EDUC	0.098*	0.007	0.098*	0.007
γ_{13}	AGE	-0.012*	0.005	-0.012*	0.005
γ_{14}	RACE	-0.011	0.040	-0.011	0.040
γ_{15}	SOUTH	-0.028	0.036	-0.019	0.039
γ_{16}	WORK_{t-1}	0.206*	0.022	0.204*	0.023
γ_{21}	EXP	0.046*	0.008	0.049*	0.009
γ_{22}	EXP-sq/100	0.024	0.041	0.010	0.047
γ_{23}	MANUFWG	0.033	0.021	0.046	0.030
	Mass points				
μ^1				0.633	0.155
μ^2				0.574	0.134
μ^3		No		0.688	0.132
q^2	Prob(type 2)	Heterogeneity		0.418	0.095
q^3	Prob(type 3)			0.080	0.065
q^4	Prob(type 4)			0.376	0.094
δ	discount factor	0.850		0.850	
	Log-likh L_1	-5376.5		-5358.4	
	Distance	2.547		1.732	

*: significant at 5 percent level.

In the estimation MANUFWG was divided by 100. For definition of acronyms, see Table 3.

FIG 1. PARTICIPATION AND MARRIAGE RATES

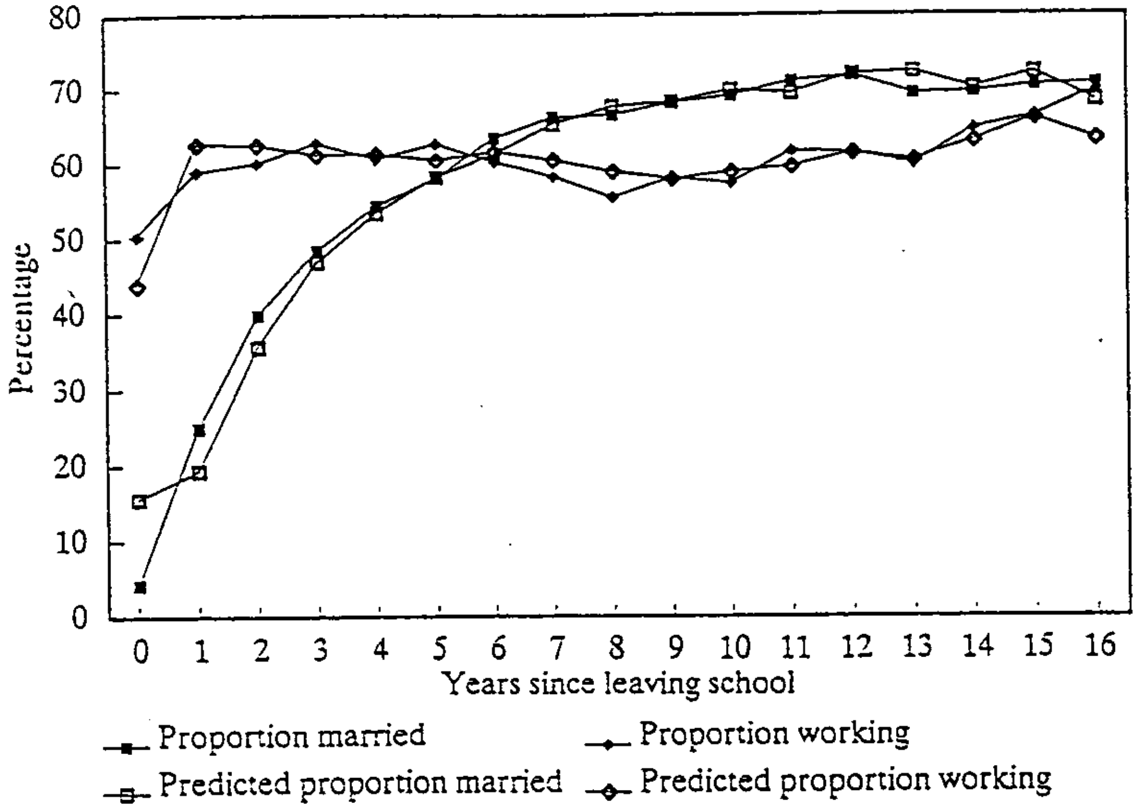


FIG 2. LFP RATES FOR SINGLE AND MARRIED WOMEN

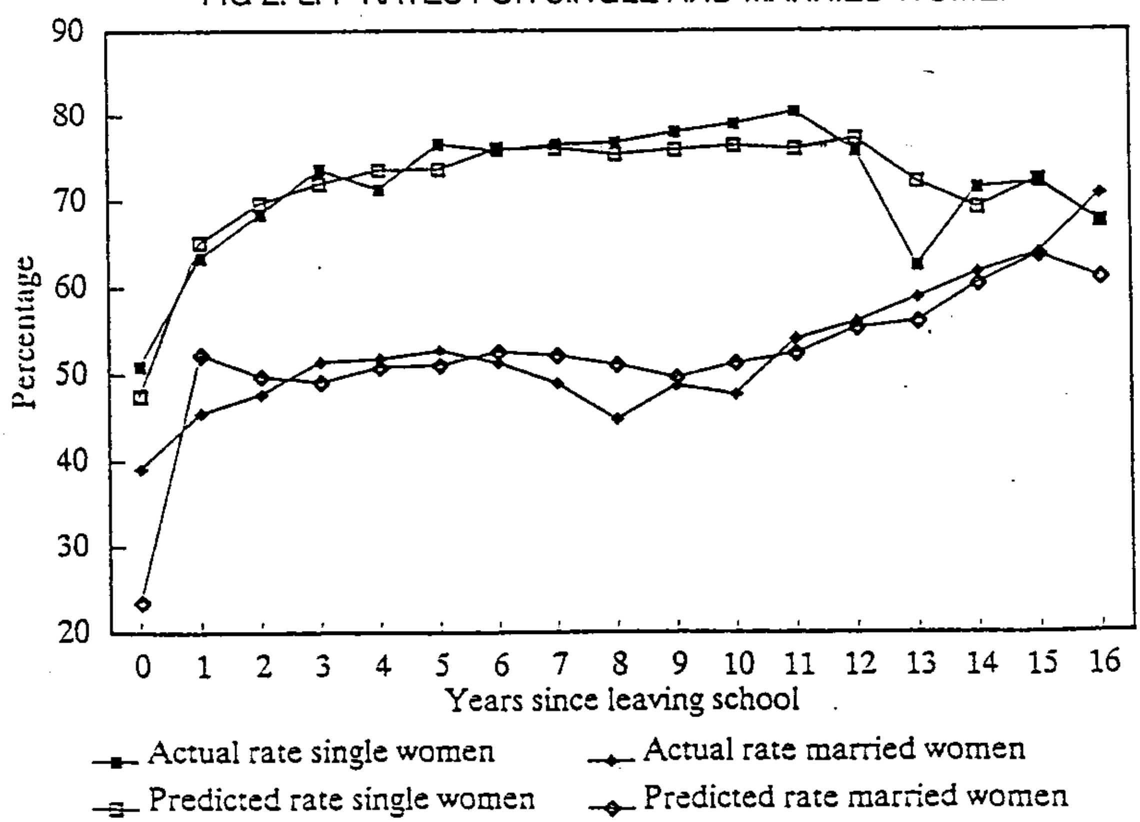


FIG 3. PREDICTED WORK PROBABILITIES

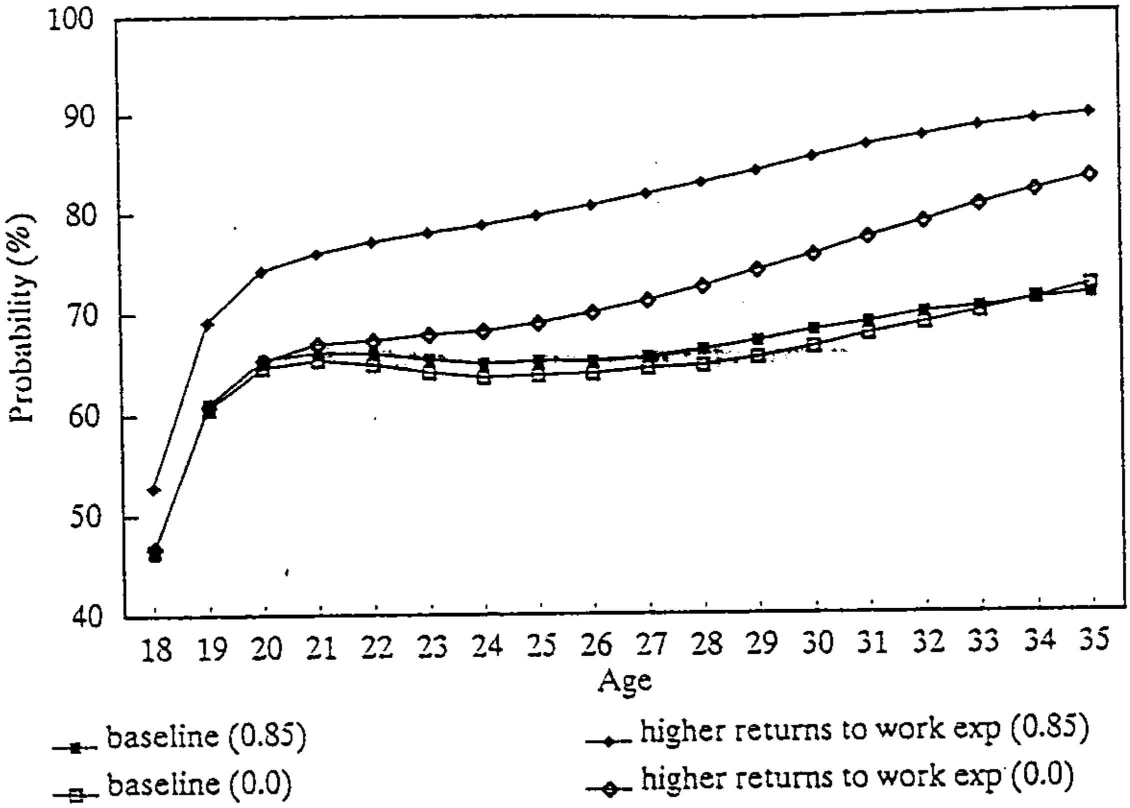


