HARRI LAHDENPERÄ

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Econometric Applications of Discrete Choise Models to Married Women's Labour Supply Decisions

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Helsinki, September 1991

Harri Lahdenperä

Contents

1 Introduction

The analysis of labour supply has been an important part of mainstream microeconomic theory and econometric work for a long time. However, during the 1980s empirical research in this field increased rapidly especially in the United States and the United Kingdom, but also in other countries.

There are two main reasons for this growing interest in labour supply research. Firstly, the advances in modern microeconomic theory and especially in econometric techniques and computer algorithms concerning discrete choice analysis have made research in this field an attractive intellectual challenge. And secondly, labour supply entails a vast range of interesting questions making it an ideal field in which to apply the new methods in empirical work.

Up until the early 1970s the empirical analysis of labour supply was methodologically quite simple. Emphasis was placed on the OLS estimation of labour supply functions using population subsamples of employed persons only. The major advance since then concern the specification, estimation and modelling of the labour supply.

The earlier ad hoc approaches to specification have been replaced by models derived from the formal analysis of utility maximization subject to constraints. Particularly the development of the theory of duality has made it possible to analyse more complicated problems and to tie together the different aspects of labour supply. Major applications of this approach are Burtless & Hausman (1978), Hausman (1980), Zabalza (1983) and Blundell & Meghir & Symons & Walker (1988). Stern (1986) is an excellent theoretical study of the subject.

The major achievements in regard to estimation have been in dealing with problems of sample selectivity (e.g. the fact that wage data are missing for nonworkers and the question of whether to exclude or include nonworkers from the sample used to estimate the labour supply function). The importance of self-selection in labour economics was already recognized by Gronau (1974). The pioneering econometric work in this area was done by Heckman (1976, 1979, 1980), who proposed a multi-stage estimation procedure to correct for selection bias. Now this technique is a standard tool for empirical analysis of the labour supply. An interesting paper by Wales & Woodland (1980) compares various methods of estimating labour supply functions when some individuals in the sample are not working, in terms of information required for estimation, complexity of computation and statistical properties of the estimators.

In addition to advances in econometrics, the rapid development of computer technology has made possible the estimation of intricate models with large cross-section or panel data sets. Some examples of labour supply studies where complicated likelihood functions are maximized are Heckman (1974), Hausman & Wise (1976) and Cogan (1981).

The advances in the modelling of labour supply in empirical studies relate mainly to non-linear (convex or non-convex) budget sets, which arise from progressive income taxation, social security benefits or costs of labour market entry. Some important works dealing with income taxation are Rosen (1976), Hausman (1979, 1980) and Blomquist (1983, 1988). The works of Hausman (1980) and Cogan (1981) deal with complicated non-convex budget sets arising from costs of entry into the labour market.

One other important area of labour supply studies that should be mentioned in this context is the analysis of labour supply with hours restrictions. These studies deal with the problem of involuntary unemployment and demand side restrictions on labour supply. Major studies of this type are Ashenfelter (1980), Ham (1982), Dickens & Lundberg (1985) and Blundell & Ham & Meghir (1987).

The second and equally important reason for the growth of labour supply literature is the importance of this field in terms of policy-making. Interest in the economic effects of taxation and social policy increased rapidly in the 1970s and the 1980s because of the growing importance of personal taxation and social transfer payments in the western economies. During the latter years important reforms of direct taxation have been made in many countries. This has raised questions concerning the economic (dis)incentive effects of progressive taxes and social transfer payments. A debate on these issues is still underway both among economists and policy makers in many countries.

The aim of this study is to analyze the female labour supply. In Finland very little work has thus far been done on the cross-section analysis of the labour supply. The few exceptions are studies by Ilmakunnas & Lahdenperä (1986), Pulli (1985), Ingberg & Pulli (1986) and Ilmakunnas (1989). Ilmakunnas & Lahdenperä examine participation and hours of work decisions of married women. Pulli and Ingberg & Pulli look at the labour supply of prime-aged men, focusing particularly on the effects of income taxation. Ilmakunnas examines the female labour supply using a model in which it is possible to identify the effects of labour supply constraints on the observed labour supply. All these studies as well as the current one are based on the same 1980 data set.

Even though our study focuses on the estimation of labour supply functions we also estimate a wage equation which gives us information about the effects on hourly wage rates of education, age, work experience and occupational status. Cross-section analysis of hourly wage determination has thus far been almost non-existent in Finland. Lilja & Vartia (1980) studied the effects of education on household income using the 1971 Household Survey data. The labour supply studies mentioned above also contain estimated wage equations which, however, are not as detailed as in our study.

Our study is largely based on a stochastic choice approach, and we utilize various econometric techniques. Special attention is devoted to the estimation of wage and income elasticities, as well as to the effects of fixed working costs and progressive taxes on the female labour supply in Finland. We use microdata from 1980 and concentrate on married women because in the last ten years the most important changes in the labour supply have taken place in this group and because other empirical studies of labour supply have pointed to this group as being the most sensitive to economic incentives.

In chapter 2 we describe some of the main features of the Finnish labour supply over a longer time period. The main trends have been the strong rise in the female labour force participation rate and the gradual decrease in normal weekly and yearly working hours. The labour force participation rate of married prime-aged females has risen to the point that there is no longer any difference between the rates for married and unmarried women. Regarding working hours, analysis of survey data indicates that many individuals are quite limited in their ability to adjust working hours towards the optimal level in the short run.

In chapter 3 we discuss the standard income-leisure choice with a linear budget constraint. In the basic model the effect of the hourly wage on hours worked can be decomposed into substitution and income effects. Because these effects are opposite in sign if leisure is a normal good, we cannot a priori determine the sign of the total effect. The introduction of proportional income taxation does not significantly change the results of the basic model. A proportional tax only has the effect of a scale factor which dampens the substitution and income effects of a change in the wage rate.

