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Marie W. Arneberg, John K. Dagsvik and Zhiyang Jia

Labor Market Modeling Recognizing Latent Job Attributes and Opportunity Constraints

An Empirical Analysis of Labor Market Behavior of Eritrean Women

Abstract:
This paper analyzes labor market behavior of urban Eritrean women with particular reference to the impact of education, earnings and labor market opportunities. Unlike traditional models of labor supply, which assume that work can be supplied freely in the labor market, we develop a framework that explicitly takes into account the notion of job opportunities and observable sets of feasible jobs. The framework is formulated within a random utility setting in which unobservable jobs can conveniently be treated as latent alternatives. The framework can also readily take into account observed restrictions on the sets of feasible jobs.

The empirical estimation of the model is based on data from the labor force module of the 1996/97 Eritrean Household Income and Expenditure Survey for urban areas. We estimate structural choice probabilities of being in the states “Not employed”, “Working in the wage sector”, and “Working as self-employed”, where it is taken into account that some women are constrained in their labor market choices.

We find that the effect on wages of changes in education level is high; improving the education levels of women greatly improves their wages, which again contributes to bringing more women into the labor force. However, our data do not support the assumption that basic education increases women’s job opportunities. In order to do so, at least secondary education is required.

Keywords: Female labor supply, Random utility model, Returns to education, Labor markets in developing countries.

JEL classification: C25, J22, J31

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Address: Marie W. Arneberg, Fafo Institute of Applied Science. E-mail: mwa@kuf.dep.no

John K. Dagsvik, Statistics Norway, Research Department. E-mail: john.dagsvik@ssb.no

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Statistics Norway
Sales- and subscription service
N-2225 Kongsvinger

Telephone: +47 62 88 55 00
Telefax: +47 62 88 55 95
E-mail: Salg-abonnement@ssb.no

1. Introduction

In this paper we develop and apply a particular empirical modeling framework to analyze the behavior of women in the urban Eritrean labor market. We focus on the behavior of women with respect to three labor market states, namely “employed in the wage sector”, “being self-employed”, and “not employed”. Since women constitute the largest labor reservoir in the country, and have in general a low economic activity level, understanding the factors affecting women’s labor supply is urgent for identifying policy measures that may increase local production capacity and economic growth.

Traditional models of labor supply rely on the assumption that hours of work can be supplied freely in the labor market at a given (equilibrium) worker-specific wage rate. Thus, this type of model abstracts from the fact that an important aspect of the labor market is the notion of “job”, which represents the activity associated with the production process, and which may be costly to create and destroy. A realistic modeling framework for behavior in the labor market should take into account that an important aspect of labor market behavior consists of choosing between feasible jobs. However, this challenge is by no means a simple one. First, it is hardly possible to give a simple and observable representation of the job dimension of the labor market. Second, the (equilibrium) individual sets of feasible jobs are in general not observable to the econometrician. Third, rationing may be present such that there may be excess supply in some markets and excess demand in others. To take into account this type of market failure in developing countries may be even more crucial than in developed economies as labor markets may be more segmented.

In the literature a number of authors have analyzed labor supply in developing countries within a three-sector framework. Examples are Heckman and Sedlacek (1990), Magnac (1991), Gindling (1991), Newman and Gertler (1994), Tiefenthaler (1994, 1999), and Pradham and van Soest (1995, 1997). Some of these authors allow for rationing and market segmentation. For example, Magnac (1991) assumes that agents must wait and face costs of entry into the wage sector. The costs are assumed to be proportional to wage rates and can therefore be accounted for in the same way as linear taxes. Pradham and van Soest (1997) use a similar approach but interpret non-wage factors that influence sector participation as non-monetary returns. Newman and Gertler (1994) and Pradham and van Soest (1997) analyze both choice of sector as well as hours of work allocation given sector, while the other authors mentioned above only analyze choice of sector.

Similarly to most of the papers mentioned above we have in this paper adopted a modeling framework based on the concepts and techniques developed within the tradition of random utility models. In contrast to the specification of conventional demand for continuous quantities, the tradition of random utility models departs from an explicit stochastic representation of preferences. As is well known, the motivation for the stochastic terms in the preference function is to allow for taste-shifters that are unobserved by the econometrician and therefore are perceived as random to him. A great advantage of the random utility framework is that it allows researchers, both to model unobserved taste variation and to take into account unobserved choice sets of market opportunities.

Theoretically, our point of departure is static neoclassical theory in which agents, in addition to having preferences over leisure and consumption, also have preferences over non-pecuniary attributes of the jobs in the wage sector and maximize utility under appropriate budget constraints and (latent) choice sets of feasible market opportunities. Also the wage rates in the wage sector are allowed to depend on latent job characteristics. Under particular assumptions about the distribution of the unobservables, we derive a probabilistic model (choice probabilities) for agents' choice behavior. This model is a function of parameters that represent the distribution of preferences, budget constraints and "aggregate" latent choice opportunities. This modeling framework therefore seems convenient for accommodating the notion of rationing in the sense that there are restrictions on the set of job opportunities. Specifically, in accordance with the "dualistic approach" (see Mazumdar, 1977 and 1989, Pradhan, 1995, Rosenzweig, 1988, and House, 1992) we allow for constrained choice sets of job opportunities resulting from excess supply of labor to the wage sector where wages are relatively high and often regulated, whereas supply and demand of labor determine returns (marginal profit) in the self-employment sector composed mainly of small family-based enterprises. For simplicity, we only derive a model that corresponds to data on "corner solutions", represented by observations on participation in the three labor market states mentioned above. Examples of analogous modeling approaches that account for latent choice sets can be found in Ben-Akiva et al. (1985), Dagsvik (1994) and Aaberge et al. (1995). The present approach is, however, simpler and less general than the one proposed in Aaberge et al. (1995)[1].

To summarize; the methodological contribution of this paper that distinguishes it from the other papers mentioned above is twofold: First, we develop a particular approach to accommodate the notion of latent market opportunities with non-pecuniary aspects that affect the agents' utility functions. Second, we derive the corresponding choice probabilities of the observable choices. Since it follows from theory that an agent may choose to work in both sectors (unless marginal returns to self-employment is constant), we derive the corresponding choice probability of working in both sectors.[2]

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[1] It would have been desirable to establish an equilibrium framework in which the rationing mechanism is explained, but this is beyond the scope of the present paper.

[2] As far as we know, the derivation of this type of joint choice probability is new.

The empirical analysis is based on a sample of micro-data from the 1996/97 urban Eritrean Household Income and Expenditure Survey (EHIES). Our data contain observations on whether or not a woman is constrained in her labor market choice, and this information is utilized when estimating the sector participation probabilities. After the parameters of the model have been estimated it is possible to perform policy simulations on labor market behavior, such as for example the effect of changes in the wage rate or the effect of changes in the education level. In particular, it is possible to assess the separate effect of education on labor supply through the wage rate and the profit function, and on actual employment through parameters that represent mean choice opportunities (and which depend on education).

The paper it organized as follows: Section 2 discusses the data and the policy relevance of this study in the social and economic context of Eritrea. In Section 3 we develop the theoretical model, and Section 4 discusses the empirical specification. Section 5 presents the estimation results, and in Section 6 we discuss selected policy simulation experiments.

2. Context and relevance

The Eritrean population is characterized by a marked lack of adults, and in particular of adult men, as a result of war and labor migration (Arneberg and Pedersen, 2001, National Statistics Office, 1997). The high dependency burden, with more than half the population being children or elderly in some regions, is worsened by a general low economic activity rate among the working age population. Only 51 per cent of the adult urban population is in the labor force, of which 71 per cent are men and 36 per cent are women (Table 2.1). With an unemployment rate at 21 per cent, this means that every working adult has to provide for 3 dependants. Accordingly, only 61 per cent of the households have income from employment as their main income source (Table 2.2). As there is no publicly provided social safety net, the remaining households live on transfer income from family elsewhere in Eritrea or abroad.

Table 2.1. Summary characteristics of the adult urban population with age between 15-65, by sex and marital status (source: EHIES 1996/97)

.	All adults	Men	Women				
			All	Married	Widowed	Divorced	Never married
Population (1000 persons)	270	114	156	70	17	18	51
Per cent of population in age group 15-65	100	42	58	26	6	7	19
Illiteracy rate (per cent)	28	13	40	48	71	55	12
Labor force (LF) participation rate (per cent)	51	71	36	25	39	65	40
Wage employment rate (per cent of LF)	51	55	46	45	38	47	48
Self-employment rate (per cent of LF)*	28	25	31	32	41	35	24
Unemployment rate (per cent of LF)	21	19	24	23	20	19	28
Mean usual working hours, the employed	51	51	52	50	49	52	54
Mean wage rate, employees (US$ per hour)	0.37	0.43	0.27	0.39	0.24	0.29	0.19

* Includes workers in family business.

The low general activity rate, and the large, potential contribution by women, makes it urgent to identify factors that contribute to women's labor force participation. Standard models for understanding female labor supply recognize that women's decisions to enter the labor market to a much larger extent than men's decisions are intertwined with other factors than those pertaining to productivity, welfare benefits, and the functioning of the labor market. (See for example, Killingsworth and Heckman, 1986, Clark and York, 1999, Gustafsson, 1995, Frank and Wong, 1990.) Childbearing as well as social norms governing the different roles of men and women regarding income provision for the family has demanded a focus on interaction between household members in order to understand why women enter the labor market or not. (See for example Schultz, 1990.)

Empirical evidence, especially the second generation models which explicitly deal with the methodological problems arising from the large amount of non-supply among women, suggest that women's labor supply is more responsive to wage incentives than that of men. (See Killingsworth and Heckman, 1986.) Although women have lower wages than men, education often tends to have a larger, positive impact on women's wages, and so female labor force participation rates are more responsive to education than those of men. Evidence on the effect of non-labor income on female labor supply is more varied and inconclusive, and several studies suggest that exogenous income elasticities are near zero (cf. Killingsworth and Heckman, 1986, pp. 189-192). Women's labor force participation is elastic with regard to child-care subsidies, and fertility seems to have a negative impact on both labor force participation and wages in high-income countries, but to a lesser extent in low-income countries. A U-shaped relationship between economic development and female labor force participation is explained by male bias in access to education and the presence of significant negative income effects in low-income countries, combined with the availability of white-collar jobs in the services sector coupled with fertility decline and equal access to education in high-income countries (cf. Goldin, 1995).