FIG 4. PREDICTED MARRIAGE RATES PER 100 SINGLE WOMEN

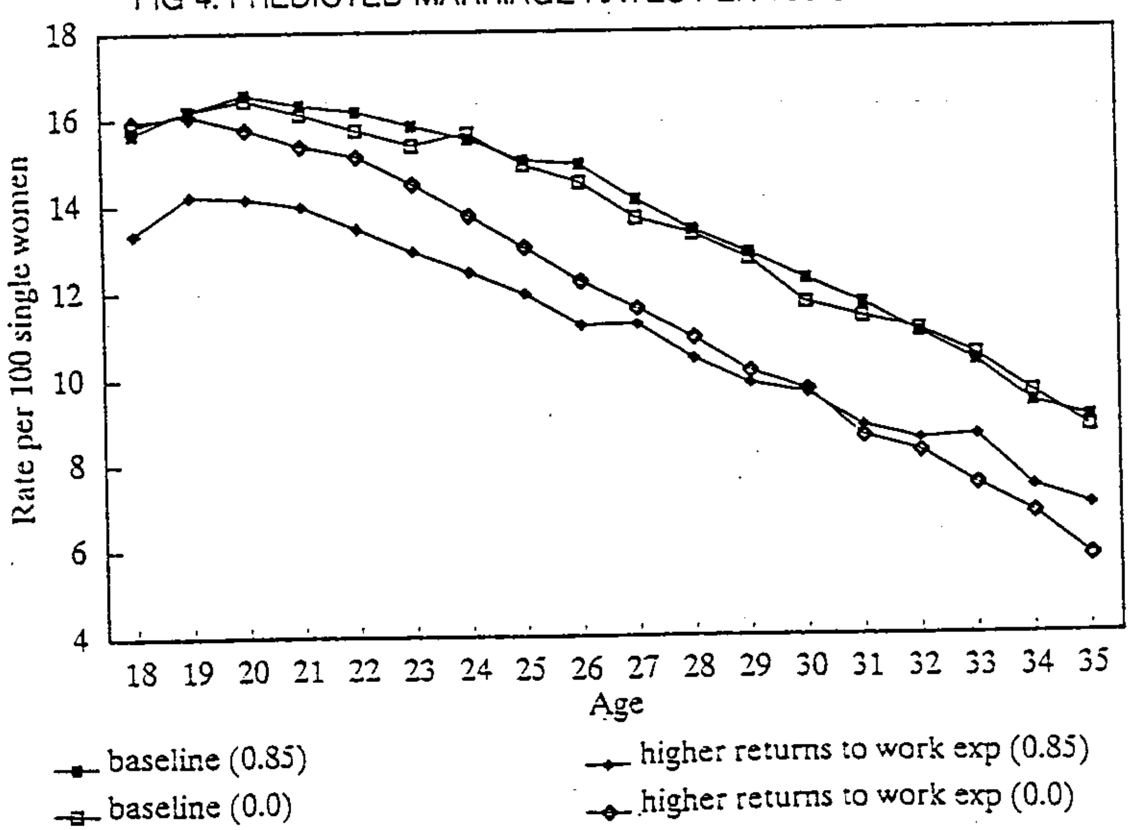


FIG 5. PREDICTED WORK PROBABILITIES

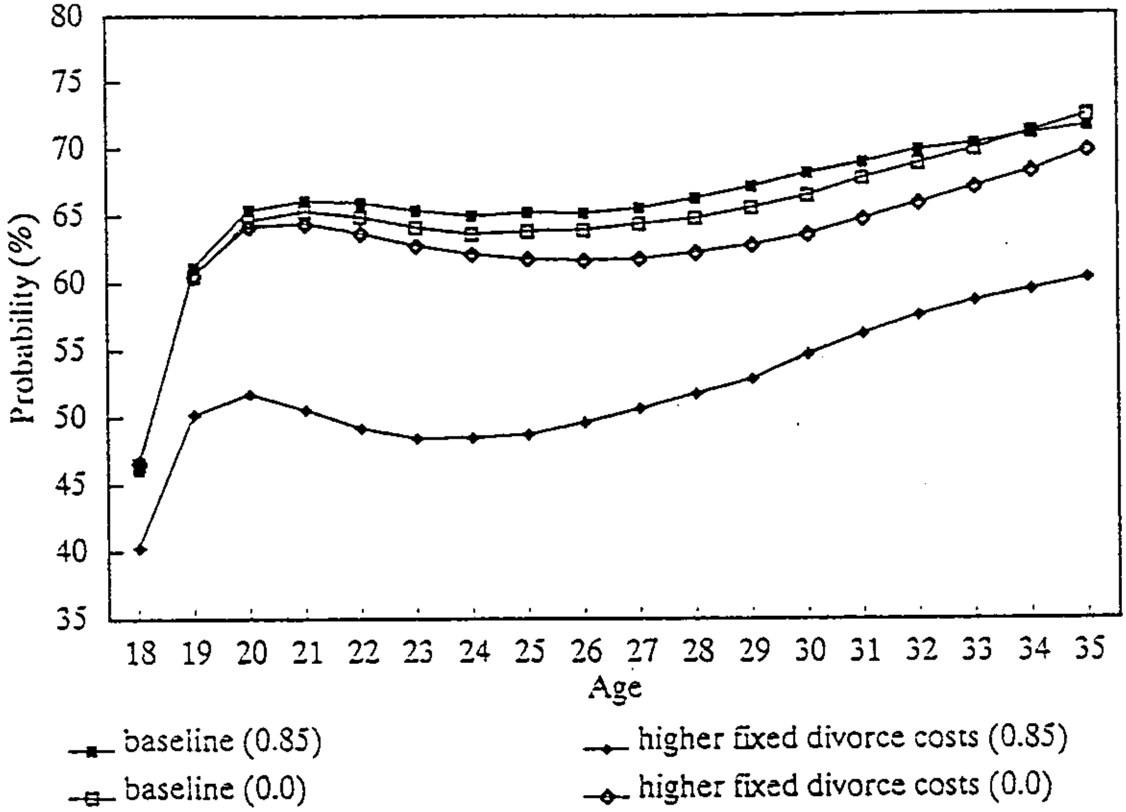
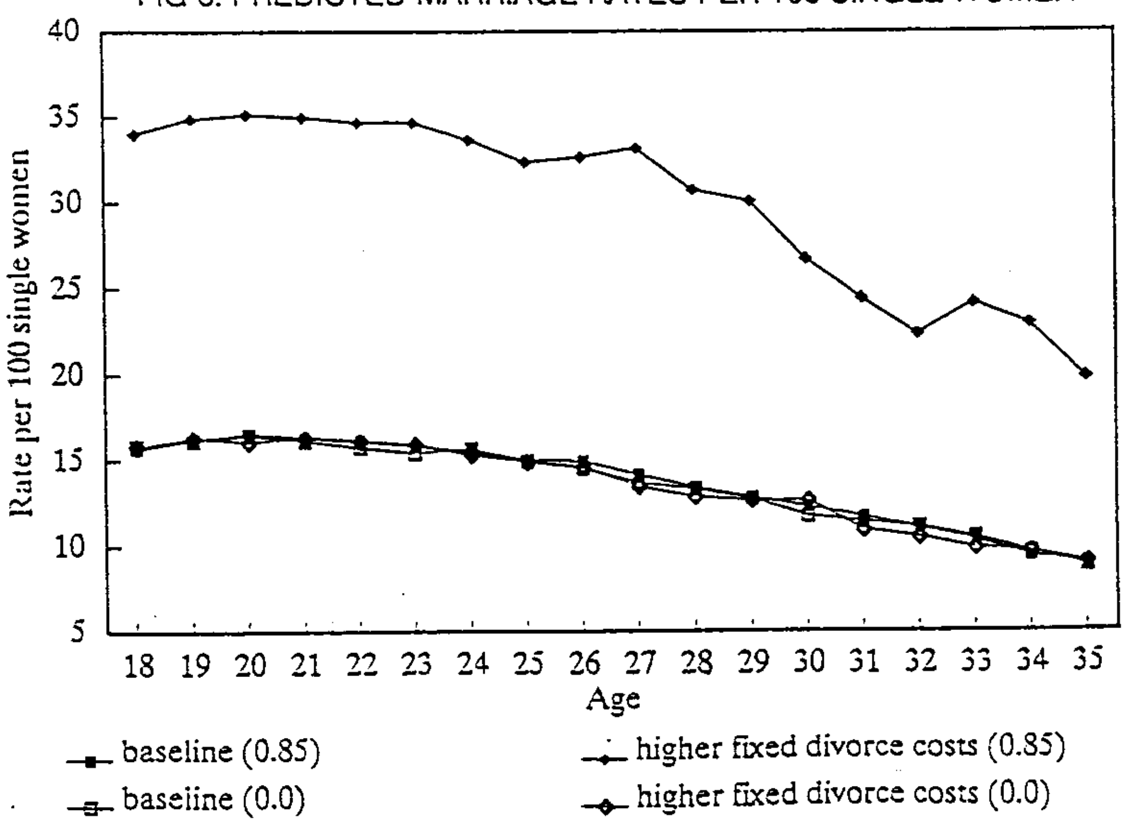