In the case of progressive semi-linear income taxation the analysis is much more complicated. In chapter 3 we present the comparative statics of progressive taxation following Blomquist (1988). The tax parameters of interest in this case are changes in the exemption level, in the tax bracket limit, in the marginal tax rate and in the gross wage rate. It is interesting to note that comparative statics analysis in the case of a piece-wise linear budget constraint yields a number of predictions about how changes in tax parameters affect labour supply. This is in sharp contrast to the case of proportional taxation where we cannot say much because of opposing income and substitution effects.

In chapter 3 we also briefly discuss the criteria relevant in the specification of labour supply functions. Among these are consistency with utility theory, convenience in estimation, ease of calculation of direct and indirect utility functions and flexibility in the type of response permitted. The specification of a labour supply function is of great importance because of its critical impact on the estimation results. In this study we choose a linear specification which can be motivated by the fact that its estimation is straightforward even in more complicated models and it is the most commonly applied specification in the literature. However, the linear specification also has some major disadvantages, which are discussed in this context.

In chapter 4 we discuss the econometrics of labour supply. This part is rather extensive, as it includes some techniques that are not applied in this study. The basic model is a censored regression model where the dependent variable (labour supply) is observable only over part of the sample. This is a tobit model which can be estimated by maximum likelihood methods. However, the assumptions underlying tobit are very stringent and therefore this type of model is usually estimated by the multi-stage method suggested by Heckman (1976, 1979). This method, which we also apply, reduces to the estimation of participation and hours of work functions by a probit model and selectivity corrected ordinary least squares.

Several techniques have been suggested for the estimation of labour supply functions in the case of progressive taxation, which entails a nonlinear convex budget constraint. Hall (1973) suggested that the true nonlinear budget constraint be replaced by a straight line tangent to the true constraint at the point of actual hours of work. Therefore, instead of gross wage rate and nonlabour income, our regressions include the net marginal wage rate and virtual income, defined as the intercept of the linearised budget set at zero hours of work. However, this method introduces both a simultaneity bias and a specification error into the model. The simultaneous equation bias is due to the fact that the observed net wage rate is itself endogenous, since it depends on the number of hours worked, and is therefore correlated with the disturbance term. The misspecification occurs if for some individuals the true utility maximization position is on a segment of the piecewise linear constraint other than the observed one.

The ordered probit model is one statistical technique for dealing with the endogeneity problem. In order to correct for the endogeneity in tax rates and unearned income one must account for the conditioning that generates the observations (i.e. the particular flat segment or kink on which an observation is situated). The most comprehensive technique for dealing with the specification problem is that discussed and applied by Hausman (1979, 1981) and Blomquist (1983). This technique locates the individual's optimum by examining the entire budget constraint, including both flat segments and kinks.

The Hausman-Blomquist approach can't be applied directly if there are costs of entry into the labour market. These costs introduce a nonconvexity into the budget constraint, which entails the possibility of multiple optima. Utility comparisons are needed to determine which of these several local optima is the global one. Entry costs also impose a discontinuity on the labour supply schedule, thus vitiating the relationship between the participation rule and the hours and wage equations. With this in mind, Cogan (1981) developed a model to estimate both hours of work and reservation hours, i.e. the minimum hours an individual is willing to work.

In chapter 5 we discuss the data used in this study. Our data set was formed by merging two Finnish surveys, the Labour Force Survey (LFS) of 1980 and the Population and Housing Census (PHC) of the same year. The problem of reliability is always serious when using survey data and the present study is no exception. Hence we discuss this problem at some length. Outside information is used to eliminate the most unreasonable observations from our data.

Chapter 6 contains the estimation results. For the standard case we estimate a tobit model, a probit model and a selectivity corrected hours-of-work equation. In the case of entry costs we estimate both a participation equation and an hours-of-work equation with fixed costs of working. In addition, we estimate Cogan's reservation hours of work model using a multi-stage procedure. Regarding taxation, we estimate two different models. In the first one the budget constraint is linearized through observed points, and in the second we linearize the budget constraint using the standard number of hours for all individuals.

Finally, chapter 7 contains a brief summary of the main findings of the study from the perspective of the other literature on labour supply and actual participation and hours-of-work trends in Finland.

2 Some Historical Trends in Labour Supply

The information on the labour force is based on the labour force sample survey conducted monthly by the Central Statistical Office of Finland. In that survey the labour force is defined as the sum of employed and unemployed persons. The labour force participation rate is the percentage ratio of labour force to population in the same age group.

From 1965 to 1988 the population of working age, 15—74 years, increased by some 510 000. The increase in the labour force was about 350 000, which raised the labour force participation rate only slightly, from 68 per cent to 69 per cent. The number of employed persons increased by some 300 000.

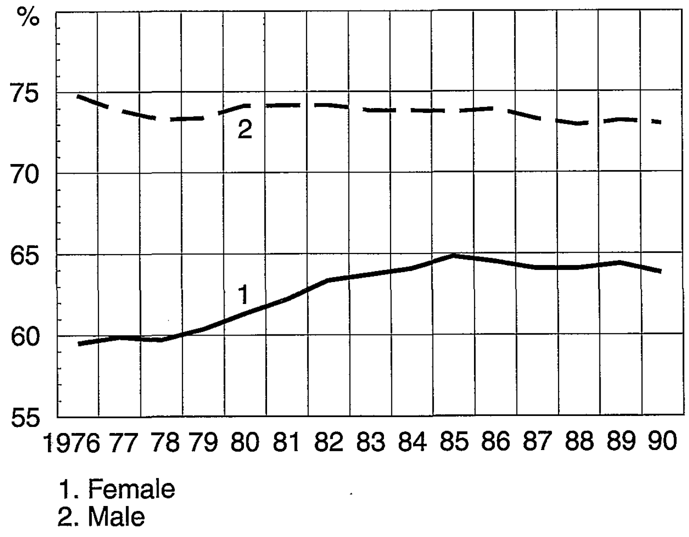
The behaviour of men and women with respect to the labour market has differed markedly. The labour force participation rate for men decreased considerably in the 1960s and in the beginning of 1970s and has been fairly stable since then (figure 2.1). The rate for females increased steadily in the 1970s and in the first half of 1980s and the difference between the rates for males and females narrowed rapidly until 1986. The recent slight decrease in the female participation rate is noteworthy because it signals a clear change in a trend that had lasted for about 20 years.