Although there are several studies on female labor supply in low-income countries it is still of interest to analyze the Eritrean case. This is motivated by the large variation in results from studies of female labor supply, which indicates that there are substantial country- and culture-specific differences in determinants that need to be investigated in order to formulate appropriate policies (cf. Clark and York, 1999).

An additional motivating factor for this study stems from the demographic composition of the urban population, where less than half of all adult women are married (Table 2.1). Thus, existing evidence on female labor supply—which is mainly focused on married women—is of less relevance in the Eritrean case. The literature on the relationship between labor force participation and marital status shows that the relationship may go in both directions: According to Becker (1985), increased relative earnings of women should diminish the returns to specialization within the household and thus reduce the incentives to remain married. However, Johnson and Skinner (1986) find the opposite causality—that higher divorce probability leads to higher labor force participation. Johnson and Skinner (1988) and World Bank (1980) find that marital status is a main determinant of female economic activity. An explanation for this may be "supply-side discrimination"—that married women have less autonomy than divorced or widowed women, and that husbands deny wives to enter the labor market in fear of losing bargaining power within the household (Braunstein, 2000, see also Boserup, 1995). To account for the impact of marital status on economic activity, the estimation of supply-side factors in section 5 is done separately for women according to their marital status.

The demographic composition of the population and the resulting high number of female-headed households in urban Eritrea (Table 2.2) adds another policy relevant dimension to the study of women's economic activity, namely poverty reduction. In many countries female-headed households are often—though not always—at great risk economically (Buvinic and Gupta, 1997, Folbre, 1995, Kennedy and Peters, 1992, Rogers, 1995). Arneberg (1999a) shows that in Eritrea, divorced and widowed women with young children have a high risk of being poor, and that divorced women are largely depending on their own labor for income provision, whereas widows depend on assistance from relatives and other households (see also Table 2.2).

Table 2.2. Summary characteristics of urban households. By sex and marital status of main income provider* (source: EHIES 1996/97)

		All house-holds	Male main provider	Female main provider				
				Total	Married**	Widowed	Divorced	Never married
Number of households (1000)		115	65	50	16	13	13	8
Per cent of all households		100	56	44	14	12	11	7
Number of employed household members. Per cent	0	31	17	48	59	59	33	33
	1	47	55	37	26	25	54	52
	2 or more	22	27	14	14	16	13	15
	Total	100	100	100	100	100	100	100
Main income source Per cent	Wage employment	44	56	28	21	21	37	41
	Self-employment	17	19	16	13	16	21	14
	Other	39	25	56	66	63	42	45
	Total	100	100	100	100	100	100	100
Mean annual household income (nominal US$)		1675	2022	1225	1361	1109	930	1573
Dependency ratio***		0.84	0.83	0.86	1.19	0.79	0.74	0.47

* Main income provider is the household head (by own definition) if the household head is employed or if there are no other employed persons in the household. If the self-defined household head is not employed and another household member is employed, then this latter person is selected as main income provider. 48 per cent of the households are female-headed (own definition), whereas 44 per cent have female main income provider.

** Widows, divorcees and single women are considered *de jure* head of household, and the married female family providers *de facto* household heads, as the husband is commonly away on labor migration (for more than 3 months) and may be the main income source for the household although he is not present in the household and as such not a household member.

*** Number of children below 15 and elderly above 65 as a share of number of working age people (15-65 years of age).

Although analysis of labor *supply* is relevant for forming policy measures, it is also important to consider disequilibrium effects that may lead to rationing. Despite efforts by the government to promote more gender equality, women are disadvantaged in the Eritrean society (World Bank, 1994, Bakhuisen, 1998). According to Table 2.1 the majority (55 per cent) of the female labor force is outside the formal wage sector as unemployed or self-employed, compared to 44 per cent for men. The high female self-employment rate is typical for developing countries (Standing, 1999). Among the wage employees, the male wage rate is 60 per cent above the female rate. The poor status of women in the labor market is partly due to their low levels of education. A high 40 per cent of urban women are illiterate compared to a rate of 13 per cent for men. However, there is also gender discrimination in the labor market. Arneberg (1999b) found that female wage employees earn 37 per cent less than males when education and experience is controlled for. Therefore, the weak position of women in the

Eritrean labor market makes it urgent to identify policy measures by which women's job opportunities may be expanded and their wages increased.

2.2 Data applied in the empirical analysis

The data are based on the 1996/97 urban Eritrean Household Income and Expenditure Survey (EHIES) of 5,000 households representing the total population of half a million people in the 12 major towns in Eritrea. It is the first survey in Eritrea ever to collect economic data from households. As there was no usable sample frame in Eritrea at the time of the survey, all towns were mapped and the sample was drawn as a one stage stratified sample. Sample inclusion probabilities differ from relatively low probabilities for households from the densely populated Highland area (which was under-sampled), to higher probabilities for households in the Lowland areas. Sample weights are therefore applied in all descriptive tables (unless indicated otherwise), and in the policy simulations presented in Section 6.

The field work was conducted in four rounds covering one calendar year in order to capture seasonal variation, and all selected households were kept in the sample in all rounds. The response rate is 96 per cent. To avoid problems associated with serial dependence in the data we have only used the subsample obtained from one round to estimate the model.

Much of the information in the survey is collected by the use of retrospective questions. For labor force questions the reference period was the week preceding the interview. The definition of employment is based on the one-hour criterion of economic activity during the reference week, following the guidelines of ILO (ILO, 1990). The questionnaire is designed so as to be able to capture activity in the self-employment sector, in particular among women. Data on working hours and wages are collected both in "usual" and "actual" terms. The present analysis is based on data on "actual" monthly wage and "actual" weekly hours of work during the week prior to the interview.

Women below 20 years of age were excluded from the sample to avoid the problem of interaction between labor supply and education demand. Also, women above 60 years of age were excluded. We originally had 4423 observations of women 20-60 years of age in the sample, of which 8 were removed due to numerical problems. Table 2.3 reports summary statistics of the explanatory variables for the sample used in the estimation.

Table 2.3. Summary statistics of the sample. Women 20-60 years of age

.	Mean unweighted	Std Dev	Minimum	Maximum	Weighted mean*
Age (years)	35.42	11.5	20.00	60.00	36.04
Number of children under 5	0.55	0.8	0.00	4.00	0.51
Education (years)	2.96	4.0	0.00	16.00	3.65
Experience (number of years since school)	25.46	13.6	0.00	53.00	25.400
Experience square	837.52	776.7	0.00	2809.00	849.38
Regional unemployment rate (per cent)	18.70	3.5	12.68	22.58	19.86
Log annual non labor income (Nakfa)	7.03	2.7	1.28	12.81	7.49
Annual non-labor income (Nakfa)	5470.26	11034.4	3.60	367453.84	7488.40
Log wage rate (Nakfa)	0.26	0.9	-1.95	3.80	0.34
Wage rate (Nakfa)	1.91	2.5	0.14	44.67	2.05
Moslem dummy	0.35		0	1	0.23
Liberation army fighter dummy	0.06		0	1	0.06
No education dummy	0.55		0	1	0.49
Incomplete basic education dummy (1-6 years)	0.24		0	1	0.24
Complete basic education dummy (7 years)	0.14		0	1	0.17
Secondary education dummy (13-16 years)	0.06		0	1	0.08
Post secondary education dummy	0.01				0.02
Husband present dummy	0.42		0	1	0.41
Married dummy	0.60		0	1	0.58
Widowed dummy	0.12		0	1	0.12
Divorced dummy	0.15		0	1	0.13
Never married dummy	0.14		0	1	0.17
Fraction unemployed	0.08		0	1	0.09
Fraction not in the labor force	0.61		0	1	0.60
Fraction employed, wage sector	0.15		0	1	0.18
Fraction employed, self-employment	0.16		0	1	0.14
Number of observations	4415				

* Sample inclusion probabilities are adjusted for non-response.

3. Theoretical framework

In this section we present the essential elements of the theoretical framework which underlies the empirical model to be specified and estimated later.

We consider labor market behavior with respect to three sectors, namely "wage work" (Sector 1) and "self-employment" (Sector 2). For expository simplicity we denote "non-employment" as Sector 3. Consider an arbitrary agent. She/he has the choice between a number of feasible jobs in Sector 1 (this number may for some agents be very small) and a self-employment activity in Sector 2. Let M denote the set of job opportunities in Sector 1 that are feasible to the agent. Specifically, $j \in M$ index the job opportunities.

Let $U^*(C, \mathbf{h}_1, h_2)$ denote the utility of consumption C and a vector $\mathbf{h}_1 = (h_{11}, h_{12}, ..., h_{1M})$, of hours of work associated with the available jobs in Sector 1 and hours of work h_2 in Sector 2. Let $F(h_2)$ denote the conditional profit function associated with self-employment activity, given input of hours of work equal to h_2. Let W_j be the wage rate associated with job $j \in M$. Let J denote the chosen job, and let $\tilde{h}_1$ and $\tilde{h}_2$ denote the chosen hours of work in Sector 1 and 2, respectively.

Assumption 1

The utility function $U^*(C, \boldsymbol{h}_1, h_2)$ *has the structure*

$$U^*(C, \boldsymbol{h}_1, h_2) = U\left(C, \sum_{j \in M} \frac{h_{1j}}{b_{1j}} + h_2\right)$$

where U(C,h) is a function that is quasi-concave, differentiable, increasing in C and decreasing in h and $b_{1j} > 0$, $j \in M$, *are random variables that account for unobservable non-pecuniary aspects of the jobs.*

Assumption 1 means that a decrease in utility as a result of an unattractive job attribute can be perfectly compensated through a decreased workload.

