NBER WORKING PAPER SERIES

THE ADDED WORKER EFFECT: A REAPPRAISAL

Shelly Lundberg

Working Paper No. 706

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge MA 02138

July 1981

I am indebted to Stephen Cosslett, Nicholas Kiefer, Dale Mortensen, George Neumann, Paul Taubman, and participants in workshops at Columbia University and the University of Pennsylvania for comments on this work, and to Paul Silver for programming assistance. The research reported here is part of the NBER's research program in Labor Studies. Any opinions expressed are those of the author and not those of the National Bureau of Economic Research.

NBER Working Paper #706
July 1981

The Added Worker Effect:

A Reappraisal

ABSTRACT

In this paper, the added worker effect is interpreted as a response to uncertain returns to labour supply offers by members of a household. A model of household labour supply is developed in which each member's current labour force status affects the job search and participation decisions of the other and thus the probabilities of observed transitions between the states of employment, unemployment, and non-participation. The determinants of actual household transitions are then investigated using continuous employment histories for a sample of low-income families. Simulations using the estimated transition functions show that increased unemployment among married men has a sizeable short-run effect on both participation and employment of married women.

Shelly Lundberg
Department of Economics
University of Pennsylvania
Philadelphia, PA 19104

(215) 243-6775

I. INTRODUCTION

"After three decades of research and occasionally animated controversy, the short-run behavior of the labor force is still not well understood."

Jacob Mincer [1966]

Cyclical fluctuations in the size of the labour force, and their effect on measured unemployment, have been controversial topics since the Depression[1]. The response of labour force participation rates to a transitory increase in the unemployment rate is usually described in terms of two components of opposite sign -- the added worker effect and the discouraged worker effect. The discouraged worker effect refers to a widespread deterioration in expected wages or employment opportunities among potential workers which leads them to drop out of the labour force or to refrain from entering it. In families whose employed members lose their jobs, this may be offset by the added worker effect, as secondary workers enter the labour force in response to the reduction in family income.

Much of the attention in this area has been focused on the relative importance of these two forces in determining movements in the size of the total labour force as demand conditions change, but the concern of this paper is with the added worker effect alone. The impact of unemployment on the distribution of family incomes, and on the demographic composition of the labour force, depends crucially upon the responses of individual households to unemployment among their members. The nature and magnitude of these short-run adjustments in household labour supply have been the subject of some disagreement in recent years.

A spell of unemployment experienced by the male head of household affects the labour supply of the wife in two ways; the transitory reduction in household income and the increase in husband's non-market time both tend to reduce the relative value of the wife's non-market time. Mincer [1962] argued that such a transitory reduction in income due to spouse's unemployment has a greater effect on the labour supply of married women does than a permanent income loss and appealed to the permanent income theory of consumption for an explanation. Cain [1966] presented evidence to the contrary and is supported by Heckman and MaCurdy [1980], who find no supply response to transitory income variations among married women and note that this is consistent with a life-cycle theory of household labour supply.

In a life-cycle context, the wife's participation decision is equivalent to deciding what proportion of her lifetime to spend working in the market. This time is allocated over the lifetime according to the relative value of home time in each period. The husband's unemployment causes a substitution of market work from other periods to the present, but if the household is not credit constrained, the wealth effect of a short spell of unemployment will be negligible.

It is necessary to depart from this deterministic life-cycle framework once we recognize that the labour force entry of secondary workers is a response to disequilibrium in the household's labour supply and that there are uncertain returns to a labour supply offer. Conditional upon current income and the nature of credit markets, the household's response will depend upon stochastic elements affecting the duration of unemployment and future wages, for both the principal earner and any potential labour force entrant. The approach followed in this paper, therefore, is to present a unified treatment of job search and participation decisions within a household labour supply framework, with search activity serving as the link between the participation decision and actual employment. Since the decision to enter the labour force can be distinguished from the decision to accept a job offer when offer arrivals are subject to uncertainty, the appropriate focus for an empirical investigation of the added worker effect in this case is on flows into and out of employment and unemployment by wives, rather than on labour force status per se.

A detailed investigation of actual labour force transitions reveals that increased unemployment among husbands has a sizable short-run effect on both unemployment rates and employment rates for married women. Although this increase in labour supply takes a variety of forms, including a reduction in the probability of leaving employment, the principal effect of husband's unemployment is to increase the probability of labour force entry for the wife. The fact that these strong results come from the analysis of low-income households suggest that the role of a credit constraint in generating the added worker effect may be an important one.

A two person model of household labour supply under uncertainty (based on Burdett and Mortensen [1978]) is developed in Section II. The optimal decision rules derived from this model are analogous to those implied by individual job search theories and static models of household time allocation, offering a basis for comparison with these approaches. Events such as the loss of a job by one member change these decision rules, which in turn affect the stochastic movement of the household between labour force states. Section III presents a technique for estimating the determinants of household transition rates from actual employment histories, and is followed by a description of the data and empirical specification. Section V contains the transition rate estimates for female household heads, and the final section employs the entire household transition matrix to simulate the effects of increased unemployment among husbands on the labour supply of wives.

II. THE MODEL: HOUSEHOLD LABOUR SUPPLY UNDER UNCERTAINTY

Burdett and Mortensen present a dynamic labour supply model in which the employment history of an individual is generated by a Markov process. In the two-person case, the transition probabilities of individual household members are interdependent, since the employment status of one member affects the labour supply decisions and search strategy of the other. In this section, a version of the model is presented in which non-participation is considered to be a state functionally distinct from the state of unemployment. The household time allocation problem is simplified by assuming that the amount of time devoted to market work, if employed, and to search, if unemployed, are fixed constants. The opportunity for time-substitution between household members is thus limited to a choice between states. To provide a more complete account of random forces operating on the household and, in particular, those which influence movements in and out of the labour force, the utility value of non-market time is permitted to vary in a stochastic manner.

It will be shown that the optimal decision rules derived from the household's joint utility maximization under uncertainty are analogous to the reservation wages arising from standard search and participation analyses.

A. Household Preferences and Time Allocation

A two-person household chooses a strategy in each period so as to maximize the expected value of household utility, U(t), where

$$U(t) = \frac{1}{1+\rho\Delta t}\,(u(t)\Delta t + U(t+\Delta t))$$

The instantaneous utility flow associated with consumption during the short interval $[t, t+\Delta t)$ is assumed to be a strictly concave function $u(x_t, \ell_t)$ where x is household income and ℓ is a vector (ℓ_1, ℓ_2) such that ℓ_i is the fraction of the time period devoted to leisure by member i.[2] It is assumed in the sequel that income and leisure are complements in household production, and that the leisure times of the two household members are substitutes, such that an increase in ℓ_1 reduces the marginal utility of ℓ_2.[3] Future utility flows are discounted at the subjective rate ρ.

The strategy is denoted by (x,ℓ,s), where $s = (s_1,s_2)$ such that s_i is the fraction of the period devoted to search by member i. At this point, we restrict the possible values of s_i to zero and some fixed amount $\bar{s}$. The residual fraction of the time period not spent in leisure or search, $h_i = 1 - \ell_i - s_i$, is interpreted as the time spent working and is restricted to zero and some fixed $\bar{h}$. Obviously, it must be true that $h_i + s_i \leq 1$.