FIG 6. PREDICTED MARRIAGE RATES PER 100 SINGLE WOMEN



Appendix I

Estimation of the covariance matrix V (the MDE weighting matrix)

Consider two estimators ψ_1 and ψ_2 that each solve a set of first order conditions:

$$1/N \sum f_1(\psi_1) = 0$$
$$1/N \sum f_2(\psi_1, \psi_2) = 0$$

where N is the number of observations. In terms of $\psi = [\psi_1 \ \psi_2]'$ we can also write this as

$$1/N \sum f(\psi) = 0$$

In our case, ψ_1 represents the vector of reduced form utility parameter estimates and ψ_2 represents the vector of estimates of the wage equation parameters. The dependence of f_2 on ψ_1 represents the inclusion of the estimated sample selection bias term, which is a function of the parameter vector ψ_1. Following Hansen (1982), ψ has asymptotic distribution

$$\sqrt{N}(\psi - \psi^o) \xrightarrow{D} n[0, (J'D^{-1}J)^{-1}]$$

where $n(\cdot, \cdot)$ represents the normal distribution, ψ^o is the 'true' value of ψ, $J = E[\partial f(\psi^o)/\partial \psi]$ and $D = E[ff']$.

In our case ψ_2 does not enter f_1 but ψ_1 does enter f_2. Therefore J and D can be estimated by

$$\hat{J} = 1/N \begin{pmatrix} \sum \partial f_1(\psi_1)/\partial \psi_1 & 0 \\ \sum \partial f_2(\psi_1, \psi_2)/\partial \psi_1 & \sum \partial f_2(\psi_1, \psi_2)/\partial \psi_2 \end{pmatrix}$$

and

$$\hat{D} = 1/N \begin{pmatrix} \sum f_1 f_1' & \sum f_1 f_2' \\ \sum f_2 f_1' & \sum f_2 f_2' \end{pmatrix}$$

As the estimator ψ_1 defined by the first set of first order conditions above is a maximum likelihood estimator, the information matrix equality property implies that we can replace $1/N \sum \partial f_1(\psi_1)/\partial \psi_1$ by $-1/N \sum f_1 f_1'$ so that there is no need to calculate the second derivatives of the log likelihood function (ie. the first derivatives of the corresponding first order conditions). The estimator of the wage equation parameters however, is not a maximum likelihood estimator, so that we do need to calculate the first derivatives of the second set of first order conditions.

Appendix II

Sample selection correction in the wage regression

To obtain estimates of the wage equation parameters γ, the female wage equation [9] was estimated by OLS on the sample of workers with non-missing wage information. To account for the fact that workers form a non-random group of the potential labor force population, a selection correction term was included in the wage equation to adjust for the fact that $E[u_t| \ State\ 3\ or\ 4\ chosen]$ does not equal zero. Given the assumption that single and married women are paid according to the same wage equation, this sample selection correction term is equivalent to an estimate of $E[u_t|State\ 3\ chosen]$ for single working women and $E[u_t|State\ 4\ chosen]$ for married working women. We can express these conditional expectations as:

$$\begin{aligned} E[u_t|State\ i\ chosen] &= cov(u_t, e_i) \cdot E[e_i|State\ i\ chosen] \\ &= \sigma_{u,e_i} \cdot E[e_i|e_i < \mathcal{X}_t'\lambda_i] \end{aligned}$$

where $e_i = \max_{j\neq i}[\mathcal{X}_t'\lambda_j + \epsilon_{jt}] - \epsilon_{it}$ Defining $F_i(e) = Prob(e_i < e)$, then $F_i(\mathcal{X}_t'\lambda_i) = Prob(State\ i\ chosen)$. By adopting a transformation of the error term e to make it normally distributed, we can write the conditional expectation above as an inverse Mill's ratio:

$$E[e_i|State\ i\ chosen] = \frac{\phi(\Phi^{-1}(F_i(\mathcal{X}_t'\lambda_i)))}{F_i(\mathcal{X}_t'\lambda_i)}$$

where ϕ and Φ^{-1} are respectively, the normal density and inverse of the normal distribution function (see Lee [1982]). Given estimates of $\lambda_i,\ i = 1, ..., 4$ from the first stage maximum likelihood estimation, we can obtain estimates y_i of these expectations.

The final wage equation estimated is then

$$w_t = X_{3t}'\gamma_1 + X_{4t}'\gamma_2 + \sigma_{u,e_3} \cdot y_{3t} \cdot I_{3t} + \sigma_{u,e_4} \cdot y_{4t} \cdot I_{4t} + \xi_{it}$$

where the σ's represent the covariances between the error terms, I_i is a dummy indicator variable with $I_i = 1$ if *State i* was chosen and $I_i = 0$ if not and ξ is the redefined error term with mean zero.

Note that estimates of $F_i(\mathcal{X}_t'\lambda_i)$ can be obtained in the last iteration of the maximization of L_1 as these probabilities enter directly into the likelihood function. For example, in the case where the error terms ϵ_{it} are independently extreme value distributed, then $Prob(State\ i\ chosen) = F_i(\mathcal{X}_t'\lambda_i)$ is given by the expression [14] which enters L_1.

Appendix III

A decomposition of the wage effects

In Section 5 the following formula was applied to decompose the total average change in the probability of working for each female who was part of the 1984 wave, resulting from a one dollar increase in her wage rate:

$$\begin{aligned} \Delta Prob(p_t = 1) = \;& \Delta Prob(p_t = 1|m_t = 0) \\ +\;& Prob(m_t = 1)[\Delta Prob(p_t = 1|m_t = 1) - \Delta Prob(p_t = 1|m_t = 0)] \\ +\;& \Delta Prob(m_t = 1)[\Delta Prob(p_t = 1|m_t = 1) - \Delta Prob(p_t = 1|m_t = 0) \\ & +(Prob(p_t = 1|m_t = 1) - Prob(p_t = 1|m_t = 0)] \end{aligned}$$

where the difference operator Δ refers to the change resulting from a one dollar increase in the wage rate. The sum of the first two terms on the right hand side gives the change in the participation probability when keeping the probability of choosing the married state constant. The third term represents the indirect effect caused by a change in the marital status probability.