Assumption 2

The function $F(h_2)$ *is differentiable, strictly increasing and concave for* $h_2 \in (0, T)$, *where T is total hours available for work.*

Assumption 2 means that profit maximum will not be attained within the interval of feasible hours. This assumption is made for convenience and could easily be relaxed. Specifically, in the empirical application below data turns out to be consistent with a linear specification of F.

Consider now the agent's optimization problem. His problem is to maximize

$$U\left(C, \sum_{j\in M} \frac{h_{1j}}{b_{1j}} + h_2\right)$$

with respect to C, $\{h_{1j}\}$, h_2, $h_{1j} \geq 0$, $h_2 \geq 0$,

(3.1)
$$C = \sum_{j\in M} h_{1j} W_j + F(h_2) + y$$

and

(3.2)
$$\sum_{j\in M} h_{1j} + h_2 \leq T,$$

where y is non-labor income. With $x_{1j} = h_{1j}/b_{1j}$, we realize that the above optimization problem is equivalent to maximizing

$$U\left(C, \sum_{j\in M} x_{1j} + h_2\right)$$

subject $x_{1j} \geq 0$, $h_2 \geq 0$,

(3.3)
$$C = \sum_{j\in M} x_{1j} W_j b_{1j} + F(h_2) + y$$

and

(3.4)
$$\sum_{j\in M} b_{1j} x_{1j} + h_2 \leq T.$$

Note that $\{x_{1j}, j \in M\}$ enter symmetrically in the utility function. Hence, the optimizing agent will, in the case she prefers an interior solution in Sector 1, choose to allocate working hours solely in one job, namely in the job that maximizes $W_j b_{1j}, j \in M$. Thus, the chosen job J is determined as

(3.5)
$$J = \operatorname{Arg}\max_{j\in M} \left(W_j b_{1j}\right).$$

Let

(3.6)
$$\tilde{W} = \max_{j\in M} \left(W_j b_{1j}\right).$$

We now realize that the chosen hours of work in the sectors are determined by $\tilde{h}_1 = \tilde{x}_1 b_{1J}$ and $\tilde{h}_2$, where $\tilde{x}_1$ and $\tilde{h}_2$ are found by maximizing $U(C, x_1 + h_2)$ subject to $x_1 \geq 0$, $h_2 \geq 0$,

(3.7) $$C = x_1 \tilde{W} + F(h_2) + y$$

and

(3.8) $$x_1 b_{1J} + h_2 \leq T.$$

We can interpret $\tilde{x}_1$ as the adjusted workload in Sector 1. That is, $\tilde{x}_1$ is the workload that corresponds to the case where all jobs in M have equal non-pecuniary attributes. The corresponding modified wage rates are $W_j b_{1j}$ for $j \in M$. Therefore, the chosen job has modified wage rate $\tilde{W}$.

The reservation wage that corresponds to the optimization problem above is defined by[3]

(3.9) $$W_R := -\frac{U_2(y,0)}{U_1(y,0)}$$

where $U_1(\cdot)$ and $U_2(\cdot)$ denote the respective partial derivative of $U(\cdot)$.

From the assumptions above we can derive the following result by straight forward analysis.

Proposition 1

Assume that Assumptions 1 and 2 hold. Then the agent will not work if

(3.10) $$W_R > max\left(F'(0), \tilde{W}\right).$$

If

(3.11) $$F'(0) > \tilde{W} > max\left(F'(T), W_R\right)$$

the agent will work in both sectors. If

(3.12) $$\tilde{W} > max\left(W_R, F'(0)\right)$$

the agent will work solely in Sector 1. Finally, if

[3] Recall that the notation, :=, in an equation means that the left hand side is defined by the relation.

(3.13) $$F'(0) > W_R > \tilde{W} \;\; or \;\; F'(T) > \tilde{W} > W_R$$

the agent will work solely in Sector 2.

The first inequality, (3.10), says that the reservation wage is greater than the modified wage rate $\tilde{W}$ and the marginal profit at zero hours in Sector 2. In this case it is evidently desirable not to work. Suppose next that (3.11) holds. Then it is desirable to work in both sectors since both the modified wage rate and the marginal profit evaluated at zero hours are greater than the reservation wage. Moreover, the modified wage rate is greater than the profit at the maximum hours of work T, which ensures that it is not desirable to spend all available time working in Sector 2. The allocation of hours in Sector 2 is determined by $\tilde{W} = F'(\tilde{h}_2)$. If (3.12) holds the modified wage rate is greater than both the reservation wage and the marginal profit at zero hours which yields that it is desirable to work only in Sector 1. Consider next the case

$$F'(0) > W_R > \tilde{W},$$

which states that the marginal profit at zero hours is greater than the reservation wage. Then it is desirable to work in Sector 2. It is not desirable to work in Sector 1 since the reservation wage is greater than the modified wage rate. Finally, consider the case

$$F'(T) > \tilde{W} > W_R$$

which means that the marginal profit at maximum hours is greater than the modified wage rate and the modified wage rate is greater than the reservation wage. But since also the marginal profit at maximum hours is greater than the modified wage rate it is desirable to spend all work effort in Sector 2.

With suitable specification of the utility function $U(\cdot)$ one can obtain expressions for $\tilde{h}_1$ and $\tilde{h}_2$ that are tractable for empirical analysis. However, since we only deal with the sector participation decisions in the empirical analysis below, we shall not pursue this matter further here.

From the decision rule above it follows immediately that $\tilde{h}_1 > 0$ when

(3.14) $$\tilde{W} > \max\left(W_R, F'(T)\right).$$

Similarly, $\tilde{h}_2 > 0$ when

(3.15) $$F'(0) > \max\left(\tilde{W}, W_R\right).$$

Recall that it is implicit in the formalism above that the set of feasible jobs and activities are accounted for since $\tilde{W}$ depends on M.

4. The empirical model

A serious difficulty facing the researcher when he wishes to apply the framework above is that the structure of the preferences and many important variables are unobservable to her/him. In this section we shall discuss assumptions about the distribution of unobservables which will, subsequently, enable us to derive the empirical model. In the following X_1, X_2 and X_3 will denote exogenous variables that affect the wage rates, the conditional profit function and the reservation wage, respectively.

Assumption 3

The wage rate satisfies the equation

(4.1) $$\log W_j = \alpha_{10} + X_1\alpha_1 + \varepsilon^*_{1j}$$

where X_1 is a vector of variables that capture the agent's level of education and labor market experience and $\left(\alpha_{10}, \alpha_1\right)$ is a vector of coefficients.

The conditional profit function F has the structure

(4.2) $$\log F\left(h_2\right) = \log g\left(h_2\right) + X_2\alpha_2 + \varepsilon_2$$

where X_2 is a vector of variables that affect the returns to self-employment activity, α_2 is a vector of coefficients and $g\left(h_2\right)$ is a deterministic function that is strictly increasing, differentiable and concave.

Furthermore, the taste shifters $\left\{b_{1j}, j \in M\right\}$ are random variables that have distribution that does not depend on X_1, X_2, X_3. Similarly, $\left\{\varepsilon^*_{1j}, j \in M\right\}$ and ε_2 are random variables with joint distribution that does not depend on X_1, X_2, X_3.

The wage equation postulated in Assumption 3 serves two purposes. First it provides an instrumental relation that can be applied to account for the possible endogeneity problem in the labor supply relation that follows from Assumption 1. Second, the wage equation also serves to "solve" the missing variable problem that is due to the fact that only the wage rate of the *chosen* job is observed. The motivation for eq. (4.2) is analogous.

Assumption 4

The reservation wage (defined in (3.9)) has the structure

$$\log W_R = \gamma_0 + X_3\gamma + \varepsilon_3 \tag{4.3}$$

where X_3 is a vector of variables that affect the agent's reservation wage (including non-labor income) while ε_3 is a random term with distribution that does not depend on X_1, X_2, X_3,. and (γ_0, γ) is a vector of coefficients.

From (4.1) and (4.2) it follows that

$$\log\left(W_j b_{1j}\right) = \alpha_{10} + d_1 + X_1\alpha_1 + \varepsilon_{1j} \tag{4.4}$$

and

$$\log F'\left(h_2\right) = \log g'\left(h_2\right) + X_2\alpha_2 + \varepsilon_2 \tag{4.5}$$

where d_1 is the mean of $\log b_{1j}, j \in M$, and $\left\{\varepsilon_{1j}, j \in M\right\}$ are random variables defined by

$$\varepsilon_{1j} := \log b_{1j} - d_1 + \varepsilon_{1j}^{*}. \tag{4.6}$$

It now only remains to specify the distribution of the random terms $\left\{\varepsilon_{1j}, j \in M\right\}$, ε_2 and ε_3, in order to obtain a model for the choice of sector.

Assumption 5

The distribution of preferences is such that the probability of choosing a job or self-employment satisfy the "Independence from Irrelevant Alternatives", property (IIA).

Assumption 5 means the following: Consider the agent's choice from a subset of mutually exclusive jobs and the self-employment alternative. Without loss of generality one can view the choice process as taking place in two stages. In the first stage a subset of the most attractive alternatives is selected, while in the second stage the most preferred alternative is selected from this subset. The crucial content of the IIA assumption is that *only* the subset selected in the first stage matters for the choice in the second stage, i.e., the alternatives discarded in the first stage are "irrelevant". For a discussion on the interpretation and limitation of IIA we refer to Domencich and McFadden (1975).