The breakdown of employed persons between wage-earners and self-employed has changed considerably in favour of wage-earners. The main reason for this has been the rapid decrease in persons working in agriculture and as unpaid family workers.

The composition of persons not in the labour force has changed considerably during the last 20 years. The number of persons performing domestic work has decreased by two thirds.

During recent years the number of females performing domestic work has been slightly over 100 000, which is only about 5 per cent of the population aged 15—74 years. The number of students increased markedly during the 1960s but has begun to decrease in recent years because of fewer cohorts reaching working age. The number of disabled increased rapidly up to 1977, but has decreased slightly since then. In the 1980s the number of persons receiving unemployment pensions increased sharply.

Figure 2.1 **Labour force participation rates for 1976—1990 — the percentage share of labour force in the working age (15—74) population**



The changes in female participation rates by age group from 1960 to 1985 are shown in figure 2.2. From this figure we see the dramatic rise in the participation rate of females in the most active age range, 15—44 years. The proportion of employed and unemployed women has also risen in the older age groups during the 1970s and first half of the 1980s. The female participation rate among the youngest age group declined considerably during the 1970s but then rose slightly in the beginning of 1980s.

In the early 1960s the labour force participation rate for married women was considerably lower than for unmarried women (figure 2.3). Since then, the rise in the rate for married women has been so substantial that there is no longer any difference between these two groups. The major part of the increase in the supply of labour during the last 20—30 years is due to changes in the labour force participation rate for married women. This makes it very important also for macroeconomic reasons to try to find the determinants of labour supply for this group.

Figure 2.2

Labour force participation rates for women by age group in 1960, 1970, 1980 and 1985

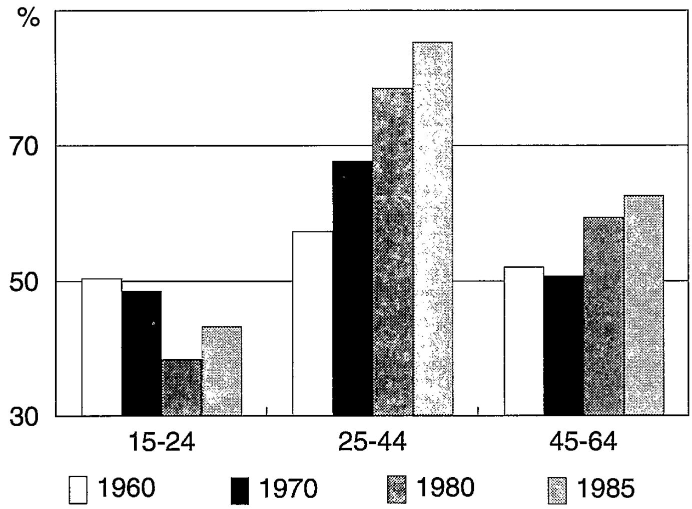
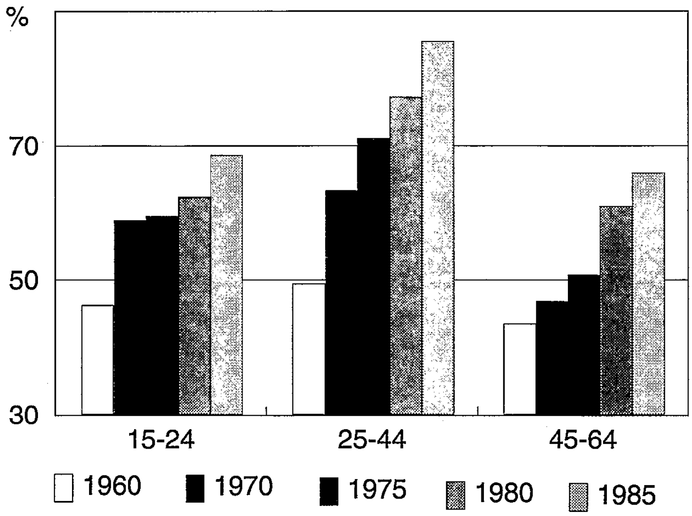


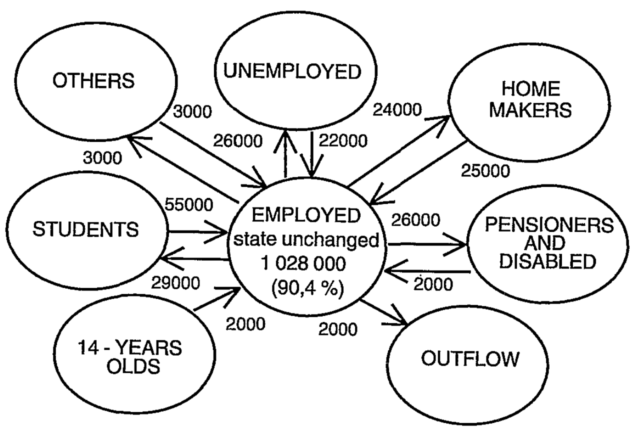
Figure 2.3

Labour force participation rates for married women by age group in 1960, 1970, 1975, 1980 and 1985



To obtain a better understanding of the choices made by working age females between employment and the main non-working categories, the flows of working age population are shown in figure 2.4. The main (two-way) flows are between the employed and student, employed and homemaker and employed and unemployed categories. However, it can be seen that persons employed in period t-1 have a very high probability of being employed in period t. This is a clear indication of the life-cycle nature of labour supply and no doubt reduces the usefulness of cross-section analysis in explaining labour supply decisions. However, as figure 2.4 clearly indicates, there is still room for voluntary choices between working and not working, especially between employment and homemaking as well as between employment and studying. Perhaps there is also a voluntary component in the flow from employed to unemployed. To find out the determinants of these choices is one of the goals of this study.