Table A1 : Husband's Wage Equation Estimates

	Husband's Log Wage Equation		Marital Status Equation	
Variable	Estimate	St.Error	Estimate	St.Error
constant	0.942*	0.117	-0.742*	0.245
EDUC	0.036*	0.005	0.042*	0.010
AGE	0.018*	0.003	-0.061*	0.007
RACE	-0.163*	0.029	-0.271*	0.055
SOUTH	-0.025	0.025	0.176*	0.056
$WORK_{t-1}$	-0.117*	0.021	-0.004	0.047
EXP	0.026*	0.008	0.080*	0.019
EXP-sq	-.0007	.0006	-0.007*	0.001
MANUFWG	.0009*	.0002	.0010*	.0005
TEN			0.002	0.007
MAR_{t-1}			2.284*	0.052
μ	0.050*	0.019		

*: Significant at the 5 percent level.

Number of person-year observations with non-missing husband wages = 3362. The sample correction term, μ, (the inverse Mill's ratio) was calculated using the parameter estimates of the reduced form marital status equation reported in the last two columns. For definition of acronyms, see Table 3. All regressor variables refer to the female's characteristics.

Table A2: Maximum Likelihood Estimates Reduced Form Model

	Variable	Estimate	SDE	Estimate	SDE
	Married+NotWork				
λ_{21}	constant	-8.371*	1.368	-7.637*	0.646
λ_{22}	EDUC	0.007	0.049	0.028	0.023
λ_{23}	AGE	-0.123*	0.035	-0.055*	0.014
λ_{24}	RACE	-0.550*	0.255	-0.201*	0.108
λ_{25}	SOUTH	0.641	0.175	0.300	0.080
λ_{26}	$WORK_{t-1}$	0.478*	0.155	0.353*	0.126
λ_{27}	log-HWAGE	4.536*	1.141	2.233*	0.516
λ_{28}	TEN	0.022*	0.040	-0.003*	0.009
λ_{29}	$MARRIED_{t-1}$	4.728*	0.242	4.694*	0.244
	Single+Work				
λ_{31}	constant	-2.151*	0.536	-3.405*	0.293
λ_{32}	EDUC	0.330*	0.023	0.181*	0.012
λ_{33}	AGE	-0.102*	0.016	-0.037*	0.008
λ_{34}	RACE	-0.530*	0.110	-0.313	0.056
λ_{35}	SOUTH	0.044	0.148	0.083	0.076
λ_{36}	$WORK_{t-1}$	1.788*	0.120	1.962*	0.109
λ_{37}	TEN	-0.040	0.047	-0.017	0.048
λ_{38}	$MARRIED_{t-1}$	0.262	0.295	0.196	0.292
λ_{39}	EXP	0.261*	0.047	0.093*	0.032
λ_{310}	EXP-sq/100	-0.053	0.312	0.129	0.152
λ_{311}	MANUFWG	-0.072	0.114	0.033	0.057
	Married+Work				
λ_{41}	constant	-6.694*	1.744	-8.745*	0.805
λ_{42}	EDUC	0.212*	0.056	0.135*	0.025
λ_{43}	AGE	-0.137*	0.035	-0.444*	0.013
λ_{44}	RACE	-0.496	0.266	-0.218*	0.107
λ_{45}	SOUTH	0.556*	0.190	0.210*	0.084
λ_{46}	$WORK_{t-1}$	2.832*	0.190	2.798*	0.140
λ_{47}	log-HWAGE	1.955	1.372	0.708	0.595
λ_{48}	TEN	0.075*	0.039	0.027*	0.008
λ_{49}	$MARRIED_{t-1}$	4.302*	0.268	4.242*	0.272
λ_{410}	EXP	0.169*	0.044	0.063*	0.027
λ_{411}	EXP-sq/100	0.040	0.261	0.179	0.134
δ	discount factor	0.000		0.850	
	Log-likh L_1	-5368.7		-5376.5	

*: significant at 5 percent level.