From Assumption 5 and the additive structure (4.1) and (4.2) one can derive the structure of the distribution of the preferences. It follows from the proof of Theorem 1 below that IIA implies that the random error terms $\left\{\varepsilon_{1j}, j \in M, \varepsilon_2, \varepsilon_3\right\}$ can with no loss of generality, be chosen to be i.i.d. with extreme value c.d.f. $\exp\left(-\exp\left(-x/\theta\right)\right)$, where $\theta > 0$ is a scale parameter that has the interpretation

(4.7)
$$\operatorname{Var}\varepsilon_{1j} = \operatorname{Var}\varepsilon_{2k} = \operatorname{Var}\varepsilon_3 = \frac{\pi^2}{6\theta^2}.$$

Theorem 1

Let m be the number of jobs in M. Assumptions 1 to 5 imply that

(4.8)
$$P\left(\tilde{h}_1 = \tilde{h}_2 = 0\right) := P\left(W_R > max\left(F'(0), \tilde{W}\right)\right) = \frac{e^{v_3}}{m e^{v_1} + e^{v_2} + e^{v_3}},$$

(4.9)
$$P\left(\tilde{h}_1 > 0\right) := P\left(\tilde{W} > max\left(W_R, F'(T)\right)\right) = \frac{m e^{v_1}}{m e^{v_1} + e^{v_2+\kappa} + e^{v_3}},$$

(4.10)
$$P\left(\tilde{h}_2 > 0\right) := P\left(F'(0) > max\left(\tilde{W}, W_R\right)\right) = \frac{e^{v_2}}{m e^{v_1} + e^{v_2} + e^{v_3}},$$

(4.11)
$$P\left(\tilde{h}_1 > 0, \tilde{h}_2 > 0\right) := P\left(F'(0) > \tilde{W} > max\left(F'(T), W_R\right)\right)$$
$$= \frac{e^{v_2}}{m e^{v_1} + e^{v_2} + e^{v_3}} \cdot \frac{m e^{v_1}\left(1 - e^{\kappa}\right)}{m e^{v_1} + e^{v_2+\kappa} + e^{v_3}},$$

(4.12)
$$P\left(\tilde{h}_1 > 0, \tilde{h}_2 = 0\right) := P\left(\tilde{W} > max\left(W_R, F'(0)\right)\right) = \frac{m e^{v_1}}{m e^{v_1} + e^{v_2} + e^{v_3}},$$

and

(4.13)
$$P\left(\tilde{h}_1=0,\tilde{h}_2>0\right):=P\left(\left(F'(0)>W_R>\tilde{W}\right)\cup\left(F'\left(T\right)>\tilde{W}>W_R\right)\right)$$
$$=\frac{e^{v_2}}{me^{v_1}+e^{v_2}+e^{v_3}}\cdot\frac{e^{v_3}}{me^{v_1}+e^{v_3}}+\frac{e^{v_2+\kappa}}{me^{v_1}+e^{v_2+\kappa}+e^{v_3}}\cdot\frac{me^{v_1}}{me^{v_1}+e^{v_3}},$$

where $v_1:=\theta\left(\alpha_{10}+d_1-\gamma_0\right)+X_1\alpha_1\theta$, $v_2:=\theta\left(\log g'\left(0\right)-\gamma_0\right)+X_2\alpha_2\theta$, $v_3:=X_3\gamma\theta$, $\kappa:=\theta\log g'\left(T\right)-\theta\log g'\left(0\right)$ *and* $\theta>0$ *is a constant.*

The proof of Theorem 1 is given in Appendix A.

In the special case where g(x) is linear we get that the conditional marginal profit function does not depend on hours. In this case we expect that the agent will work at most in one sector. From (4.11) in Theorem 1 we realize that this is indeed the case because when $g\left(h_2\right)$ is linear it follows that $\kappa=0$ which yields that the probability of working jointly in both sectors is zero.

There are several interesting features of the model represented in Theorem 1 which distinguishes it from the traditional approach. First, this model allows for the notion that a worker's choice set may consist of jobs, which differ with respect to wage rates as well as unobservable non-pecuniary attributes, over which the worker has preferences. Second, it enables us to represent the choice opportunities the worker faces in Sector 1 through an aggregate index m, which can be interpreted as the number of market opportunities in Sector 1 that are available to the agent. Third, it departs from the standard discrete choice setting in that alternatives are not necessarily mutually exclusive.

Although m is not directly observable they can be specified as functions of variables that affect the opportunity sets such as in Assumption 6 below.

Assumption 6

The number of opportunities in M has the structure

(4.14)
$$\log m=\delta_0+X_4\delta$$

where $\left(\delta_0,\delta\right)$ *is a vector of parameters and* X_4 *is a vector of variables that affect the set of choice opportunities.*

Due to qualification requirements and sticky wages there may be excess supply to Sector 1. For example, lack of suitable skills may prevent a worker from being hired since the worker must be found acceptable to the employer before he will be hired. Thus, it is of substantial interest to separate households' preferences for work in Sector 1, conditional on the respective wage rates, from the preferences of the employers.

When (4.14) is inserted into (4.7), (4.9), (4.11) and (4.12) we obtain

$$(4.15)\qquad P_{00} := P\left(\tilde{h}_1 = \tilde{h}_2 = 0\right) = \frac{1}{1 + e^{Z_1\beta_1} + e^{Z_2\beta_2}},$$

$$(4.16)\qquad P\left(\tilde{h}_2 > 0\right) = \frac{e^{Z_2\beta_2}}{1 + e^{Z_1\beta_1} + e^{Z_2\beta_2}}$$

and

$$(4.17)\qquad P_{10} := P\left(\tilde{h}_1 > 0, \tilde{h}_2 = 0\right) = \frac{e^{Z_1\beta_1}}{1 + e^{Z_1\beta_1} + e^{Z_2\beta_2}},$$

$$(4.18)\qquad P_{01} := P\left(\tilde{h}_1 = 0, \tilde{h}_2 > 0\right) = \frac{e^{Z_2\beta_2}}{1 + e^{Z_1\beta_1} + e^{Z_2\beta_2}} \cdot \frac{1}{1 + e^{Z_1\beta_1}} + \frac{e^{Z_2\beta_2 + \kappa}}{1 + e^{Z_1\beta_1} + e^{Z_2\beta_2 + \kappa}} \cdot \frac{e^{Z_1\beta_1}}{1 + e^{Z_1\beta_1}}$$

where

$$(4.19)\qquad Z_1\beta_1 := \theta\tilde{\alpha}_{10} + \delta_0 + X_4\delta + X_1\alpha_1\theta - X_3\gamma\theta$$

and

$$(4.20)\qquad Z_2\beta_2 := \theta\tilde{\alpha}_{20} + X_2\alpha_2\theta - X_3\gamma\theta,$$

where $\tilde{\alpha}_{10} := \alpha_{10} + d_1 - \gamma_0$ and $\tilde{\alpha}_{20} := \log g'(0) - \gamma_0$.

Without further information it is not possible to identify the parameters δ_0 and δ in (4.14). Fortunately, we have such information because the available data set contains information about whether or not each agent is rationed in Sector 1. The question asked in the survey to those who do not work is whether they wish to work if they were offered to work in Sector 1. This information can be used to identify and estimate the parameters in (4.14).

Let M^* denote the opportunity set of jobs when no rationing is present and let m^* be the number of opportunities in M^*. The set M^* is a benchmark which we interpret as the total set of different types of jobs in the economy. Only a small number of jobs within M^* will, however, be of interest to a particular woman because she will in practice be offered low and unacceptable wages in most jobs since her skills may be relevant to only a small number of jobs.

Let

(4.21) $$Z_1\beta_1^* := \theta\tilde{\alpha}_{10}^* + X_1\alpha_1\theta - X_3\gamma\theta,$$

where $\tilde{\alpha}_{10}^* := \tilde{\alpha}_{10} + \theta^{-1}\log m^*$. The corresponding choice probabilities in this case with no rationing are found by replacing $Z_1\beta$ by $Z_1\beta^*$ in (4.15) to (4.18). In Appendix B we derive the full information maximum likelihood function including the case when data on individual rationing is available.

Next we shall consider the estimation of the wage equation (4.1). Since we only observe the wage rate for those who work we must take into account possible selection bias that stems from the fact that the random term in the wage equation may be correlated with the decision to work in Sector 1. To this end we need the following result.

Lemma 1

Assume that Assumptions 3 to 5 hold. Then

(4.22) $$E\left(\theta\varepsilon_{1J} \,\middle|\, \tilde{h}_1 > 0\right) = -\log P\left(\tilde{h}_1 > 0\right).$$

The proof of Lemma 1 is given in Appendix A.

Let

$$E\left(\varepsilon_{1j}^* \middle| \varepsilon_{1j}\right) \cong \rho_1\theta\varepsilon_{1j}$$

be a first order Taylor approximation of $E\left(\varepsilon_{1j}^* \middle| \varepsilon_{1j}\right)$. Then it follows readily that $\theta\rho_1$ has the interpretation

$$\theta\rho_1 = \frac{\operatorname{Cov}\left(\varepsilon_{1j}^*, \varepsilon_{1j}\right)}{\operatorname{Var}\varepsilon_{1j}}.$$

Hence, by Lemma 1

(4.23) $$E\left(\varepsilon_{1J}^* \,\middle|\, \tilde{h}_1 > 0\right) \cong \rho_1 E\left(\theta\varepsilon_{1J} \,\middle|\, \tilde{h}_1 > 0\right) = -\rho_1 \log P\left(\tilde{h}_1 > 0\right).$$

From (4.23) it follows that

(4.24) $$\log W_J = \alpha_{10} + X_1\alpha_1 - \rho_1 \log P\left(\tilde{h}_1 > 0\right) + \eta_J$$

where η_J is a random variable that has the property that

$$E\left(\eta_J \,\middle|\, \tilde{h}_1 > 0\right) = 0.$$

Thus, if $P\left(\tilde{h}_1 > 0\right)$ were known one could estimate (4.24) consistently by OLS with X_1 and $\log P\left(\tilde{h}_1 > 0\right)$ as independent variables. Thus, one can apply Heckman's two stage estimation procedure (cf. Heckman, 1979) which in this case consists of estimating $P\left(\tilde{h}_1 > 0\right)$ in a first stage and estimating (4.24) in a second stage with the estimated value of $\log P\left(\tilde{h}_1 > 0\right)$ as an additional explanatory variable to control for selectivity bias.