Figure 2.4 **Flows of population of working age by main group, transitions between the employed and other main groups, 1st quarter 1985–1986, women**



Source: Central Statistical Office of Finland

Changes in the labour supply are not only due to changes in participation rates but also to changes in hours worked among participants. The average number of hours worked among employed wage- and salary earners has declined considerably during the last 30 years. One reason for this has been the legislated increases in the length of summer and winter holidays. Also the number of normal weekly hours has diminished, especially in sectors with irregular working hours.

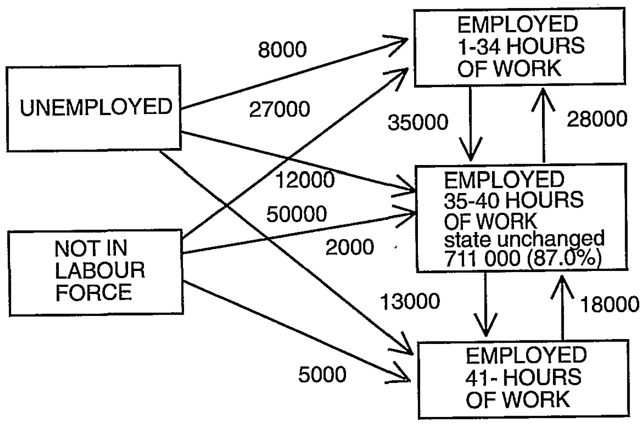
It is clear that the Finnish labour market is quite rigid with respect to working time. The proportion of part-time workers, i.e. those working 1—29 hours per week, is low by international comparisons. It is also noteworthy that the proportion of part-time employed did not increase during the 1980s even though the service industries grew rapidly. This proportion was 7.4 per cent in 1980 and in 1989. Most part-time workers are females who work in the public and private services. According to labour force surveys a much greater proportion of females would have been willing to work part-time had such jobs been available. It seems evident that in the Finnish labour market individuals are very limited in their choice of working hours.

In addition to normal weekly working hours individuals can adjust their working hours through overtime work and second jobs. In 1989, a boom year in the Finnish economy, 9.0 per cent of the employed population worked overtime and 6.6 per cent had second jobs. Both overtime work and second jobs are more common among male workers.

Individuals' possibilities of adjusting their working hours also depend to a great extent on the time horizon. In the longer run individuals can, in addition to working overtime and second jobs, take voluntary leaves, renegotiate working time or change primary jobs in order to adjust their working hours towards the optimal level. From the life-cycle perspective, individuals can also to some extent decide on the starting and ending times of their work careers.

Flows of population of working age by main group and normal weekly hours of work are shown in figure 2.5. About two thirds of employed women normally work 35—40 hours per week. Of those so employed in the last quarter of 1985, about 87 % were working the same number of hours per week a year later. Some 5 % of them were working more or less hours per week, 2 % were unemployed and the rest were not in the labour force. From figure 2.5 it can be seen, that of those changing from unemployment or non-participation in the labour force to employment, a substantial part has working times of more or less than 35—40 hours per week. Particularly in the new jobs generated by the growing service sector there seems to be more flexibility even with respect to weekly working hours.

Figure 2.5 **Flows of population of working age by main group and normal weekly hours of work, 1st quarter 1985—1986, women**



There are many different factors which are important for labour supply behavior. A short list of relevant factors would include:

— general demand for labour
— real wages, unearned income
— socioeconomic factors
— family size and composition
— flexibility of working time
— taxation and transfer payment systems
— pension system rules
— mobility in the labour market, factors affecting it.

The main features of participation rates and working hours depicted above clearly indicate that empirical cross-section analysis is seriously limited as a tool in establishing the determinants of individual labour supply. In this type of cross-section analysis it is best to concentrate on the factors that are most relevant to short-run decision making. Therefore, we focus here on factors such as hourly wage, unearned income, taxation, socioeconomic variables and family composition. Data limitations are also of concern here. For example, the analysis of transfer payment systems or pension system rules would have reguired prohibatively rich panel data.

3 The Theory of Labour Supply

3.1 Labour supply under a linear budget constraint

In the standard theory of consumer choice the labour supply decisions of individuals are the result of utility maximization subject to constraints. In the basic model the individuals utility depends on the amount of (market) goods c and hours of leisure time l. The individual is subject to two constraints: the budget constraint and the time constraint. Under the budget constraint spending on market goods, pc, must equal total income from work, wh, and other income (nonlabour income), y. Under the time constraint the total amount of time available to the individual per period (day, week, year) is fixed at T hours and can be allocated to working hours h and leisure hours l. So the problem of the consumer is the following:

$$\max u = u(l,c) \quad \text{subject to} \quad \begin{array}{ll} (a) & wh + y = pc \\ (b) & h + l = T. \end{array} \tag{3.1}$$

In equation (3.1), c is the Hicksian composite commodity (see Hicks 1946, pp. 312–313).

Solving the maximization problem above gives us the Marshallian allocation equations for consumption goods c and leisure time l

$$\begin{aligned} c &= c(w,y,p) \\ l &= l(w,y,p). \end{aligned} \tag{3.2}$$

We can rewrite the budget constraint in (3.1) directly in terms of c and l:

$$pc + wl = y + wT. \tag{3.3}$$

We see that w, the price of leisure, appears not only in the normal role of a price on the left-hand side of (3.3) but also as part of the budget in valuing the time endowment T. In equation (3.3) the quantity y+wT is called full income, i.e. the total purchasing power available to the consumer to be spent on leisure and goods. Hereafter, we denote it by X.

Definition 1: Leisure is a normal good if $X_1 > X_2$ implies $l(X_1,w) > l(X_2,w)$.