The decision horizon, T, at the time of leaving school was fixed at 45 years minus the age at leaving school. In the estimation MANUFWG was divided by 100. For definition of acronyms, see Table 3.

Note that for estimation purposes MANUFWG had to be excluded from the MARRIED-WORK utility specification (because Z and X_4 contain exactly the same variables). The minimum distance estimator imposes the corresponding restrictions implied by leaving one of the variables in X_4 out.

Table A3: Wage Equation Estimates (OLS)

	Variable	Estimate	SDE	Estimate	SDE
γ_{11}	constant	0.116	0.091	0.116	0.091
γ_{12}	EDUC	0.097*	0.004	0.097*	0.004
γ_{13}	AGE	-0.012*	0.003	-0.012*	0.003
γ_{14}	RACE	-0.012	0.020	-0.012	0.020
γ_{15}	SOUTH	0.011	0.020	0.011	0.020
γ_{16}	WORK_{t-1}	0.202*	0.021	0.206*	0.021
γ_{21}	EXP	0.052*	0.007	0.052*	0.007
γ_{22}	EXP-sq/100	-0.015	0.044	-0.015	0.044
γ_{23}	MANUFWG	0.086*	0.019	0.086*	0.019
σ_{uv_3}	μ_3	-0.024	0.015	-0.024	0.015
σ_{uv_4}	μ_4	-0.006	0.014	-0.007	0.014
δ	discount factor	0.000		0.850	
	Adj. R^2	0.327		0.327	

*: significant at 5 percent level.

The two selection terms, μ_3 and μ_4, were calculated using the corresponding reduced form maximum likelihood estimates reported in Table A2. The standard errors were not corrected for the fact that these selection terms were estimated. In the estimation MANUFWG was divided by 100. For definition of acronyms, see Table 3.

Table A4: Asymptotic T-statistics for Differences in Structural Parameters

Differences	$\delta = 0$ Estim.	$\delta = 0$ T-stat.	$\delta = 0.85$ Estim.	$\delta = 0.85$ T-stat.
$\alpha_2 - \alpha_1$	-1.649	2.856	-0.288	1.249
$\beta_{47} - \beta_{27}$	-2.835	2.422	-2.389	3.573
$\beta_{44} - \beta_{24}$	0.048	0.187	-0.142	0.985
$(\beta_{44} - \beta_{24}) - \beta_{34}$	0.524	1.974	0.156	1.121
$\beta_{44} - \beta_{34}$	0.024	0.092	-0.003	0.032
$\beta_{42} - \beta_{22}$	-0.130	2.460	-0.065	2.161
$(\beta_{42} - \beta_{22}) - \beta_{32}$	0.049	0.847	-0.013	0.476
$\beta_{42} - \beta_{32}$	0.046	0.916	0.005	0.315
$\beta_{45} - \beta_{25}$	0.073	0.450	-0.058	0.629
$(\beta_{45} - \beta_{25}) - \beta_{35}$	-0.304	1.758	-0.248	2.692
$\beta_{45} - \beta_{35}$	0.388	2.565	0.084	1.532
$\beta_{49} - \beta_{38}$	4.034	25.442	4.053	26.127
$(\beta_{49} - \beta_{38}) - \beta_{29}$	-0.725	2.490	-0.657	2.318
$\beta_{48} - \beta_{37}$	0.117	3.908	0.046	1.078
$(\beta_{48} - \beta_{37}) - \beta_{28}$	0.098	2.006	0.049	1.019
$\beta_{46} - \beta_{26}$	1.624	6.185	1.914	11.715
$(\beta_{46} - \beta_{26}) - \beta_{36}$	0.865	3.269	0.458	2.713
$\beta_{46} - \beta_{36}$	1.381	5.151	0.833	5.184
$\beta_{43} - \beta_{23}$	0.033	1.028	0.051	2.796
$(\beta_{43} - \beta_{23}) - \beta_{33}$	0.074	2.142	0.062	3.289
$\beta_{43} - \beta_{33}$	-0.057	1.646	0.000	0.018

All t-statistics are reported in absolute values.

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