Utility maximization is subject to the constraint $x \leq y + w_1 h_1 + w_2 h_2$ where w_i is the wage earned by member i when employed and y is non-labour income. This constraint can be re-written in a "full income" sense as

$$x + w_1\ell_1 + w_2\ell_2 + w_1 s_1 + w_2 s_2 \leq y + w_1 + w_2$$

given the definition of h_i.

B. The State Space and Transition Functions

At any date, the household occupies a participation state j, which is a vector (j_1,j_2) representing the employment status of both members. If $j_i = E$, then person i is employed, while $j_i = U$ implies that person i is unemployed and searching for a job, and $j_i = N$ implies that person i is not participating in the labour force. Therefore, $j_i \varepsilon J = \{E,U,N\}$ for $i = 1,2$.[4]

We now introduce a stochastic movement of the household from one state to another over time, where $P_{jk}(\Delta t)$ is the probability of a transition from state j to state k during the interval $[t,t + \Delta t)$. Of course, these probabilities are influenced by the household's allocation of time to search and market work, and the household's choice of a strategy is affected by uncertainty regarding future state occupancies. Assume that the transition function can be written as

$$P_{jk}(\Delta t) = \lambda_{jk}\Delta t + O(\Delta t) \quad , \ j \neq k$$

where λ_{jk} is a constant and $O(\Delta t)/\Delta t \to 0$ as $\Delta t \to 0$. This implies that

$$\lim_{\Delta t \to 0} P_{jk}(\Delta t) = \begin{cases} 1 \text{ if } j = k \\ 0 \text{ if } j \neq k \end{cases}$$

so that the probability of making any transition in a sufficiently short time interval is negligible.

In interpreting the parameters $\{\lambda_{jk}\}$, we follow the discussion in Burdett and Mortensen. Suppose that the job offers received by worker i arrive randomly in sequence according to a Poisson process with mean $\alpha_i s_i$ where s_i is the fraction of any time period allocated to search activity and α_i is the expected number of offers received per unit of search time by person i. If $f_i(w_i)$ is the probability that an offer is equal to $w_i \varepsilon W$ where W is the set of all possible wage rates, then the probability that member i will receive an offer w_i during a short time interval $[t, t + \Delta t)$ is $\alpha_i s_i f_i(w_i)\Delta t + O(\Delta t)$. This implies that, for a one-person household,

$$\lambda_{UE} = \alpha_i s_i [1 - F_i(w_i^*)]$$

where $F_i(w_i)$ is the c.d.f. corresponding to $f_i(w_i)$ and w_i^* is the minimal acceptable wage. That is, the instantaneous transition rate from unemployment to employment is equal to the arrival rate of acceptable job offers. Similarly, the probability that i is separated, given employment, is denoted $\delta_i \Delta t + O(\Delta t)$. The probability that both members receive job offers, or that of any other joint event, is negligible when Δt is small.

C. The Intertemporal Decision Problem

The household's optimal strategy can be derived using dynamic programming. A full description of the problem is contained in Lundberg and will not be repeated here, except to note a number of assumptions imposed to make it tractable. In the infinite horizon case, the household's optimal strategy is stationary, transition rates are constant over time, and it is appropriate to characterize the household's employment history as a Markov process. To allow for changes in asset holdings over time or a finite time horizon would, on the other hand, result in time-dependent strategies and transition rates.

If job search while employed is ruled out, the household's time allocation is uniquely determined by the state occupied or, conversely, the choice of a strategy (x,ℓ,s) is equivalent to a choice among feasible states. The optimal allocation of time can be derived by comparing the expected utility associated with occupying alternative states.

First, consider the value to the household of alternate allocations of member 1's time, given that member 2 is working. To represent this, we introduce the function V^{j_1}, which is the sum of the current utility flow when member 1 is in state j_1, plus the expected utility gain attributable to the current allocation of 1's time, given that an optimal policy is followed subsequent to any event.[5]

Let $w_1^r(w_2)$ be the solution to $V^E(w_1^r(w_2),w_2) = V^U(0,w_2)$ (1a)

and $w_1^\ell(w_2)$ be the solution to $V^E(w_1^\ell(w_2),w_2) = V^N(0,w_2)$ (1b)

Then member 1 will continue to work at a job paying w_1 if and only if $w_1 > w_1^*(w_2)$, where the minimal acceptable wage w_1^* can be interpreted as $\max[w_1^r(w_2),w_1^\ell(w_2)]$. If member 1 is unemployed, the household will accept a job offer w_1 if the value of member 1 working at that wage exceeds the value associated with 1 continuing to search, or $V^E(w_1,w_2) > V^U(0,w_2)$. This implies that a job offer w_1 is acceptable only if $w_1 > w_1^r(w_2)$. [6]

In deciding whether member 1 should participate in the labour market, given no job attachment, the household will compare $V^U(0,w_2)$ and $V^N(0,w_2)$. This implies that 1 will participate as an unemployed job searcher if the cost of search, in terms of the utility loss from foregone leisure, is less than the expected return to search, which is the expected rate at which acceptable offers arrive times the conditional expectation of household utility gain from an acceptable offer. An equivalent participation condition, in view of (1), is $w_1^r(w_2) > w_1^\ell(w_2)$.

By following a similar procedure for the case when member 2 is not employed, and for 2's time allocation given the employment status and wage of member 1, we can see that the household's optimal strategy in terms of market work and search activity can be completely described by $(w_i^r(\cdot),w_i^\ell(\cdot))$ for i = 1,2. The function $w_i^r(\cdot)$ represents the wage-equivalent value to the household of unemployed search by member i, and is analogous to the reservation wage in individual job search models. The wage-equivalent value of non-participation by member i, $w_i^\ell(\cdot)$, is similar to the "reservation wage" in a static participation analysis (and would, in fact, be equivalent were job durations not uncertain). The decision rules relating to the time allocation of each member are interdependent and, when combined with offer arrival and separation rates, can be used to describe household transition rates between labour market states.

<u>Proposition 1</u>: $\frac{\partial w_1^\ell}{\partial w_2} > \frac{\partial w_1^r}{\partial w_2} > 0$

This proposition, which is proved elsewhere, states that an increase in the wage of an employed member of the household makes the other member less likely to participate in the labour force and, if they do participate, less likely to accept a job offer. This leads directly to the result that member 1 is more likely to search for work and to accept a given wage offer if member 2 is unemployed, rather than employed at any acceptable wage, and provides a rationale for the "added worker effect" under conditions of uncertainty.[7]

D. Stochastic Value of Non-Market Time

The model outlined above is capable of capturing a variety of interactions between the labour supply and search behavior of household members, and clearly demonstrates the source of an added worker type of response to unemployment in the household. Transitions in and out of the labour force, however, will occur only as an immediate result of a change in the other member's employment status. We could expand this range of possibilities by allowing the job searcher to acquire information about the wage distribution while unemployed, or introduce some other type of time-dependence to household strategies. An alternative approach is to consider a wider variety of random events which may be experienced, and to some degree anticipated, by the household.

A simple way to allow a stochastic value of non-market time in the current model is to introduce individual-specific parameters b_i which affect the productivity of leisure time, so the current utility flow is now $u(x, b_1\ell_1, b_2\ell_2)$. Suppose that each b_1 is the current value of a random variable, which changes over time in a manner analogous to the arrival of job offers. Thus the waiting time between changes in b_i has a negative exponential distribution with mean $1/\beta_i$. For each member of the household the value of b_i is selected at random from a known distribution with a cumulative distribution function $G_i(b_i)$ such that the density $g_i(\tilde{b}_i)$ represents the probability that the new value is equal to $\tilde{b}_i$.