The comparative statics in this model can be more compactly derived using the theory of duality, i.e. by using the properties of expenditure and indirect utility functions. Define the "full" expenditure function and the "full" indirect utility function as:

$$e(u,w,p) = \min\{pc+wl;\ u(c,l)\geq u\} \tag{3.4}$$

$$v(X,w,p) = \max\{u(c,l);\ pc+wl\leq y+wT\} \tag{3.5}$$

The compensated (Hicksian) demand function for leisure is given by Shephard's lemma (see Varian 1984, p. 123):

$$l = h(u,w,p) = \frac{de(u,w,p)}{dw} \tag{3.6}$$

The market (Marshallian) demand function for leisure is given by Roy's identity (see Varian 1984, pp. 126—127):

$$l = g(y+wT,w,p) = g(X,w,p) = -\frac{dv/dw}{dv/dX} \tag{3.7}$$

The effect of a change in wage w on labour supply can be derived directly from (3.7):

$$\frac{dl}{dw} = \frac{dg}{dw}\bigg|_X + \frac{dg}{dX} * T \tag{3.8}$$

Using (3.7) and the expenditure function we get the compensated demand function:

$$l = g\{e(u,w,p),w,p\} = h(u,w,p) \tag{3.9}$$

Differentiating with respect to w gives

$$\frac{dl}{dw}\bigg|_u = \frac{dh}{dw} = \frac{dg}{dX} * \frac{de}{dw} + \frac{dg}{dw}\bigg|_X = \frac{dg}{dX} * 1 + \frac{dg}{dw}\bigg|_X \quad (3.10)$$

Substituting (3.10) into (3.8) gives

$$\frac{dl}{dw} = \frac{dl}{dw}\bigg|_u - \frac{dl}{dX} * 1 + \frac{dl}{dX} * T = \frac{dl}{dw}\bigg|_u + \frac{dl}{dX} * h \quad (3.11)$$

Equation (3.11) is the so-called Slutsky equation, which decomposes the effect on labour supply of a change in gross wage into substitution and income effects. The first equality in (3.11) decomposes the move from B to B_1 (total effect) into B to E (substitution effect), E to B_2 (income effect due to change in the price of leisure) and B_2 to B_1 (revaluation-of-time-endowment effect).

The effect on labour supply of a change in nonlabour income can be derived directly from (3.7):

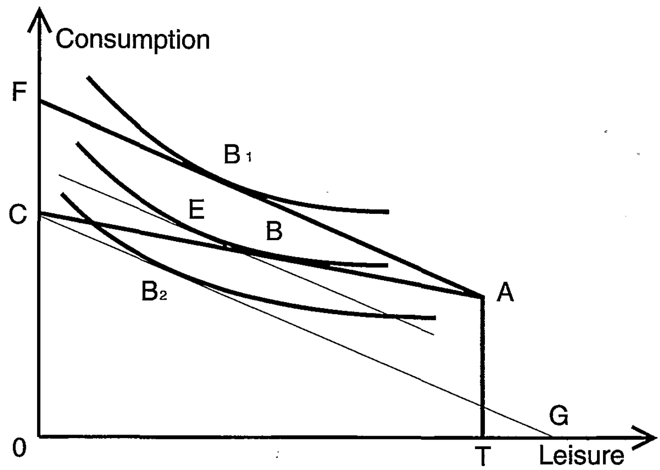
$$\frac{dl}{dy} = \frac{dg}{dX} \quad (3.12)$$

We see that if leisure is normal, an increase in nonlabour income will reduce the supply of labour.

The same analysis is depicted graphically in figure 3.1. (see Deaton & Muellbauer 1980, p. 90).

Let TAC be the budget constraint under the original wage rate w_1. Then the optimum position of the consumer is at point B, where he works $T\text{-}l^*$ hours. Suppose an increase in w causes the budget constraint to shift to TAF. The effect of a wage increase can be decomposed into three effects, one substitution effect and two income effects. The substitution effect is the move from B to E. The move from E to B_2 is caused by the increase in the price of leisure, and the move from B_2 to B_1 is the extra income effect on full income X of the change in w through the revaluation of T. Hence, with respect to the demand for leisure, the total income effect, from E to B_1, of a change in the wage rate w is positive if leisure is a normal good. We see that the income and substitution effects have opposite signs, and the total (net) effect of a wage rate change on labour supply cannot be determined a priori.

Figure 3.1 **Income and substitution effects of a change in the wage rate**



3.2 Taxation and labour supply

In the previous section we investigated the labour supply decision without taxation. The introduction of proportional taxation doesn't essentially change the outcome of the model. The effects of a proportional income tax may be considered in two stages. First there is a tax on nonlabour income y. This shifts the budget constraint down and, assuming that leisure is a normal good, increases the supply of labour. Secondly, a linear tax on wage income rotates the budget constraint downwards counterclockwise. Just as in the case of a change in gross wage, this effect can be decomposed into income and substitution effects, according to the Slutsky equation.

Formally the effect of a proportional tax on labour supply can be written as (Atkinson & Stiglitz (1980), p.34)

$$\frac{dl}{dt} = -w * \left.\frac{dl}{dw}\right|_u - [w(T-1)+y] * \frac{dl}{dX}, \tag{3.13}$$

where t is the proportional tax on wage and nonwage income. The first term in equation (3.13) is the substitution effect, which is positive. The second term is the income effect, which is negative if leisure is normal. So we cannot determine a priori whether a proportional income tax increases or decreases the labour supply of an individual.