From the discussion above it is straight forward to verify that once $\left(\alpha_{10}, \alpha_1\right)$ and $\left(\alpha_{20}, \alpha_2\right)$, β_1, β_2 and κ have been estimated it is possible to recover θ and δ. Even if the marginal conditional profit is not observed we realize that we can recover θ and α_2 from the estimated choice probabilities and the wage equation. As a consequence, it is possible to compute elastisities for the choice probabilities (4.8) to (4.13) with respect to the wage rate and the marginal profit at zero hours of input. Furthermore, when δ has been estimated we are able to compute how changes in the unemployment rate or the level of education, ceteris paribus, affect the choice probabilities through the opportunity index m.

5. Estimation results

In this section we present the parameter estimates for the wage equation and for the choice probabilities obtained by the maximum likelihood procedure, as outlined in Appendix B.

In our subsample there are very few that work in both Sector 1 and Sector 2 (two women). Since there are so few in the sample that works in both sectors, we conclude that the probability that a woman shall work in both sectors is approximately equal to zero, which by (4.11) implies that the estimate of κ can be set equal to zero. The resulting choice probabilities and likelihood function are in this case given in Appendix B.

To obtain estimates for the marginal effect of education on wages[4] for the women in the sample, the wage equation given in (4.24) was estimated. Recall that the dependent variable is the logarithm of the *observed* wage rate. The wage is assumed to be a function of the level of education, work experience, local unemployment rate and experience as a guerrilla soldier during the liberation war (fighter status).

Two different specifications of the wage equation are estimated. The first specification is the standard Mincer method (Mincer, 1974) where education is represented by years of schooling. The second specification is the "extended model" (Psacharopoulos, 1994) where schooling is represented by the *level* of educational attainment. In both specifications, a selection term is included to adjust for non-observable wages for those who do not work. Experience is defined as "potential work experience" which is the number of years since the individual left school. To account for possible declining marginal returns to experience, the logarithm of the wage rate is allowed to depend linearly on experience and squared experience.

Table 5.1. Estimates of two specifications of the wage equation. Female wage employees 20-60 years of age

	Model 1 (standard Mincer)		Model 2 (extended)	
	Coefficient	t-value	Coefficient	t-value
Constant	-1.019	-4.7	-0.899	-4.3
Education years	0.112	12.4		
Incomplete basic education (1-6 years)			0.145	1.8
Completed basic education (7 years)			0.658	6.5
Completed secondary education (12 years)			1.290	10.9
Post-secondary education (13-16 years)			1.809	12.1
Experience · 10^{-1}	0.454	4.8	0.478	5.0
Experience squared · 10^{-2}	-0.050	-2.8	-0.065	-3.5
Regional unemployment rate	-0.398	-0.5	-1.219	-1.5
Liberation army fighter	0.722	7.9	0.905	9.4
Selection term	-0.040	-0.8	-0.153	-2.9
Number of observations	626		626	
R^2	0.32		0.34	

[4] As pointed out by Psacharopoulos (1994), it is better to use the term "marginal wage effects" than the commonly used term "private returns to education" as the latter necessitates taking into account the private cost of education (foregone labor income plus schooling expenses paid by the student). Chiswick (1997) discusses the unrealistic assumptions that are required in order to even interpret the coefficient as marginal effect on wage from schooling.

Table 5.1 displays the estimation results of the two specifications of the wage equation. All coefficients have the expected signs and most of them are highly statistically significant. Our results seem to be consistent with the results from other studies that find that wages in urban areas in Africa are depressed by higher levels of unemployment (see for example Hoddinott, 1996) although the coefficient associated with regional unemployment is hardly significant. We also find as expected that the marginal returns to experience are positive but declining, and that experience from the liberation army has a large positive impact on wages. The model is robust in the sense that the estimated coefficients associated with variables other than education are not affected much by changes in model specification. The only exception is the selection term, which is small and imprecisely estimated in the first model, but significantly negative in the second model.

The coefficient associated with “Education years” in Model 1 (the Mincer regression coefficient) shows that one additional year of education increases the wage by 11 per cent on average. This result is consistent with cross-country evidence where effects in low-income countries generally are found to be higher (10-13 per cent) than in middle- and high-income countries (4-8 per cent), and where effects are higher for women than for men in countries where women have less access to education than men (see Psacharopoulos, 1994, Bennell, 1996, Bils and Klenow, 2000, and Harmon et al., 2001, for an overview of comparative results). Compared to more recent evidence from Africa, our estimate is lower than the one estimated by Siphambe (2000) for Botswana (18 per cent in 1994/95) but higher than the ones estimated for Ghana by Glewwe (1996), (6 per cent for the government sector and insignificant for the private sector, men and women pooled) and the one estimated for Libya by Arabsheibani and Manfor (2001), (7 per cent, men and women pooled).

The specification applied in Model 1 yields the same effect on wage rates from, say, an increase of one year in primary school as an increase of one year at the university. This restriction may be unrealistic. Further, the policy relevance of the Mincer coefficients is not too evident since the education system is built on supplying blocks of education rather than years, and since individuals make decisions to enroll to a schooling cycle rather than to a single grade.

The estimated coefficients from the extended model show that basic school drop-outs on average get a 15 per cent wage premium compared to women who have not attended school at all (the reference group). The premium of completing basic schooling (grade 7) instead of dropping out is 67 per cent, or 93 per cent compared to not attending school at all. The wage effect of leaving school after grade 12 with a completed secondary education is 263 per cent compared to not having any schooling—or 88 per cent more than for those leaving school after completing basic school. Post-secondary education gives a wage premium at 510 per cent compared to no schooling and 68 per cent more than for those quitting school after completing secondary level[5].

A comparison of the results from the two different specifications shows that the log-linearity assumption underlying the simple Mincer method in Model 1 seems to slightly overestimate the effects of secondary education. The Mincer specification implies a wage effect of completed basic education of 119 per cent and of completed secondary education of 283 per cent. The corresponding effect of post-secondary schooling (16 years) is 500 per cent. When taking the standard errors of the coefficients into account we therefore conclude that the Models 1 and 2 yield approximately the same predictions. We have, however, chosen to rely on the extended model due to the fact that this model, as mentioned above, corresponds more closely to the schooling choices. In the estimation of choice probabilities we therefore use the extended model.

In principle, one could also apply data on the marginal returns to self-employment to estimate α_2 similarly to the estimation of the wage equation. However, the data on self-employment income are questionable so we obtained the estimates of α_2 indirectly through the estimates from the choice probabilities. As concerns the marginal profit equation for Sector 2 we cannot identify the constant term α_{20} without additional data. If we compare the results from the estimation of α_2 in Table 5.2 with the estimated wage equation we realize that the income effect of education is much higher in the wage sector than in the self-employment sector. For example, the marginal returns to self-employment of increasing level of schooling from completed basic- to completed secondary schooling is 22 per cent, compared to 88 per cent for the wage sector. (That we did not succeed in establishing a significant effect of post-secondary education on self-employment profits is most likely due to the very few observations of women with post-secondary education who engage in self-employment activities.)

Having established the positive effect of education on wages and profits, we now turn to look at the effect on choices and opportunities regarding employment. In Table 5.2 we report maximum likelihood estimates of the parameters of the choice probabilities[6]. The parameter estimates have the expected signs and most of them are determined very precisely. In Table 5.3 we report how well the model reproduces the aggregate fractions. The table shows that the model predicts the aggregate fractions rather well.

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[5] Persons with post-secondary education is a very heterogeneous group, where the length of education varies from 1-year diploma to a full Ph.D. As very few women in Eritrea have tertiary education, the few observations available makes it impossible to do a more detailed analysis of this group.

[6] The model was estimated both with and without a selection effect, but we report only the latter in Table 5.2. We found that when selection is not accounted for we underestimated the coefficient associated with the wage rate (q) for married women, while there appeared to be no selection effect for the other groups. As regards the remaining parameters the estimates suggested that the selection effect is negligible.

The estimation of the parameters of the choice model associated with the choice of sector was done separately for groups of women according to their marital status. The motivation for this is the assumption that marital status is a proxy for autonomy, which affects a woman's decision regarding whether to work or not. We a priori believe that divorced women have a high degree of autonomy since they commonly do not continue any relationship with their former in-laws. On the other extreme we expect to find married women, as they will usually not be able to take a job without acceptance from the husband. For married women we also include a dummy indicating whether the husband lives in the household or is away on labor migration, as we believe that an absentee husband increases the woman's autonomy. Widowed women commonly continue to have a close relationship with the deceased husband's family, and their degree of autonomy is a priori believed to be somewhere in between married and divorced women. Single women is a more heterogeneous group, and their autonomy most likely depends on whether they live alone or together with other family members such as parents or brothers. Is it therefore difficult to have any a priori opinion on the autonomy of the single women in our sample.

The estimated parameters associated with working in the wage sector in Table 5.2 show that "money matters" in getting women into the labor force. The parameter θ, which measures the impact of wages on the work decision, is significantly positive for all groups. As expected, married women's labor supply is much more responsive to wage than for the other groups, and the smallest response is found among the divorcees.

Since by (4.17) the parameter θ is inversely proportional to the standard error of the random terms in the utility function, the estimate of θ given in Table 5.2 imply that *unobserved* population heterogeneity in tastes is much less for married women than for the other groups. This is also reflected in the fact that as much as 49 per cent of the "variation" in the data is explained by the model (as measured by McFadden's ρ^2, cf. Ben-Akiva and Lerman, 1985) while the corresponding number is 28 per cent for widowed and only about 10 per cent for the two other groups.