These random changes in the productivity of non-market time are intended to reflect a variety of uncertain events. Of these, the most obvious may be changes in the individual's health status. Other possibilities include alterations in family composition such as deaths or the departure of older children, unexpected pregnancies, changes in the availability of child care, or even the weather, to the extent that it affects the value of non-market pursuits.[8]

It is now clear that the household decision rules represented by (w_i^ℓ, w_i^r) depend upon both the prevailing b_i's and the distributions from which they are drawn.

Proposition 2: $\frac{\partial w_1^\ell}{\partial b_2} < \frac{\partial w_1^r}{\partial b_2} < 0$

If member 2's leisure is relatively more productive in household production, then member 1 will be more likely to participate, and will have a lower reservation wage. This result also holds if member 2 is assumed to be employed throughout or, even more strongly, if the increase in b_2 raises w_2^ℓ enough to induce member 2 to drop out of the labour force.

The effect of events which change the value of household non-market time in general can be analyzed by assuming $b_1 = b_2 = b$. In this case, the impact of a change in b on w_1^r and w_1^ℓ is ambiguous, even if the employment status of member 2 is held constant. An increase in b is more likely to have a positive effect on w_1^r and w_1^ℓ if member 2 is working, compared to when member 2 is unemployed or not participating. We might expect, therefore, to find that the usually-discouraging effects of children, age, and poor health on the labour force participation of married women are less pronounced when the husband is unemployed.

We can now express the transition rates of a household among labour force states in terms of the arrival rates of random events and the jointly determined decision rules of household members. The next section discusses a methodology for estimating these transition rates which is compatible with the stochastic properties of the development above.

III. ESTIMATING LABOUR FORCE TRANSITION RATES

In the previous section, the instantaneous transition rates of a household over labour market states, $\{\lambda_{jk}\}$, were derived as functions of the arrival rates of random events and the household's strategy. The arrivals of job offers and changes in the value of non-market time were assumed to be Poisson, while the household's strategy (w_i^r, w_i^ℓ) was asserted to be stationary, given the restrictions placed on the model. These assumptions result in transition rates which are time-independent and can be simply estimated if the date of each transition is known.[9]

The advantages of applying maximum likelihood methods to continuous-time models for the analysis of event histories have been pointed out in several recent works.[10] The alternatives, including a cross-sectional analysis of state-occupancies using probit or logit and a regression analysis of durations, all have serious shortcomings which will not be reiterated in detail here. A few aspects of the continuous time method, however, are particularly relevant to the problem at hand.

1. Estimating the transition rates, themselves, rather than state occupancy probabilities, permits the different types of household response to unemployment to be treated separately. The added worker effect can appear in various manifestations, including an increased rate of labour force entry

(given $g_i(\tilde{b}_i)$ and the arrival rate of shocks to the value of leisure), a reduced rate of labour force exit from either employment or unemployment, and an increased rate of job acceptance from unemployment.

2. The average length of a spell of unemployment is short relative to the periods over which labour supply measures are aggregated in most cross-sectional or panel methods. A transitory labour supply response to a short-run change in the household's circumstances is therefore not likely to be observed. A continuous-time technique, on the other hand, is capable of examining the process of adjustment to a temporary event.

3. As Tuma and Robins have noted, a binary logit model is the appropriate representation of the equilibrium state distribution resulting from a two-state transition process with exponentially-distributed durations. This result, however, does not generalize to more than two states, so there is no obvious cross-sectional counterpart to a household transition model.

For constant transition rates, state occupancy durations have a negative exponential distribution which depends upon the λ_{jk}. In particular, the cumulative distribution function representing the probability of a transition from state j before t_1, given that the household occupies state j at time t_0, is

$$F_j(t_1|t_0) = 1 - e^{-\lambda_j(t_1 - t_0)} \qquad (2)$$

where $\lambda_j = \sum_{\substack{k \\ k \neq j}} \lambda_{jk}$ or the rate of leaving state j.

The density function is

$$f_j(t_1|t_0) = \frac{dF_j(t_1 t_0}{dt} = \lambda_j e^{-\lambda_j(t_1 - t_0)} \ . \qquad (3)$$

Given that a transition does occur from state j, the conditional probability that the destination is state k is λ_{jk}/λ_j, so that the probability of a spell in j which ends in a transition to state k at time t_1 is

$$f_j(t_1|t_0) \cdot \frac{\lambda_{jk}}{\lambda_j} = \lambda_{jk} e^{-\lambda_j(t_1-t_0)} .$$

We can now construct a likelihood function for any sequence of state occupancies by a sample of households, including both completed and uncompleted spells, and form maximum likelihood estimates of the transition rates.

As an example, consider a household which begins at time t_0 in the state (E,N), so member 1 is employed and member 2 is a non-participant. At time t_1, this household is observed to make a transition to (U,U). It then returns to (E,N) at time t_2 and remains there until the end of the observation period, T. The contribution of this household to the likelihood function, then, is

$$[e^{-(t_1-t_0)\lambda_{EN}} \cdot \lambda_{EN\to UU}] \cdot [e^{-(t_2-t_1)\lambda_{UU}} \cdot \lambda_{UU\to EN}] \cdot [e^{-(T-t_2)\lambda_{EN}}]$$

where $\lambda_{EN} = \sum_{k\neq EN} \lambda_{EN\to k}$.

We do not, of course, wish to assume that transition rates are identical for households, but rather examine their dependence upon observable characteristics. A convenient specification, since λ_{jk} must be positive for all households, is

$$\lambda_{jk}(i) = \exp\{\theta_{jk} X_j(i)\} \qquad \text{for } i = 1,\ldots,N \quad j,k\neq j,\ldots,n$$

where θ_{jk} is a vector of parameters to be estimated for each transition rate and $X_j(i)$ are observable explanatory variables for household i which may be state-dependent.

The above specification has some very convenient properties. The log of the likelihood function is separable in the individual transition rates, so that each parameter vector, θ_{jk}, can be estimated independently. In addition, each spell in state j can be easily divided into sub-spells to allow the values of exogenous variables to vary. These same properties, of course, are sources of the major limitations of this method. The assumed time-independence of the λ_{jk} rules out any duration dependence in the rate of leaving a state.[11] Parameterizing the λ_{jk} as exact functions of household characteristics which is not necessary, but sufficient, for the separability of the likelihood function does not permit the isolation of unobserved individual effects, and thus fails to take advantage of one of the major opportunities presented by longitudinal data. Such a formulation may also lead to biased coefficients if such unobserved heterogeneity is important.[12] Both of these shortcomings can be readily overcome by a more complicated model. For analyzing the movements of a large sample over a number of employment states, however, the simple exponential model offers obvious computational advantages while maintaining a close correspondence with the theoretical framework.