The effect on labour supply of a change in gross wage with proportional taxation can be written as

$$\frac{dl}{dw} = (1-t) * \{\frac{dl}{dw}\Big|_u + (T-1) * \frac{dl}{dX}\}. \tag{3.14}$$

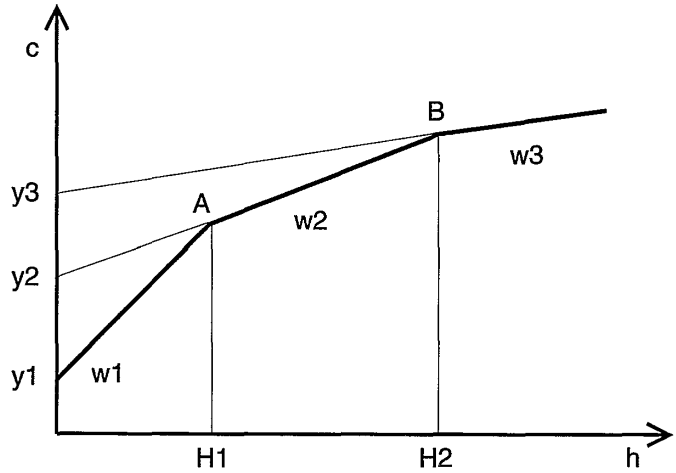
We see that a proportional tax has only the effect of a scale factor which dampens the substitution and income effects of a change in the wage rate, compared to the case of no taxation. This is a logical consequence of the fact that it is the change in after-tax wage which affects labour supply behavior.

However, in real world situations linear budget constraints and proportional income taxation are an exception. Real world income tax systems are mostly semi-linear and progressive. Moreover, income-related social security benefits can also have effects similar to those of nonlinear taxation because they change net marginal wage as a function of hours worked. In this section we take progressive, semi-linear income taxation into account and investigate how it influences the labour supply behavior.

Edlefsen (1981) analyzed the comparative statics of optimization models with nonlinear constraints. He showed that individual substitution and income effects are systematically affected by the nature and degree of nonlinearity of the constraint. Blomquist (1985) studied the effects of a nonlinear progressive income tax in an intertemporal model showing that many of the traditional results are changed when nonlinear taxation is introduced into the model.

Budget constraints created by nonlinear income tax are not well-behaved in the sense of standard models. Figure 3.2. presents the budget constraint under a progressive income tax system such as in Finland or in many other countries.

Figure 3.2 **Semi-linear budget constraint**



The budget constraint is piecewise-linear (semi-linear) with non-decreasing marginal tax. This creates a convex budget set. The first budget segment refers to the marginal tax rate t_1 and the net wage $(1-t_1)w$. The second budget segment refers to the marginal tax rate t_2 and the corresponding net wage $(1-t_2)w$, and so on. Corresponding to each budget segment there is a "virtual" non-labour income (y_1,y_2,y_3), and, for example, a person whose hours of work are on segment AB behaves "as if" her non-labour income were the virtual income y_2. If she works more, her net marginal wage decreases and her virtual income increases. If there is significant negative income elasticity, this increase in virtual income can justify the strong disincentive effects of progressive taxation even if the wage elasticity is small.

Blomquist (1988) was the first to systematically study the effects on labour supply of changes in tax parameters in a semi-linear tax system. In the following, we briefly review the main results of Blomquist.

The problem of the consumer is to maximize a strictly quasiconcave utility function u(c,l), increasing in c and locally increasing in l, subject to a nonlinear constraint. To be able to study this case formally we need to define taxable income, tax function and virtual incomes associated with each tax bracket.

Let B_t and B_{nt} be taxable and nontaxable nonlabour income respectively, and E a general exemption. Taxable income can then be written as $x = wh+B_t-E$. Let the income tax be of the form

$$\text{Tax}(x) = \int_0^x t(z)dz, \tag{3.15}$$

where t is an increasing step function such that $t(z) = t_i$ for $A_{i-1} < z \le A_i$, i = 1, ... The slope of the i^{th} segment is $w_i = w(1-t_i)$ and the upper limit of the corresponding interval on the h-axis is $H_i = (A_i + E - B_t)/w$. The intercepts on the c-axis, i.e. the virtual incomes can be calculated by the recursive formula $y_i = y_{i-1} + (w_{i-1} - w_i)H_{i-1} = y_{i-1} + (t_i - t_{i-1})(A_{i-1} + E - B_t)$, 1 = 2, ... If $B_t > E$, but $B_t - E < A_1$, then $y_1 = B_{nt} + E + (1-t_1)(B_t - E) - T$.

Corresponding to each budget segment (H_{i-1}, H_i), we can define the indirect utility function

$$v_i(y_i, w_i, p) = \max \{u(c,l);\ pc + w_i l \le y_i + w_i T\}. \tag{3.16}$$

Properties of the indirect utility function v_i:

$v_i(y_i, w_i, p)$ is continuous at all $y_i > 0$, $w_i > 0$, $p > 0$. (3.17a)

$v_i(y_i, w_i, p)$ is nondecreasing in y_i and w_i and non-increasing in p. That is, if $w_i' \ge w_i$, $v_i(y_i, w_i', p) \ge v_i(y_i, w_i, p)$, and similarly for y_i and p. (3.17b)

$v_i(y_i, w_i, p)$ is homogenous of degree 0 in (y_i, w_i, p). (3.17c)

Proof:

This follows from the theorem of the maximum, see e.g. Varian (1978), pp. 326–327. (3.17a)

For the proof in the case of y_i and p, see Varian (1978), p. 121. (3.17b)

The case of w_i is a little more complicated. Let $B = \{(c,l): pc + w_i(l-T) \le y_i\}$ and $B' = \{(c,l): pc + w_i'(l-T) \le y_i\}$ for $w_i \le w_i'$, $l \le T$. Suppose $(c,l-T) \varepsilon B$. If $pc + w_i(l-T) \le y_i$, then $pc + w_i'(l-T) \le y_i$ because $w_i \le w_i'$. Hence $(c,l-T) \varepsilon B'$. Let $l = 0$, then $c' = y_i + w_i'T \ge c = y_i + w_iT$ at the boundary of the budget set. It follows that B is contained in B'. Hence the maximum of u(c,l) over B' is at least as great as the maximum of u(c,l) over B.