Table 5.2. Parameter estimates of choice probabilities. Women 20-60 years of age

		All women		Married		Widowed		Divorced		Never married	
		coeff.	t-value	coeff.	t-value	coeff.	t-value	coeff.	t-value	coeff.	t-value
Parameters associated with Sector 1 $\left(\alpha_{10}^{*}, \theta\right)$	Constant			-1.779	-6.8	-1.402	-5.3	-1.259	-4.6	-0.851	-2.8
	Log wage rate θ			2.645	15.5	2.513	5.1	1.294	5.8	1.233	6.2
Parameters associated with Sector 2 $\left(\tilde{\alpha}_{20}, \alpha_{2}\right)$	Constant	-1.288	-5.4								
	Incomplete basic	0.030	0.5								
	Basic	0.115	1.3								
	Secondary	0.323	2.5								
	Post-secondary	0.199	0.7								
	Experience/10	0.223	2.0								
	$\frac{(\text{Experience})^2}{100}$	0.001	0.0								
Parameters associated with preferences (γ)	Age/10			-0.513	-3.4	-0.749	-4.3	-0.829	-4.4	-0.235	-1.1
	$(\text{Age})^2/100$			0.094	4.5	0.122	4.8	0.133	4.7	0.038	1.0
	# Children < 5 years			0.150	6.2	0.232	2.2	0.118	1.1	-0.133	-1.2
	Log non-labor income			0.029	4.2	0.075	4.1	0.096	3.9	0.050	2.4
	Husband present			0.266	6.3						
	Moslem			0.449	8.9	0.513	4.1	0.390	2.8	0.266	1.7
Parameters associated with choice constraints $\left(\delta_0 - \log m_1^{*}, \delta\right)$	Constant	-0.688	-3.0								
	Incomplete basic	0.008	0.1								
	Basic	-0.089	-0.8								
	Secondary	0.272	2.0								
	Post-secondary	0.513	4.0								
	Experience/10	0.226	2.1								
	$\frac{(\text{Experience})^2}{100}$	-0.020	-1.0								
	Regional unemployment	-0.173	-1.9								
	Fighter	-0.181	-1.5								
Number of observations		4415		2642		513		640		620	
Log likelihood		-3971.65		-1871.57		-515		-800.876		-784.2	
McFadden's ρ^2		0.35		0.49		0.28		0.10		0.09	

Table 5.3. Observed (*obs.*) versus predicted (*pred.*) fractions. Per cent of women 20-60 years of age

		All women		Married		Widowed		Divorced		Never married	
		obs.	pred.	obs.	pred.	obs.	pred.	obs.	pred.	obs.	pred.
Weighted	Unemployed	0.087	0.086	0.051	0.058	0.086	0.067	0.133	0.118	0.175	0.170
	Not in the labor force	0.600	0.588	0.735	0.722	0.558	0.545	0.298	0.319	0.401	0.372
	Wage employee	0.177	0.164	0.119	0.105	0.167	0.156	0.328	0.262	0.263	0.296
	Self-employed	0.136	0.161	0.095	0.115	0.189	0.232	0.242	0.301	0.161	0.161
Un-weighted	Unemployed	0.079	0.079	0.051	0.052	0.074	0.066	0.128	0.118	0.150	0.166
	Not in the labor force	0.610	0.612	0.753	0.752	0.538	0.542	0.309	0.319	0.374	0.377
	Wage employee	0.152	0.151	0.088	0.088	0.154	0.160	0.261	0.264	0.308	0.294
	Self-employed	0.159	0.158	0.108	0.108	0.234	0.232	0.302	0.299	0.168	0.163

Consistent with the discussion above, we assume that the logarithm of the reservation wage depends on age, age squared, number of children less than 5 years old, dummies for religion and the presence of husband, and the logarithm of non-labor income. Turning to the parameters associated with the reservation wage, (γ), we note that the demographic variables have the expected signs. Age shows a U-shaped relationship to the reservation wage. As may be expected, the impact on the reservation wage of small children is higher for widowed women than for married women. However, it is surprising that the effect is significant for divorced women who we would expect have less access to relatives who can look after the children than widows have. For married women, whether the husband lives in the household or is away on labor migration, matters a great deal for her preferences to stay out of the labor market. As expected, religion has a large impact on women's labor force participation.

Non-labor income has a positive effect on the reservation wage, and thus contributes to keeping women out of the labor force. The effect is 3 times as high for divorcees and widows compared to married women. This is consistent with Bertrand et a1., (1999), who report that whereas men's labor supply fell as a response to increased household non-labor income in South Africa, their wives' labor supply was unaffected. The offered explanation is that married women do not get access to this income because they lack bargaining power. This is consistent with our finding that labor supply response is related to autonomy (as measured by marital status).

The choice constraints—the job opportunities facing each individual—are not assumed to be related to marital status, as we do not believe that employers use marital status as a hiring criterion (nor did we include marital status as a determinant of wages or profits). The variables that affect the number of opportunities (m) are assumed to be level of education, local unemployment rate and fighter status.

Whether or not the woman has been a liberation army guerilla fighter seems not to affect her opportunities. The unemployment rate is not highly significant for the choice set of job opportunities. Recall, however, that since we only have cross sectional data we are unable to identify the impact of temporal variations in the unemployment rates.

The estimated effect on available job opportunities of having an incomplete basic education is slightly negative and the effect of completing basic school slightly positive, but neither is statistically significantly different from zero. However, the effect of secondary and higher education is strongly positive. Hence, the estimated parameters show that basic education does not contribute to an increase in the available job opportunities, and that women need to complete a senior secondary or higher education in order to expand the opportunity set available to them.

6. Selected policy simulation experiments

The properties of the estimated model are illustrated by a simulation experiment reported in Table 6.1. The upper part of the table reports the effect of a 10 per cent increase of the wage rate. We see that the female labor force participation rate increases from 41.2 to 43.6 per cent, as slightly more than 2 per cent of the women who were inactive now decides to enter the labor force, but 0.6 per cent end up as unemployed. The number of women working as wage employees increases by 2.3 per cent, of which 0.5 per cent has switched from self-employment.

In Table 6.1 we also report the corresponding wage elasticities. Recall that the supply consists of those who work in Sector 1 and those who would like to work (in Sector 1) but cannot find work. The elasticities are aggregate ones in the sense that they measure the percentage effect on the respective aggregates (for example the number of women employed in the wage sector) of percentage changes in wage rates. We see that the wage elasticity for married women is 1.92, which is at the high end of the comparative results reported in Mincer (1985) ranging from 0.5 to 2 with a mean at 1. Widows have an elasticity close to this average, whereas the wage elasticities in the wage sector for divorced and never married women are below one, at 0.87 and 0.79. The wage (cross) elasticities for supply to the self-employment sector are between -0.29 and -0.45, and do not vary much with marital status.

The effect of a 10 per cent decrease in non-labor income is rather small as seen from the lower part of Table 6.1. The resulting increase in the overall female labor force participation rate is only 0.2 per cent. Thus, contrary to what perhaps may be a popular belief, the significance of non-labor income as a determinant of the reservation wage is, as discussed above, rather limited according to our results.

Having established positive effects of education on labor supply, both through behavioral response to significantly higher wages and profits, but also increased job opportunities for women with secondary or higher education, Table 6.2 provide numerical illustrations of further properties of the estimated model by reporting simulations of two examples of education policy. From Table 5.2 we see that the two parameters associated with basic schooling are not significant and one of them has the wrong sign. In the simulation experiments reported in Table 6.2 these parameters are set equal to zero.

Table 6.1. Results from model simulation of 10 per cent wage increase and 10 per cent reduction in non-labor income

	All women		Married		Widowed		Divorced		Never married	
.	Before	After	Before	After	Before	After	Before	After	Before	After
Effect of 10 per cent increase in the wage rate										
Fraction of wage employee	0.164	0.187	0.105	0.126	0.156	0.186	0.262	0.284	0.296	0.320
Fraction unemployed	0.086	0.093	0.058	0.066	0.067	0.074	0.118	0.123	0.170	0.175
Aggregate wage elasticity for wage sector supply	1.35		1.92		1.91		0.87		0.79	
Fraction self-employed	0.161	0.156	0.115	0.112	0.232	0.222	0.301	0.291	0.161	0.156
Aggregate wage elasticity for self-employment supply	-0.33		-0.29		-0.45		-0.32		-0.34	
Female labour force participation rate	0.412	0.436	0.278	0.303	0.455	0.482	0.681	0.698	0.628	0.650
Female unemployment rate	0.209	0.213	0.207	0.216	0.147	0.154	0.174	0.176	0.271	0.269
Effect of 10 per cent decrease in non-labor income										
Fraction of wage employee	0.165	0.166	0.105	0.106	0.157	0.158	0.262	0.263	0.296	0.297
Fraction unemployed	0.086	0.086	0.058	0.058	0.067	0.067	0.118	0.119	0.170	0.170
Aggregate non-labor income elasticity for wage sector supply	-0.05		-0.05		-0.10		-0.05		-0.03	
Fraction self-employed	0.161	0.162	0.115	0.116	0.232	0.235	0.301	0.303	0.161	0.162
Aggregate non-labor income elasticity for self-employment supply	-0.06		-0.06		-0.11		-0.06		-0.04	
Female labour force participation rate	0.412	0.414	0.278	0.280	0.455	0.460	0.681	0.684	0.628	0.629
Female unemployment rate	0.209	0.208	0.207	0.206	0.147	0.146	0.174	0.173	0.271	0.271

In the first simulation we introduce a policy of universal basic education, i.e. we "give" basic education to all women in our sample who have no schooling or incomplete basic education. The resulting employment structure is displayed for the affected group—the sub-sample of women with less than basic education—and for the total female labor force. In order to isolate the effect of increasing wages from that of increased opportunities we report in a separate column the effects when choice constraints are kept constant. The interpretation of this is that, as labor supply to the wage sector increases, the set of job opportunities in the wage sector increases such that, on average, the individual choice sets of feasible jobs remain unchanged.