IV. DATA AND ESTIMATION

Household transition rates were estimated using longitudinal data from a sub-sample of two-head families from the Seattle and Denver Income Maintenance Experiments (SIME/DIME). These experiments were the largest of several federally-funded programs designed to test the effects of a negative income tax (NIT) on labour supply. About 4,800 families were initially enrolled in the experiment; data are available for 2,038 families in Seattle and 2,657 families in Denver. These families did not constitute a random sample from the populations of the two cities, but were chosen both to facilitate the analysis of labour supply response, and to correspond as closely as possible to the target population of a future, hypothetical NIT program. Four groups were therefore excluded from the sample:

1. Families with heads over 58 years of age or under 18 years of age.
2. Families with disabled heads who were unable to work.
3. Families with pre-experiment earnings in excess of $9,000 for a family of four with one working head, or above $11,000 for a family of four with two working heads.
4. Individuals who did not belong to a "family," defined as a unit consisting of either a married couple, or a single parent with a dependent child, plus other relatives permanently residing with this unit.

Race and family structure, plus pre-experiment earnings adjusted for family size, were used to assign families in a non-random fashion among eleven different financial treatments, and a financial control group containing 40% of the total sample.

The sample actually used in the estimation of household transition rates consists of 1,388 families living in Denver and 993 in Seattle. All were required to satisfy the following criteria:

1. The family contains two heads -- i.e., consists of a married or cohabiting couple plus dependents.
2. The family was one of those originally enrolled in the experiment. This excludes families formed during the course of the experiment, and guarantees that a full year of pre-experiment data is available for each.
3. The family remains in the sample until the second periodic interview has been administered, or approximately 6 to 8 months after enrollment.

Earlier attrition, due to the structure of the periodics, results in considerable missing data, including the absence of education and real property information.

Some aggregate evidence of the added worker effect can be found in Table 1, where the unemployment of the male head is seen to be associated with a markedly higher probability of female head unemployment in the DIME sub-sample.[13]

TABLE 1

Unemployment and Labour Force Participation Rates for Female Heads by Employment Status of Male Head (DIME sub-sample - 1972 annual averages)

	Male Head		
	Employed	Unemployed	Out of Labour Force
White			
Unemployment rate	7.7	26.5	17.3
Participation rate	41.5	50.0	42.6
Black			
Unemployment rate	9.2	31.1	22.8
Participation rate	51.0	52.5	47.2
Mexican-American			
Unemployment rate	8.5	22.9	--
Participation rate	26.1	19.2	9.9

I have shown elsewhere that household strategies, and therefore household transition rates, should be affected by the flow of non-labour income received, and by the parameters of the wage offer distribution facing unemployed members. Use of the SIME/DIME sample in estimating these effects presents some difficulties, since the operational equivalents of these concepts are not straight-forward. Individual households are faced with a variety of support levels, tax rates, and other financial parameters which result in very complicated non-linear budget constraints. Even if the wage offer distribution appears in the transition equation to be estimated only as a single value representing the conditional expectation of an accepted wage, it is still the net predicted wage we are interested in and no family faces a constant marginal tax rate over all levels of family labour supply.

Rather than attempting to control for these effects by including SIME/DIME treatment parameters in the form of dummy variables, the estimates in the next section represent the family's opportunities in the form of a current income flow and an estimated hourly tax on predicted earnings. The tax is disaggregated into one component associated with the SIME/DIME program and another due to other tax and transfer programs, and is calculated by comparing current net income with a predicted level of net income resulting from a change in the household's employment status. This procedure requires not only a predicted wage for the unemployed, but also predicted hours of work, which is proxied by mean hours of work over the employed sample (by year and sex). The fixed hours assumption avoids the complete specification of the non-linear budget constraint in the actual estimation of transition rates, though of course it is required to construct the hourly tax rates.

Predicted gross wage rates are derived from regressions on average annual wage observations for the entire sample of controls, run separately by race and sex. Other current income includes monthly receipts from all sources — earnings of family members other than the two heads, AFDC and other government transfer payments, SIME/DIME payments, alimony, and asset income. All dollar amounts are deflated using Seattle and Denver Metropolitan Price Indices and are reported in July 1972 dollars. Age and number of children under six years of age are included in the transition rate equations to represent the relative value of non-market time.

The log of the likelihood function described in Section III was maximized with respect to the parameters of each transition rate separately using a Newton-Raphson technique. Since the function is globally concave, any maximum must be unique. The values of the independent variables are held constant at their initial values for the duration of each household employment spell, but allowing them to vary freely each month does not seem to alter the results significantly.

V. EMPIRICAL RESULTS: TRANSITION RATE ESTIMATES

This section presents maximum likelihood estimates of the transition rates specified in Section III. The determinants of transitions between the three labour market states - employment, unemployment, and non-participation - are discussed for female household heads, with emphasis on the effects of intra-household interactions. The section concludes with a summary of the major results.

A. Labour Force Entry

Column 1 in Table 2 contains the estimated coefficients of the transition rate from non-participation directly into employment (N→E) for all female heads who were non-participants during the sample period (male heads may be employed, unemployed, or out of the labour force). One of the most striking aspects of this equation is the effect of the male head's employment status. If the male head is employed, the female head is less likely to make a transition from non-participation to employment, and the effect is highly significant. In fact, controlling for other observable characteristics, the transition rate of women whose husbands were unemployed or not in the labour force is some 1.4 times the transition rate of those with employed husbands.[14]

The hourly wage rate of the male head (predicted or actual, depending on employment status), does not have a significant effect on the rate at which the female head enters employment from outside the labour force. The predicted wage of the female head herself serves as a proxy for the mean of the wage offer distribution and was expected to have a positive effect on probabilities of moving into the labour force and into employment. This expectation is strongly confirmed in this case and in most of those which follow. Age and the number of children under six years of age have a negative effect on the N→E transition, presumably because both variables are positively related to the value of non-market time.

The dummy variables for race and ethnic origin are significant determinants of this transition rate, and of many others. The magnitude and direction of the effects vary considerably across experimental sites and according to employment status of spouse, and in another context it would be interesting to attempt an interpretation of these results. This will not, however, be undertaken here, nor will a detailed examination of income and tax effect.

Columns 2 and 3 in Table 2 present estimates of the N→E transition rate with the sample split according to employment status of the male heaad. In general, the number of observations on households with male heads who were non-participants was too small to estimate female head transition rates, so these cases are excluded. A comparison of the two disaggregated models with that estimated on the entire sample reveals some interesting patterns. In particular, the number of children under six has a negative influence on the N→E transitions of female heads only if the male head is employed. As was shown above, this pattern of influence among factors increasing the value of non-market time is a likely result of the household utility model. A comparison of age effects across equations also supports this contention.[15]

The estimated coefficients of the transition rate into unemployment for non-participating female heads are not reported here, but can be briefly summarized. Employment of the male head does not have a significant effect on this transition rate. However, this apparent absence of a household effect on the N→U transition rate reflects the behavior of the Seattle subsample only. If this model is estimated on the Denver subsample only, the coefficient on the dummy variable representing spouse's employment status is negative, as expected, and significant at a 90 percent level. Age and children under six once again have a discouraging effect on labour force participation.

B. The Outcome of Unemployment Spells

The most surprising results contained in Table 3 are that employment of the male head increases the rate at which unemployed female heads accept jobs by nearly 50 percent, and that this positive effect is reinforced by a higher wage. Given the analysis of Section II, we had expected that employment of the male head would increase the reservation wage of the female head, thus making job acceptance less likely. An increase in the male head's wage, if working, or predicted wage, if unemployed, should have a similar effect.