If y_i, w_i, p are all multiplied by a positive number, the budget set doesn't change at all. Thus, $v_i(ty_i, tw_i, tp) = v_i(y_i, w_i, p)$ for $t > 0$. (3.17c)

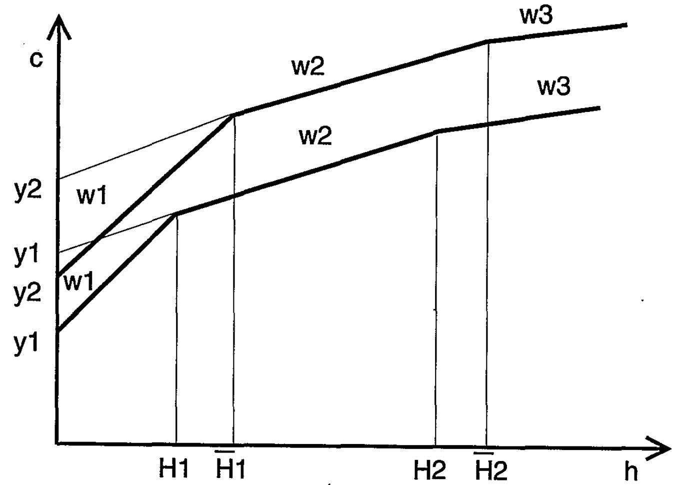
Let us consider the effects on labour supply of variations in E, A_i, t_i and w.

Change of exemption level

An increase in the exemption level E will (figure 3.3):

i) increase all y_i,
ii) not change any w_i,
iii) increase all the H_i.

Figure 3.3 **Change of exemption level**



Proposition 1. If leisure is a normal good, then an increase in the exemption level has the following effects:

i) individuals whose prior optimums are in the intervals $(0, H_1)$ and (H_i', H_{i+1}), i = 1, ... will decrease their labor supply.
ii) individuals with prior optimums in intervals (H_i, H_i'), i = 1, ... may increase or decrease their labour supply. It can increase at most up to the upper limit H_i'.

Proof:

i) there is only an income effect.
ii) Let the original optimum be on segment i+1 in the interval (H_i, H_i'). Suppose (for the purpose of contradiction) that the new optimum is to the right of H_i' on segment i + 1, i + 2, ... Since leisure is a normal good the prior optimum must have been to the right of H_i' on the prior budget constraint, which is a contradiction. Hence the new optimum must be less than or equal to H_i'.

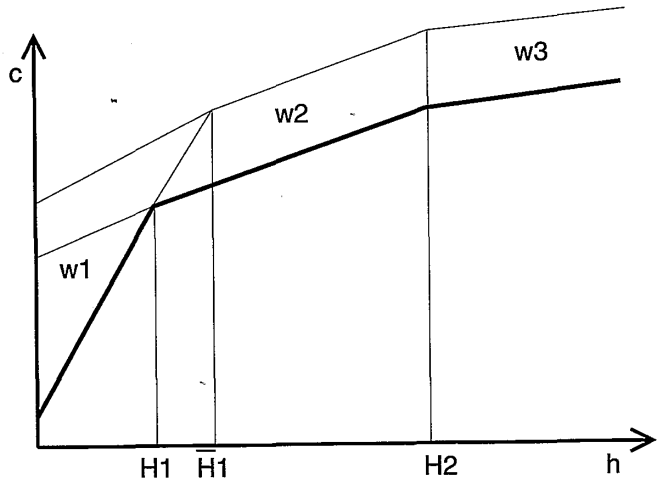
Thus we see that if the exemption level is increased there is a strong tendency for a decrease in labour supply even if some individuals may increase their labour supply. Notice that if the exemption level is increased by dE, the virtual income for tax bracket i will increase by t_i*dE. Hence if we use a linear labour supply function with a constant derivative, the negative income effect from an increase in the exemption level is strongest in the highest marginal tax brackets.

Change of tax bracket limit

An increase in the upper limit A_j of an income tax bracket will (figure 3.4):

i) leave all lower segments unchanged,
ii) increase the value of H_j by dA_j/w,
iii) increase the value of y_i for i = j+1, j+2, ...

Figure 3.4 **Change of tax bracket limit**



Proposition 2: If leisure is a normal good, then an increase in A_j will

i) not change the optimum if it is on any of the segments $i = 1, ..., j.$,
ii) decrease the labour supply if the prior optimum was greater than H_j',
iii) increase or decrease the labour supply if the prior optimum was in the interval (H_j, H_j'). It can increase at most up to H_j'.

Proof:

i)–ii) are obvious
iii) proof is similar to that of part ii) of proposition 1.

Note that an increase only in the first tax bracket limit A_1 will increase the virtual incomes in all income tax brackets by the same amount, $(t_2 - t_1)A_1$. However if all tax bracket limits are increased by an equal amount, the change in virtual income is higher the higher the income tax bracket.

Change of marginal tax rate

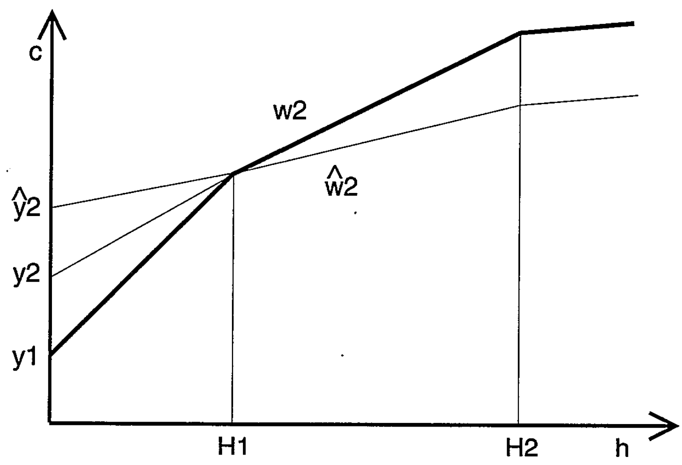
An increase (decrease) of the marginal tax rate for tax bracket j will (figure 3.5)

i) leave segments 1, ..., j−1 unchanged,
ii) decrease (increase) the slope of segment j and increase (decrease) the corresponding virtual income,
iii) decrease (increase) the virtual incomes of segments j+1, j+2, ...