Table 6.2 shows that introducing universal basic education for women has a large impact on the employment pattern for the least educated women. The labor force participation rate for women who have not completed basic education increases from a very low of 33.1 to a high of 54.2 per cent after they complete basic education. The main effect is that the number of wage employees in this group increases from 13.1 to 27.3 per cent, while self-employment only increases from 14.3 to 15.9 per cent. The unemployment rate for the group increases from 17.4 to 20.3 per cent of the labor force. Since the group of uneducated women is quite large, this policy measure also has a significant effect on the overall female labor force participation rate, which increases from 40 to 55.5 per cent. The increase in the number of all women working as wage employees rises from 17.7 per cent to 28.6 per cent, and the number of self-employed increases from 13.6 to 15.1 per cent. The aggregate female unemployment rate remains practically constant at about 21 per cent of the female labor force.

The largest response is found for married women: They constitute by far the largest demographic group, have an initially low labor force participation rate and, as we showed above, they are highly responsive to wages. Thus their labor force participation rate increases from 26.5 per cent to 44.3 per cent. In the sub-sample of those who are affected by increased education, the labor force participation rate for married women more than doubles from 20 to 43.3 per cent. Recall that basic education has no effect on the sets of job opportunities.

The second simulation presented in Table 6.2 introduces universal secondary education for women. When all women in our sample who have left school before grade 12 or who have never attended school are "given" secondary education, the female labor force participation rate increases from 40 to 76.5 per cent and the employment gap between married women and other women declines substantially.

In line with the significant impact of secondary education on employment opportunities that was established in Table 5.2, we find that increased job opportunities play a major role in explaining the employment effect in the wage sector of compulsory secondary education. When opportunity sets are kept constant, the per cent of women who work as wage employees increases from 17.7 to 52.5 per cent, but when opportunity sets are allowed to increase as a result of increased educational level, 57.9 per cent of the women will work in the wage sector. Keeping opportunity sets constant produce effects that are smaller than when opportunities are allowed to increase as a result of additional education. The reason is that (on average) job opportunity sets will increase as the level of education increases, which implies that the total effect of increased level of schooling will be smaller when opportunity sets are constrained compared to the unconstrained case. Moreover, we observe that when opportunities are restricted we get a somewhat higher participation rate in the self-employment sector, and a substantially higher female unemployment rate at 16.7 instead of 9.9 per cent of the labor force.

Table 6.2. Model simulation of two education policy options: universal basic school and universal secondary school. Employment pattern before (*before*) and after (*after*) policy, and when opportunities are kept constant (*after)**

	All women			Married			Divorced		
	Before	After	After*	Before	After	After*	Before	After	After*
Introducing universal basic education, effect on subsample affected (women with no or incomplete basic education)									
Fraction unemployed	0.058	0.110		0.040	0.100		0.100	0.128	
Fraction wage employee	0.131	0.273		0.065	0.210		0.301	0.381	
Fraction self-employed	0.143	0.159		0.092	0.128		0.267	0.278	
Female labor force participation rate	0.331	0.542		0.200	0.433		0.666	0.787	
Female unemployment rate	0.174	0.203		0.202	0.232		0.148	0.163	
Introducing universal basic education, effect on whole sample (all women)									
Fraction unemployed	0.087	0.119		0.051	0.102		0.133	0.134	
Fraction wage employee	0.177	0.286		0.119	0.224		0.328	0.385	
Fraction self-employed	0.136	0.151		0.095	0.117		0.242	0.266	
Female labor force participation rate	0.400	0.555		0.265	0.443		0.702	0.784	
Female unemployment rate	0.218	0.214		0.192	0.231		0.190	0.170	
Introducing universal secondary education, effect on subsample affected (women with less than sec. education)									
Fraction unemployed	0.077	0.071	0.132	0.047	0.069	0.130	0.130	0.067	0.132
Fraction wage employee	0.145	0.594	0.533	0.083	0.573	0.512	0.303	0.600	0.535
Fraction self-employed	0.141	0.110	0.129	0.093	0.089	0.103	0.255	0.196	0.229
Female labor force participation rate	0.363	0.775	0.793	0.223	0.731	0.745	0.689	0.863	0.896
Female unemployment rate	0.212	0.091	0.166	0.210	0.094	0.174	0.189	0.078	0.148
Introducing universal secondary education, effect on whole sample (all women)									
Fraction unemployed	0.087	0.076	0.130	0.051	0.071	0.127	0.133	0.069	0.130
Fraction wage employee	0.177	0.579	0.525	0.119	0.562	0.506	0.328	0.600	0.539
Fraction self-employed	0.136	0.111	0.127	0.095	0.089	0.102	0.242	0.194	0.225
Female labor force participation rate	0.400	0.765	0.782	0.265	0.721	0.735	0.702	0.863	0.894
Female unemployment rate	0.218	0.099	0.167	0.192	0.098	0.172	0.190	0.080	0.145

7. Conclusion

In this paper we have developed a particular modeling framework for structural analysis of labor supply. This framework allows preferences to depend on non-pecuniary job opportunity aspects and also accommodates for observed and unobserved rationing on agents' market opportunities. The model has been estimated on a sample of Eritrean women. The estimated model has been applied to conduct selected policy simulation experiments. These simulation experiments may be useful for identifying possible policy interventions with the purpose of increasing the economic activity level in Eritrea by mobilizing more women into the labor force, and for improving the earnings capacity of the many female household heads in Eritrea through job opportunities and incomes.

From the simulation experiments we are able to draw the following conclusions: (i) The returns to schooling are high in the wage sector and much higher than in the self-employment sector. (ii) While basic schooling seems to have negligible effect on the set of job opportunities in the wage sector, the corresponding effects of secondary, and in particular post-secondary schooling, are substantial. (iii) The own wage elasticities for the wage sector are rather high, especially for women that are married or widowed, while the income elasticities are very small. (iv) Women's behavior are influenced by the lack of autonomy, where the degree of autonomy in the model is represented through marital status and type of religion of the household.

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Appendix A

Proof of Theorem 1:

Under the IIA assumption, Strauss (1979), Theorem 6, has demonstrated that one can, without loss of generality, assume that the joint distribution of the random terms ε_{1j}, $j \in M$, ε_2 and ε_3 have the structure

$$\text{(A.1)} \qquad P\left(\bigcap_{j\in M}\left(\theta\varepsilon_{1j} \le y_{1j}\right)\bigcap\left(\theta\varepsilon_2 \le y_{2k}\right)\bigcap\left(\theta\varepsilon_3 \le y_3\right)\right) = \psi\left(\sum_{j\in M} e^{-y_{1j}} + e^{-y_2} + e^{-y_3}\right)$$

where $\theta > 0$, is a suitable constant and $\psi(\cdot)$ is a positive and decreasing function on R_+ such that (A.1) is a well defined multivariate distribution function. We realize that the random terms are independent when $\psi(x) = \exp(-x)$.

Recall that J denotes the index of the most preferred jobs in M. It follows from (A.1) that the joint distribution of $\left(\tilde{W}, F'(0), W_R\right)$ is given by

$$\begin{aligned} &P\left(\theta\log\tilde{W} \le y_1, \theta\log F'(0) \le y_2, \theta\log W_R \le y_3\right) \\ \text{(A.2)} \quad &= P\left(\theta\left(\alpha_{10} + d_1\right) + X_1\alpha_1\theta + \theta\max_{j\in M}\varepsilon_{1j} \le y_1, \theta\log g'(0) + X_2\alpha_2\theta + \theta\varepsilon_2 \le y_2, \gamma_0 + X_3\theta\gamma + \theta\varepsilon_3 \le y_3\right) \\ &= \psi\left(e^{\gamma_0 + u_1 - y_1} + e^{\gamma_0 + v_2 - y_2} + e^{\gamma_0 + v_3 - y_3}\right) \end{aligned}$$

where $u_1 = \log m + \theta\left(\alpha_{10} + d_1 - \gamma_0\right) + X_1\alpha_1\theta$, $v_2 = \theta\log g'(0) - \theta\gamma_0 + X_2\alpha_2\theta$ and $v_3 = X_3\theta\gamma$. From (A.2) it now follows immediately from Strauss (1979) that

$$\text{(A.3)} \qquad P\left(W_R > \max\left(F'(0), \tilde{W}\right)\right) = \frac{e^{v_3}}{e^{u_1} + e^{v_2} + e^{v_3}},$$

$$\text{(A.4)} \qquad P\left(\tilde{W} > \max\left(W_R, F'(T)\right)\right) = P\left(\tilde{W} > \max\left(W_R, F'(0)\exp(\kappa/\theta)\right)\right) = \frac{e^{u_1}}{e^{u_1} + e^{v_2+\kappa} + e^{v_3}}$$

and

$$\text{(A.5)} \qquad P\left(F'(0) > \max\left(\tilde{W}, W_R\right)\right) = \frac{e^{v_2}}{e^{u_1} + e^{v_2} + e^{v_3}},$$

which prove (4.8) through (4.10). Similarly, (4.12) follows.

To prove (4.11) note that

(A.6) $P\left(F'(0) > \tilde{W} > \max\left(F'\left(T\right), W_R\right)\right) + P\left(F'(0) > \tilde{W} > W_R, \tilde{W} < F'\left(T\right)\right) = P\left(F'(0) > \tilde{W} > W_R\right).$

Moreover, since $F'\left(T\right) \leq F'(0)$ with probability one, it must be true that

(A.7) $$P\left(F'(0) > \tilde{W} > W_R, \tilde{W} < F'\left(T\right)\right) = P\left(F'\left(T\right) > \tilde{W} > W_R\right).$$

When (A.6) and (A.7) are combined we thus get

(A.8) $$P\left(F'(0) > \tilde{W} > \max\left(F'\left(T\right), W_R\right)\right) = P\left(F'(0) > \tilde{W} > W_R\right) - P\left(F'\left(T\right) > \tilde{W} > W_R\right).$$

From Strauss (1979), Lemma, p. 47, we obtain that

(A.9) $$P\left(F'\left(T\right) > \tilde{W} > W_R\right) = P\left(\exp\left(\kappa/\theta\right)F'(0) > \tilde{W} > W_R\right) = \frac{e^{v_2+\kappa}}{e^{u_1} + e^{v_2+\kappa} + e^{v_3}} \cdot \frac{e^{u_1}}{e^{u_1} + e^{v_3}}$$

and

(A.10) $$P\left(F'(0) > \tilde{W} > W_R\right) = \frac{e^{v_2}}{e^{u_1} + e^{v_2} + e^{v_3}} \cdot \frac{e^{u_1}}{e^{u_1} + e^{v_3}}.$$

When (A.9) and (A.10) are inserted into (A.8), (4.11) follows.