There are two possible explanations for these anomalous results. First, an employed husband may be able to assist his wife's job search by providing contacts or simply information, thus making her search time more productive. The second possibility is that unobserved individual characteristics which affect wage offer distributions and/or search productivities are positively correlated within households. It may be possible in the future, by making explicit use of repeated unemployment spells over the sample period, to separate the effects of spouse's employment status from such marital matching effects.

TABLE 2

Out of Labour Force → Employment Transition Rate for Female Heads

(ML estimates of effects on the logarithm of the transition rate)*

	Total Sample	Male Head Employed	Male Head Unemployed
Constant	- 3.34 (- 9.43)	- 3.22 (-21.67)	- 4.65 (- 8.24)
1 = Male head employed	- 0.32 (- 5.12)		
Actual or predicted hourly wage - male head	- 0.01 (- 0.35)	- 0.02 (- 0.76)	- 0.17 (- 1.48)
Predicted hourly wage - female head	0.67 (28.77)	0.57 (26.88)	1.25 (8.25)
Hourly tax - SIME/DIME ($)	- 0.01 (- 0.13)	- 0.50 (- 4.85)	- 0.75 (- 3.14)
Hourly tax - other tax and transfer programs ($)	- 0.35 (- 7.23)	- 0.14 (-4.60)	- 0.36 (- 2.62)
Other current income ($/100)	0.01 (0.45)	0.004 (0.37)	0.03 (0.62)
Age in years/10	- 0.19 (- 6.31)	- 0.30 (- 8.40)	- 0.04 (- 0.35)
Number of children under 6 years	- 0.17 (- 5.97)	- 0.18 (- 5.29)	0.09 (0.78)
1 = Black	0.14 (2.50)	0.20 (3.01)	- 0.25 (- 1.08)
1 = Mexican-American	- 0.19 (- 2.79)	- 0.15 (- 1.94)	- 0.59 (- 2.05)
1 = Seattle	- 0.49 (- 8.64)	- 0.48 (- 7.09)	- 0.94 (- 4.10)
χ^2	660.12	511.88	76.12
Number of spells	3658	4212	1687
Number of transitions	1817	1343	106

*(asymptotic t-statistics are in parentheses)

The predicted wage of the female head has a positive effect on the probability of entering employment, though the own-wage elasticity of this transition rate is lower than that of the U→E rate. Other income discourages job acceptance, as expected, and so do children under six. Age, however, does not affect the entry rate into employment, conditional upon the participation decision. Columns 2 and 3 reveal a familiar pattern in the coefficients on age and children; they are significantly negative only when the male head is employed.

The effect of spouse's employment status on the rate at which unemployed female heads drop out of the labour force (U→N) has the right sign, but falls short of significance at the 90% level (results not reported). In fact, very few of the independent variables appear to contribute individually to an explanation of the dropout rate, though the χ^2 statistic confirms the explanatory power of the model as a whole. The own-wage effect is significant and negative, other income has a significant positive coefficient, and Seattle residence discourages a U→N transition.

It is clear that these models are more successful in explaining transitions into employment than transitions between unemployment and non-participation. Part of this can probably be traced to the measurement errors in timing the U→N and N→U transitions which resulted from the data collection procedures. Another part of the problem may be that the random events we expect to affect the relative values of non-market time and search activity, such as illness and changes in family size, are not well represented by the available independent variables. The issue arises, however, of whether any meaningful distinction can be made between the states of non-participation and unemployment. In this context, the continuing importance of own predicted wage in the U→N model provides a reassuring indication of economic content.

TABLE 3

Unemployment → Employment Transition Rate for Female Heads

(ML estimates of effects on the logarithm of the transition rate)*

	Total Sample	Male Head Employed	Male Head Unemployed
Constant	- 2.21 (-10.45)	- 1.51 (-6.16)	- 2.77 (-4.27)
1 = Male head employed	0.34 (3.35)		
Actual or predicted hourly wage - male head	0.03 (2.21)	0.02 (1.56)	- 0.08 (- 0.62)
Predicted hourly wage - female head	0.32 (4.85)	0.29 (4.06)	0.47 (2.56)
Hourly tax - SIME/DIME ($)	0.02 (0.18)	- 0.30 (- 1.67)	- 0.29 (- 1.26)
Hourly tax - other tax and transfer programs ($)	- 0.06 (- 0.76)	- 0.05 (- 0.59)	- 0.39 (- 2.30)
Other current income ($/100)	- 0.06 (- 1.72)	- 0.01 (- 0.36)	0.12 (1.46)
Age in years/10	- 0.06 (- 1.27)	- 0.17 (- 2.96)	0.10 (0.92)
Number of children under 6 years	- 0.14 (- 3.05)	- 0.15 (- 2.91)	- 0.22 (- 1.46)
1 = Black	- 0.31 (- 3.67)	- 0.28 (- 2.89)	- 0.32 (- 1.40)
1 = Mexican-American	- 0.29 (- 2.19)	- 0.27 (- 1.90)	- 1.14 (- 1.82)
1 = Seattle	- 0.64 (- 7.45)	0.64 (- 6.31)	- 0.47 (- 1.83)
χ^2	131.82	75.78	19.08
Number of spells	1263	1102	376
Number of transitions	676	519	90

*(asymptotic t-statistics are in parentheses)

An examination of transitions out of the two states should also provide a basis for disaggregation on behavioral grounds. A combined estimate of the U→E and N→E transition rates with all coefficients constrained to be equal permits a likelihood ratio test of whether a disaggregation of the initial states gives a significantly better explanation of transitions into employment. This test was performed on observations from the last three years of the Denver subsample, and strongly rejected the hypothesis that all coefficients are equal.

C. Leaving Employment

In the total sample results presented in column 1 of Table 4, the employment status of the male head and his hourly wage have no significant effect on the transition rate from employment to unemployment (E→U) for female heads. Age and number of children decrease the E→U rate, so the increasing relative value of home time which these variables represent seems to be outweighed by influences such as tenure and experience effects on job separations, and the effect of children on the marginal utility of income to the household.

Both the employment of the male head and the wage of the male head when employed have positive effects on the rate at which female heads leave the labour force from employment (E→N). These influences, together with the positive coefficient on the number of children under six years, suggest that these E→N transitions are a response to some change in the relative value of non-market time. A comparison of these results with those in Table 4 provides some justification for disaggregating flows out of employment in this manner, though a formal test of the non-equivalence of unemployment and non-participation in this context has not been undertaken.[16]

D. Summary of the Transition Rate Estimates

In general, the results presented above offer considerable support for the hypothesis that individual labour force transitions depend upon the employment status and wage of other household members. The estimates of these household effects are not, however, uniformly consistent with those predicted by the theory. Where an anomalous result appears to be caused by some deficiency in either the data or the empirical specification, this has been noted in the preceding discussion with a view towards implementing more effective tests in the future. It is clear, however, that household influences are not equally important in the determination of all labour force transitions, and some interesting patterns emerge.

1) In particular, the labour force participation decisions of female heads appear to be strongly influenced by spouse's employment status. This is most evident in the case of transitions between employment and non-participation.

2) Transitions between non-participation and unemployment are rather poorly explained by this model, and household variables in particular rarely make a significant contribution. This may be the result of imprecision in the timing of recorded transitions, or of the often-discussed weakness of the behavioral distinction between the two states.

3) The importance of unobserved personal characteristics which affect the efficiency or intensity of job search activities is apparent from the unemployment-employment transition results. The question naturally arises of why the unexpected household effects which appear here do not appear in the N→E estimates as well.

TABLE 4

Employment → Unemployment Transition Rate for Female Heads

(ML estimates of effects on the logarithm of the transition rate)*

	Total Sample	Male Head Employed	Male Head Unemployed
Constant	- 2.73 (- 6.50)	- 2.68 (- 9.21)	- 2.84 (- 4.59)
1 = Male head employed	0.14 (0.89)		
Actual or predicted hourly wage - male head	0.02 (0.78)	0.02 (0.66)	0.13 (1.92)
Actual hourly wage - female head	0.02 (0.21)	0.18 (1.65)	- 0.12 (- 0.48)
Hourly tax - SIME/DIME ($)	0.07 (0.56)	- 0.12 (- 2.48)	- 0.42 (- 1.68)
Hourly tax - other tax and transfer programs ($)	- 1.45 (- 3.93)	- 1.67 (- 5.14)	- 0.96 (- 0.65)
Other current income ($/100)	0.03 (1.88)	0.03 (1.18)	0.06 (2.93)
Age in years/10	- 0.35 (- 5.98)	- 0.39 (- 5.38)	- 0.21 (- 1.68)
Number of children under 6 years	- 0.17 (- 2.78)	- 0.13 (- 1.97)	- 0.31 (- 1.70)
1 = Black	0.10 (0.99)	0.22 (1.92)	- 0.43 (- 1.73)
1 = Mexican-American	- 0.26 (- 1.52)	- 0.17 (- 0.91)	- 2.06 (- 1.99)
1 = Seattle	0.15 (1.36)	0.02 (0.16)	0.35 (1.24)
χ^2	98.40	67.60	29.14
Number of spells	3116	3095	923
Number of transitions	473	353	69

*(asymptotic t-statistics are in parentheses)

TABLE 5

Employment → Out of Labour Force Transition Rate for Female Heads

(ML estimates of effects on the logarithm of the transition rate)*

	Total Sample	Male Head Employed	Male Head Unemployed
Constant	-1.73 (-10.56)	- 1.47 (- 9.23)	- 1.24 (- 2.32)
1 = Male head employed	0.38 (4.07)		
Actual or predicted hourly wage - male head	0.04 (3.51)	0.05 (5.40)	0.03 (0.24)
Actual hourly wage - female head	- 0.01 (- 0.15)	0.20 (3.91)	- 0.57 (- 2.76)
Hourly tax - SIME/DIME ($)	- 0.17 (- 11.33)	- 0.16 (- 12.14)	0.08 (0.43)
Hourly tax - other tax and transfer programs ($)	- 1.43 (- 7.18)	- 1.89 (- 14.82)	- 0.06 (- 0.04)
Other current income ($/100)	0.03 (3.11)	0.02 (1.57)	0.04 (1.76)
Age in years/10	- 0.31 (- 9.08)	- 0.34 (- 8.29)	- 0.43 (- 3.60)
Number of children under 6 years	0.10 (3.23)	0.13 (3.92)	0.03 (0.26)
1 = Black	- 0.43 (- 7.60)	- 0.45 (- 6.50)	0.08 (0.34)
1 = Mexican-American		0.09 (1.21)	0.30 (0.97)
1 = Seattle	- 0.24 (- 3.97)	- 0.44 (- 6.14)	0.08 (0.33)
χ^2	454.54	477.16	43.02
Number of spells	3116	3095	923
Number of transitions	1584	1223	105

*(asymptotic t-statistics are in parentheses)

The observance of a direct transition from non-participation to employment may be regarded as evidence of a spell of unemployment which was too brief to be recorded. The fact that household income and time substitution effects are observed to affect N→E transition but not U→E transitions may then indicate some duration dependence in the response of an individual's search strategy to changes in household conditions.

4) The effect of other variables are interesting in their own right and many results, such as the consistency of own-wage effects even in the context of U→N and N→U transitions, have been noted above. More important for the purposes of this study, however, is the confirmation of the theory's predictions regarding interactions between spouse's employment status and the value of home time provided by the pattern of coefficients on age and number of children under six years.

VI. EMPIRICAL RESULTS: EMPLOYMENT STATE DISTRIBUTIONS

The transition rate estimates in the previous section give a detailed picture of how the employment status of husbands and other variables affect the labour market experience of married women. We would like, however, to have a summary measure of the impact of spouse's unemployment on the distribution of wives over labour market states -- i.e. on their unemployment and participation rates. To this end, note that the transition rates define a continous time stochastic process for which we should be able to find a steady-state probability distribution.

Following Howard, we define $\phi_j(t)$ as the probability that a continous time Markov process occupies state j at time t and let $\Phi(t)$ be the row vector of state probabilities for all states. Let Λ be the square matrix such that the j-kth off-diagonal element is the transition rate λ_{jk} and the

j^{th} diagonal element is $-\lambda_j$.

Then,

$$\Phi(t) = \Phi(0)e^{\Lambda t}$$

where $e^{\Lambda t} = I + \Lambda t + \frac{\Lambda^2 t^2}{2!} + \frac{\Lambda^3 t^3}{3!} + \ldots$

Differentiating this expression produces,

$$\frac{d}{dt}\Phi(t) = \Phi(t)\Lambda$$

as that the limiting state probability vector Φ satisifies

$\Phi\Lambda = 0$ and $\sum_{j=1}^{n} \phi_j = 1$.

In this section, we concentrate on the equilibrium state distribution of financial controls in the Denver sample only. The mean values of independent variables are calculated for black and white subgroups of this population[17], and the coefficient estimates presented in columns 2 and 3 of each table in the last section are used to produce average transition rates by race and by employment status of the male head.

The simplest procedure is to calculate the equilibrium state distribution of female heads as individuals, conditional upon the employment status of male heads — i.e., ignore the transitions of male heads. There is, however, a major problem with this technique. Since the female heads reach an equilibrium state distribution conditional upon the state of their spouses, it is implicitly assumed that unemployed men remain unemployed forever. Since the mean duration of an unemployment spell in this sample is just over two months, transitions by both household heads must be permitted.

For this purpose, it is necessary to estimate transition functions for the entire, nine-by-nine household transition matrix. Many of the estimates for transitions of the male heads are presented in Lundberg, but for cells where the number of observed transitions was very small, a population average rate has been substituted.

In Table 6, the steady-state unemployment rates and participation rates of female heads by the employment status of spouse can be compared with previous estimates and actual 1972 averages. Reassuringly, the estimated household matrix generates a reasonable steady-state distribution. Controlling for factors such as expected wage, other income, age, and number of children, the equilibrium unemployment and participation rates of women with unemployed husbands are higher than these rates for women with employed husbands. This relationship holds for both black and white subsamples and is generated by higher rates of labour force entry and lower rates of labour force exit for "added workers".

A better way to assess the magnitude of the added worker effect may be to observe the effect of an increase in the unemployment of married men on the labour supply of their wives. This can be simulated by introducing a disturbance to a sample of households which are in labour market equilibrium. The adjustment of the system back to its steady-state distribution can be traced over time using interval transition probabilities.

Leaving the transition rate matrix unchanged, the initial state distribution was altered so that the unemployment rate for male heads was twice its equilibrium level. The monthly changes in the state distribution of the households are presented in Table 7.