Eq. (4.13) follows from (A.9) and an expression analogous to (A.10) (obtained by interchanging $\tilde{W}$ and W_R), and the fact that the events

$$\left\{F'(0) > W_R > \tilde{W}\right\} \text{ and } \left\{F'\left(T\right) > \tilde{W} > W_R\right\}$$

are disjoint. We notice that the choice probabilities are independent of ψ. Thus, one can without loss of generality choose $\psi(x) = e^{-x}$, which implies independent error terms. This completes the proof of Theorem 1.

Q.E.D.

From the results above we realize that we could have chosen $\psi(x) = \exp(-x)$, (which means that the random error terms are i.i.d.), since ψ cancels in the expressions for the choice probabilities.

Proof of Lemma 1:

We have that

$$(A.11)\qquad \begin{aligned} &E\left(\varepsilon_{1J}\,\middle|\,\tilde{h}_1>0\right)=E\left(\log\tilde{W}\,\middle|\,\tilde{h}_1>0\right)-E\log\tilde{W}\\ &=E\left(\log\tilde{W}\,\middle|\,\log\tilde{W}>\max\left(\log W_R,\log F'(T)\right)\right)-E\log\tilde{W}.\end{aligned}$$

From (A.1) we get, similarly to (A.2);

$$(A.12)\qquad P\left(\theta\log\tilde{W}\le y_1,\theta\log F'(T)\le y_2,\theta\log W_R\le y_3\right)=\psi\left(e^{u_1-y_1}+e^{u_2-y_2}+e^{v_3-y_3}\right)$$

which implies that

$$(A.13)\qquad P\left(\theta\log\tilde{W}\in(y,y+dy)\,\middle|\,\log\tilde{W}>\max\left(\log F'(T),\log W_R\right)\right)=-\frac{\psi'\left(e^{\lambda-y}\right)e^{u_1-y}\,dy}{P\left(\tilde{h}_1>0\right)}$$

where

$$(A.14)\qquad \lambda=\log\left(e^{u_1}+e^{u_2+\kappa}+e^{v_3}\right).$$

From (A.13) it follows that

$$(A.15)\qquad E\left(\theta\log\tilde{W}\,\middle|\,\log\tilde{W}>\max\left(\log W_R,\log F'(T)\right)\right)=-\frac{e^{u_1}}{P\left(\tilde{h}_1>0\right)}\int_R y\,\psi'\left(\exp(\lambda-y)\right)e^{-y}dy.$$

With the change of variable, $x=y-\lambda$,

$$\int_R y\,\psi'\left(\exp(\lambda-y)\right)e^{-y}dy=e^{-\lambda}\int_R(x+\lambda)\psi'\left(e^{-x}\right)e^{-x}\,dx.$$

Since

$$-\int_R x\,\psi'\left(e^{-x}\right)e^{-x}\,dx=E\,\theta\,\varepsilon_{1j}=0$$

it follows that

$$-\int_R(x+\lambda)\psi'\left(e^{-x}\right)e^{-x}\,dx=-\lambda\int_R\psi'\left(e^{-x}\right)e^{-x}dx=\lambda\Big|_{-\infty}^{\infty}\psi\left(e^{-x}\right)=\lambda.$$

Moreover, (4.9) implies that

$$\frac{e^{u_1}}{P(\tilde{h}_1 > 0)} = e^{\lambda} .$$

Hence, (A.15) becomes

(A.16) $$-\frac{e^{u_1}}{P(\tilde{h}_1 > 0)} \int_R y\,\psi'(\exp(\lambda - y))e^{-y}dy = -\int_R (x+\lambda)\psi'(e^{-x})e^{-x}dx = \lambda .$$

Consequently, (A.11) and (A.16) yield

(A.17) $$E\left(\theta\varepsilon_{1J} \,\middle|\, \tilde{h}_1 > 0\right) = \lambda - E\log\tilde{W} = \lambda - u_1 = -\log P(\tilde{h}_1 > 0).$$

Similarly to the results of Theorem 1 we notice that (A.16) is independent of ψ.

Q.E.D.

Note that even if Strauss (1979) has proved that the transformation ψ cancels in the derivation of the choice probabilities, his result does not immediately hold for our case since we allow for simultaneous choice of wage work and self-employment. Furthermore, we also need to prove Lemma 1, which proof is not found elsewhere as far as we know.

Appendix B

In this appendix we outline the derivation of the likelihood function. Let $i = 1,2,...,$ represent the indexation of the individuals in a random sample. Let P_{i00}, P_{i10}, P_{i01} be the individual choice probabilities as given by (4.15), (4.17) and (4.18). Let Y_{i00}, Y_{i10}, Y_{i01}, Y_{i11} and V_{i10} be indicator variables representing the individuals labor market status, i.e. Y_{i00} is equal to one if individual i does not wish to work and zero otherwise, Y_{i10} is equal to one if individual i works solely in Sector 1 and zero otherwise, Y_{i01} equals one if individual i works solely in Sector 2 and zero otherwise, and Y_{i11} equals one if individual i works in both sectors, and V_{i10} equals one if individual i wish to work in the wage sector but cannot obtain work in this sector. Let h_{ij}^* denote hours of work in Sector j, $j = 1,2,$ when there is no rationing in Sector 1. From (4.16) to (4.21) it follows that

(B.1) $$P_{i00} := P\left(\tilde{h}_{i1} = \tilde{h}_{i2} = 0\right) = \frac{1}{1 + e^{Z_{i1}\beta_i} + e^{Z_{i2}\beta_2}}$$

(B.2) $$P_{i10} := P\left(\tilde{h}_{i1} > 0, \tilde{h}_{i2} = 0\right) = \frac{e^{Z_{i1}\beta_1}}{1 + e^{Z_{i1}\beta_1} + e^{Z_{i2}\beta_2}}$$

(B.3) $$P_{i01} := P\left(\tilde{h}_{i1} = 0, \tilde{h}_{i2} > 0\right) = \frac{e^{Z_{i2}\beta_2}}{1 + e^{Z_{i1}\beta_1} + e^{Z_{i2}\beta_2}} \cdot \frac{1}{1 + e^{Z_{i1}\beta_1}} + \frac{e^{Z_{i2}\beta_2 + \kappa}}{1 + e^{Z_{i1}\beta_1} + e^{Z_{i2}\beta_2 + \kappa}} \cdot \frac{e^{Z_{i1}\beta_1}}{1 + e^{Z_{i1}\beta_1}}$$

(B.4) $$P_{i10}^* \equiv P\left(h_{i1}^* > 0, h_{i2}^* = 0\right) = \frac{e^{Z_{i1}\beta_1^*}}{1 + e^{Z_{i1}\beta_1^*} + e^{Z_{i2}\beta_2}},$$

(B.5) $$P_{i01}^* := P\left(h_{i1}^* = 0, h_{i2}^* > 0\right) = \frac{e^{Z_{i2}\beta_2}}{1 + e^{Z_{i1}\beta_1^*} + e^{Z_{i2}\beta_2}} \cdot \frac{1}{1 + e^{Z_{i1}\beta_1^*}} + \frac{e^{Z_{i2}\beta_2 + \kappa}}{1 + e^{Z_{i1}\beta_1^*} + e^{Z_{i2}\beta_2 + \kappa}} \cdot \frac{e^{Z_{i1}\beta_1^*}}{1 + e^{Z_{i1}\beta_1^*}}$$

where

(B.6) $$Z_{i1}\beta_1^* := \theta\tilde{\alpha}_{10} + \log m^* + X_{i1}\alpha_1\theta - X_{i3}\gamma\theta,$$

(B.7) $$Z_{i1}\beta_1 := \theta\tilde{\alpha}_{10} + \delta_0 + X_{i4}\delta + X_{i1}\alpha_1\theta - X_{i3}\gamma\theta$$

and

(B.8) $$Z_{i2}\beta_2 := \theta\tilde{\alpha}_{20} + X_{i2}\alpha_2\theta - X_{i3}\gamma\theta.$$

It follows that

(B.9)
$$P\left(V_{i10}=1\right)=P_{i10}^{*}-P_{i10}$$

and

(B.10)
$$P\left(Y_{i00}=1\right)=P_{i00}-P_{i10}^{*}+P_{i10}.$$

The log-likelihood function equals

(B.11)
$$\log L=\sum_{i}\left(Y_{i00}\log\left(P_{i00}-P_{i10}^{*}+P_{i10}\right)+V_{i10}\log\left(P_{i10}^{*}-P_{i10}\right)+Y_{i10}\log P_{i10}+Y_{i01}\log P_{i01}+Y_{i11}\log\left(1-P_{i00}-P_{i10}-P_{i01}\right)\right).$$

When $Y_{i11}=0$ for all i it must be the case that

$$P\left(\tilde{h}_{i1}>0,\tilde{h}_{i2}>0\right)=0.$$

But then (4.11) implies that $\kappa=0$ in which case P_{i01} reduces to $\tilde{P}_{i01}$, given by

$$\tilde{P}_{i01}:=\frac{e^{Z_{i2}\beta_2}}{1+e^{Z_{i1}\beta_1}+e^{Z_{i2}\beta_2}}.$$

The likelihood function in this case becomes

(B.12)
$$\log L=\sum_{i}\left(Y_{i00}\log\left(P_{i00}-P_{i10}^{*}+P_{i10}\right)+V_{i10}\log\left(P_{i10}^{*}-P_{i10}\right)+Y_{i10}\log P_{i10}+Y_{i01}\log\tilde{P}_{i01}\right).$$