The initial effects of a doubling in the unemployment rate of male heads can be summarized as follows. If 100 white husbands became unemployed simultaneously, 36 additional wives will have entered the labour force by the end of the first month. Of this 36, about 29 wives will have become employed. If 100 black husbands become unemployed, 25 wives will join the labour force and, of these, 20 will be employed by the end of the month. Unemployment rates return very rapidly to their equilibrium levels, so the

Table 6

Unemployment and Participation Rates for
Female Heads by Race and Employment
Status of Male Head
(Denver Financial Controls only)

	Average 1972	Household Steady-State
White		
Unemployment rate		
- male head employed	6.2	7.9
- male head unemployed	12.8	14.0
Participation rate		
- male head employed	43.7	37.0
- male head unemployed	59.7	75.1
Black		
Unemployment rate		
- male head employed	6.3	11.0
- male head unemployed	14.6	13.2
Participation rate		
- male head employed	50.9	54.2
- male head unemployed	65.8	81.7

system is stable. The participation rates of wives, however, are still 1.5 to 2% above their steady-state levels at the end of one year, indicating some persistence in the employment effect.

SUMMARY AND CONCLUSIONS

In recent years, the high unemployment rates and volatile participation behavior of groups in the labour force which are often considered to be "secondary workers", such as women and teenagers, have received considerable attention. The apparent importance of family structure in explaining changes in the labour force status of these workers emphasizes the need to consider job search behavior in a household labour supply context, and to expand the

Table 7

Unemployment and Participation Rates by Month Following A Doubling of the Male Head Unemployment Rate in Month 0.

End of Month	WHITE Unemployment Rates MH	WHITE Unemployment Rates FH	WHITE Participation Rate FH	BLACK Unemployment Rates MH	BLACK Unemployment Rates FH	BLACK Participation Rate FH
1	9.6	9.0	42.4	15.9	11.5	58.8
2	8.4	8.9	42.3	14.2	11.4	58.6
3	7.6	8.9	42.2	12.9	11.4	58.4
4	7.0	8.8	42.0	12.0	11.4	58.3
5	6.7	8.8	41.9	11.3	11.3	58.1
6	6.4	8.7	41.8	10.8	11.3	58.0
7	6.2	8.6	41.6	10.4	11.3	57.8
8	6.1	8.6	41.5	10.1	11.2	57.7
9	6.0	8.6	41.4	9.9	11.2	57.6
10	5.9	8.5	41.4	9.7	11.2	57.5
11	5.9	8.5	41.3	9.6	11.2	57.4
12	5.9	8.5	41.2	9.5	11.2	57.4
Steady-State	5.7	8.4	40.5	9.1	11.2	56.6

traditional two-state labour market of job search theory to allow movements into and out of the labour force.

This paper brings together the joint utility maximization of static household models and the stochastic events which affect labour supply opportunities in search theory, and applies a more comprehensive model to a study of the added worker effect. The theory suggests a continuous-time exponential model of state-occupancy durations, with the transition rates depending upon both household strategies and the arrival rates of random events (job offers, job separations, and changes in the value of non-market time).

These transition rates are then expressed as functions of individual and household characteristics, and the parameters of the model are estimated using maximum likelihood methods on the employment histories of a sample of households enrolled in the Seattle and Denver Income Maintenance Experiments. The dependence of individual and household transition rates on the employment status and wages of both household heads is then tested.

Cross-wage effects are found to be negligible, but the influence of spouse's employment status on the observed transition rates of female household heads is generally consistent with the theory. This effect is particularly strong on transitions into and out of the labour force.

In the final section, the steady state unemployment and participation rates of women with unemployed husbands are shown to be markedly higher than the rates of women whose husbands are employed for both blacks and whites in the DIME sample. A simulation of the effects of increasing the unemployment rate of married men produces an additional response in the form of increased participation and employment among their wives in the short-run.

FOOTNOTES

1. See the references in Mincer [1966] and Wachter.

2. As noted by Burdett and Mortensen, strict concavity can also be interpreted as risk aversion under conditions of uncertainty.

3. "Leisure" in this model can also be viewed as time devoted to non-market or household production. This interpretation renders the assumption of substitutability between ℓ_1 and ℓ_2 more palatable. Some of the results below are dependent upon this assumption -- in particular those which do not hold the employment status of member 2 constant become ambiguous in sign if strong complementarities between ℓ_1 and ℓ_2 are permitted. The empirical evidence on this point is contradictory, but Ashenfelter and Heckman conclude that the cross-substitution effect is zero.

4. The state E should be indexed by the wage, but this is ignored for the moment to simplify the notation.

5. V^{ji} is thus a function of the arrival rates of job offers and job separations decribed above.

6. Throughout, it is assumed that member 2 is devoting time to market work at the wage w_2.

7. Proposition 1 does not depend upon the assumption that ℓ_1 and ℓ_2 are substitutes, but this additional result does. All proofs are contained in Chapter 2 of Lundberg.

8. We can expect that the values b_i will change in some predictable manner over the life-cycle of household members and the current approach, which focuses on the short-run dynamics of the labour market, abstracts from such considerations. To the extent that future events which change the value of non-market time, such as births or educational opportunities, are anticipated and planned for, this stochastic model will not provide an adequate description of household behavior. The same argument, of course, can be applied to predictable change in available wage rates over the life cycle, which affect household response to current wages. In what follows, the distributions $f_i(\tilde{w}_i)$ and $g_i(\tilde{b}_i)$ are assumed to be exogenous, though their dependence on factors under the long-run control of the household is here acknowledged.

9. Ideally, we should like to identify the household's decision rules (w_i^r, w_i^ℓ) themselves, so that the effect of one member's wage on the other's reservation wage and value of non-participation can be estimated directly. Unfortunately, the four elements of the household's strategy are unobservable and observing transitions alone will not permit identification of the reservation wage function, so a reduced form estimation of the transition probabilities is necessary.

10. In particular, see Tuma, Hannon, and Goreneveld [1979] for a general discussion and Flinn and Heckman for empirical comparisons of discrete and continuous-time methods.

11. Considerable evidence is accumulating that duration dependence is an important attribute of the rate of leaving unemployment. See, most recently, Flinn and Heckman, or, for a treatment explicitly based on non-stationary search strategies, Kiefer and Neumann [1979].

12. This has been shown by Heckman and Borjas.

13. In general, the unemployment rates for SIME/DIME female heads were much higher than for married women in the U.S. population, and participation rates were somewhat lower, particularly in the arly years of the experiment.

14. The antilog of the coefficient on a dummy variable in this model gives the multiplier effect of the dichotomous variables on the transition rate.

15. To perform a test of the explanatory power of the model, we compare it with another model where all coefficients except the constant term are constrained to equal zero. The constant term in this model is the average transition rate, or the total number of transitions divided by the total length of time the sample is observed in the initial state. If all households were identical and durations were controlled by a single-parameter exponential process, this statistic would be the appropriate estimator of the exponential parameter.

Implementing the comparison for the model in column 1, the value of the log of the likelihood function is 38.31 for the constrained version, as opposed to 368.37 for the unconstrained model. A standard likelihood ratio test gives a test statistic of 660.12, which is distributed $\chi^2(11)$. The critical value of the test statistics at a 99 percent siginificance level is 24.7, so we can reject the null hypothesis that all coefficients other than the constant term are equal to zero. All models reported here are able to pass a similar test at a 95 percent level, enabling us to conclude that they explain the specified transitions better than a single-parameter exponential process.

16. The puzzling aspect of the $E \to N$ transition rate estimates appears when we turn our attention to the own-wage and tax effects. A negative sign on the own wage effect was expected, and this expectation is confirmed for the male head unemployed subsample (Column 3). When the male is employed, however, the own-wage effect is positive and accompanied by large, negative tax effects. The possibility that these results are due to non-linearities in the wage effect, since the tax variables are so highly correlated with the wage when employed, points up the need for future experimentation with various functional forms in the specification of these transition rates. At present, it must simply be noted that misspecification may be a serious problem.

17. Other income and hourly taxes are allowed to vary by employment state, due to the state dependence of transfer payments and the non-linearity of income taxes.

REFERENCES

Ashenfelter, O. and J.J. Heckman, "The Estimation of Income and Substitution Effects in a Model of Family Labor Supply," Econometrica, 42 (January 1974), pp. 73-85.

Bowen, W.G. and T.A. Finegan, The Economics of Labor Force Particpation, Prinecton, N.J., Princeton University Press (1969).

Burdett, K. and D.T. Mortensen, "Labor Supply under Uncertainty," in Research in Labor Economics, Vol. 2 (1978), edited by R. Ehrenberg, aslo N.U. Math Center Discussion Paper, No. 297.

Cain, G.G., Married Women in the Labor Force: An Economic Analysis, Chicago, University of Chicago Press, (1966).

Flinn, C.J. and J.J. Heckman, "Models for the Analysis of Labor Force Dynamics," Economics Research Center NORC (June 1980).

Heckman, J.J. and G. Borjas, "A Continous Time Model of Heterogeneity and State Dependence with Simple Tests and Applications to Labor Mobility and Unemployment," presented to Summer Meetings of Econometric Society, Montreal (1979).

Heckman, J.J. and T.E. MaCurdy," A Life Cycle Model of Female Labor Supply," Review of Economic Studies, January, 1980.

Howard, R.A., Dynamic Probabilistics Systems: Volume II: Semi-Markov and Decision Processes, New York, John Wiley & Sons, (1971).

Kalbfleisch, J.D. and R.L. Prentice, The Statistical Analysis of Failure Time Data," New York, John Wiley & Sons, (1980)

Keeley, M.C. et al., "The Estimation of Labor Supply Models Using Experimental Data," American Economic Review, 68 (December, 1978), pp. 873-87.

Kiefer, N.M. and G. Neumann, "An Empirical Job-Search Model," Journal of Political Economy, 87 (February, 1979), pp. 89-107.

Kurz, M. and R.G. Spiegelman, "The Design of the Seattle and Denver Income Maintenance Experiments," Stanford Research Institute, Research Memorandum No. 18 (June, 1972).

Kurz, M., R.G. Spiegelman, and J.A. Brewster, "The Payment System for the Seattle and Denver Income Maintenance Experiments," Stanford Research Institute, Research Memorandum No. 19 (June, 1973).

Kurz, M. et al., "A Cross-Sectional Estimation of Labor Supply for Families in Denver 1970," Stanford Research Institute, Research Memorandum No. 24 (November, 1974).

Lippman, S. and J.J. McCall, "The Economics of Job Search: A Survey," Economic Inquiry, 14 (1976), pp. 155-89 (a), pp. 347-68 (b).

Lundberg, S.J., "Unemployment and Household Labour Supply," unpublished dissertation, Northwestern University (1981).

Marston, S.T., "Employment Instability and High Unemployment Rates," Brookings Papers on Economic Activity, 1 (1976), pp. 169-203.

Mincer, J., "Labor Force Participation of Married Women," in Aspects of Labor Economics, edited by H.G. Lewis, Princeton, N.J., Princeton University Press (1962), pp. 63-105.

Mincer, J., "Labor Force Participation and Unemployment," in Prosperity and Unemployment, edited by R.A. Gordon and M.S. Gordon, New York, John Wiley & Sons, (1966), pp. 73-112.

Toikka, R.S., "A Markovian Model of Labor Market Decisions by Workers," American Economic Review, 66 (December, 1976), pp. 821-34.

Tuma, N., M. Hannon, and L. Goreneveld, "Dynamic Analysis of Event Histories," American Journal of Sociology, 84 (January, 1979), pp. 820-54.

Tuma, N. and P.K. Robins, "A Dynamic Model of Employment Behavior: An Application to the Seattle and Denver Income Maintenance Experiments," Econometrica, 48 (May, 1980).

Wachter, M.L., "A New Approach to the Equilibrium Labour Force," Economica, (February, 1974), pp. 35-51.

Watts, H.W. and A. Rees, eds., The New Jersey Income - Maintenance Experiment, Vol. II, New York, Academic Press (1977).

APPENDIX A

Table A-1

Spell Sample Means of Variables By Employment State of Female Head*

Denver

	Employed	Unemployed	Out of Labour Force
1 = Male head employed	0.78	0.76	0.70
1 = Black	0.32	0.43	0.23
1 = Mexican-American	0.27	0.26	0.39
Age in years - female head	29.5	28.9	29.0
Years of schooling - female head	11.4	11.2	10.8
Hourly wage - female head ($)	2.02	---	---
Predicted wage - female head ($)	---	1.83	1.70
Actual or predicted hourly wage - male head ($)	3.26	3.30	3.29
Other income ($/mo.)	83.44	111.76	116.99
Net assets ($)	3,730	3,084	3,101
Hourly tax on earnings of female head			
- DIME	0.10	0.14	0.14
- other taxes and transfers	0.44	0.75	0.69
Number of children < 6	0.92	0.99	1.11
< 16	2.01	1.94	2.16
Number of Observations	2553	765	3548

* (All dollar quantities in July 1972 dollars)

Table A-2

Spell Sample Means of Variables By Employment

State of Female Head*

Seattle

	Employed	Unemployed	Out of Labour Force
1 = Male head employed	0.70	0.65	0.62
1 = Black	0.44	0.49	0.34
Age in years - female head	32.0	31.2	31.4
Years of schooling - female head	11.4	10.9	11.2
Hourly wage - female head ($)	2.46	---	---
Predicted wage - female head ($)	---	2.11	1.89
Actual or predicted hourly wage - male head ($)	3.86	3.70	3.97
Other income ($/mo.)	71.83	114.42	97.55
Net assets ($)	5,120	4,395	4,376
Hourly tax on earnings of female head			
- SIME	0.16	0.09	0.11
- other taxes and transfers	0.40	0.79	0.65
Number of children < 6	0.72	0.74	0.96
< 16	1.89	1.87	2.06
Number of Observations	1742	752	2432

* (All dollar quantities in July 1972 dollars)

Table A-3

Characteristics of the Household Sample

	Denver	Seattle
Financial control, no SIME/DIME payment (%)	43.4	48.1
Remained in sample for entire 4 years (%)	68.5	80.1
Black (%)	28.4	38.8
Mexican-American (%)	34.5	---
White (%)	37.1	61.2
Years of schooling completed (%)		
12 or less - male head	84.3	79.2
12 or less - female head	90.0	82.7
10 or less - male head	33.8	34.5
10 or less - female head	38.3	25.8
Mean Age in years - January 1, 1972		
- male head	33.4	36.9
- female head	30.6	33.0
Mean predicted wages - 1972		
- male head	3.34	3.86
- female head	1.86	2.02
Number of households	1389	993