Proposition 3. An increase (decrease) in the tax rate t_j, which leaves the budget constraint convex, will:

i) not change labour supply if the prior optimum was on segment 1, ..., j-1,
ii) increase (decrease) labour supply if leisure is a normal good and the prior optimum is greater than H_j,
iii) might either increase or decrease labour supply if the prior optimum was on segment j. However, if t_j increases, labour supply cannot decrease to less than H_{j-1}. If t_j decreases, labour supply cannot increase to more than H_j nor decrease to less than H_{j-1}.

Figure 3.5 **Change of marginal tax rate**



Note that if we change each marginal tax rate t_j by the same number of percentage points, the change in net wages and virtual incomes for each income tax bracket is the same. However, if we e.g. decrease marginal tax rates more for higher income tax brackets, then the increase in net wages and the decrease in virtual incomes are greater for the higher income tax brackets.

Change of gross wage rate

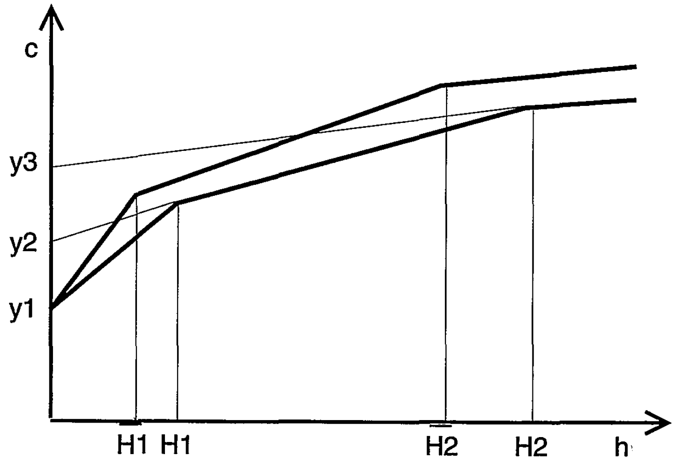
An increase in the gross wage rate will (figure 3.6.):

i) increase the slope of all segments,
ii) decrease the upper limits H_i for all segments,
iii) leave all virtual incomes unchanged.

Proposition 4: An increase of the gross wage rate w has the following effect:

i) if leisure is a normal good and the prior optimum is in an interval (H_i', H_i) and $w_{i+1}(new) < w_i(old)$, then labour supply decreases,
ii) if the conditions in i) are not satisfied, then labour supply might increase or decrease.

Figure 3.6 **Change of gross wage rate**



From the above discussion we see that the comparative statics in the case of a piece-wise linear budget constraint yield a number of predictions about how changes in tax parameters affect labour supply. This is in sharp contrast to the case of proportional taxation where we cannot say much because of opposing income and substitution effects.

3.3 Choosing the labour supply function

In empirical studies of the labour supply one can in general start with the labour supply function and derive the utility function or vice versa. There are several possible criteria which one could emphasize in choosing a functional form for a labour supply function, for example: consistency with utility theory, convenience in estimation, ease of calculation of direct and indirect utility functions or flexibility in the type of response permitted.

The specification of the labour supply is a matter of great importance because of the possibly extreme sensitivity thereto of the estimation results. This problem has clearly received too little attention in the literature and in fact is often completely ignored. However, Stern (1986) contains a detailed analysis of the pros and cons of various functional forms, concentrating especially on two features: the flexibility of response permitted by a function and its use in the analysis of tax reform. Stern's general conclusion is in favour of diversity of functions and great caution in drawing policy conclusions from results based on a particular form.

In this study we use the linear supply function, which has some desirable features in the analysis of female labour supply. One advantage is that the estimation is straightforward, which is significant here because we are interested in testing several statistical assumptions (self-selection, exogeneity assumptions) which could affect the empirical results. The extensive use of linear supply functions in the literature also permits comparisons to other empirical studies. The use of a linear specification can also be motivated as a first order approximation to an arbitrary nonlinear labour supply curve.

Disadvantages of the linear supply function include its inflexible response of h as a function of w and the fact that it is impossible for leisure to be inferior for low l. In addition, the monotonic relation between hours supplied and the wage rate can be restrictive e.g. in the analysis of taxation, as was indicated in section 3.2.

The linear supply function has the form

$$h_i = \alpha_1 w_i + \alpha_2 y_i + Z\beta + \varepsilon_h, \quad h \geq 0, \tag{3.18}$$

where w_i is the net wage on budget segment i, y_i is the virtual nonlabour income, Z is a vector of socioeconomic characteristics and ε_h is a stochastic term. The corresponding direct and indirect utility functions are given by (see Hausman (1981) and appendix 5)

$$u(c,h) = \exp\left[-\left(1 + \frac{\alpha_2(c+(Z\beta+\varepsilon_h)/\alpha_2-\alpha_1/\alpha_2)}{\alpha_1/\alpha_2-h}\right)\right]\left(\frac{h-\alpha_1/\alpha_2}{\alpha_2}\right) \tag{3.19}$$

and

$$c = v(w,y) = \exp(\alpha_2 w)\left(y + \frac{\alpha_1 w}{\alpha_2} + \frac{Z\beta+\varepsilon_h}{\alpha_2} - \frac{\alpha_1}{(\alpha_2)^2}\right). \tag{3.20}$$

The direct utility function is defined and is quasiconcave on the set $\{(h,c): \alpha_1 - \alpha_2 h > 0\}$, which contains the set $\{(h,c): h \geq 0\}$ if $\alpha_1 > 0$ and $\alpha_2 < 0$.

4 The Econometrics of Labour Supply

4.1 The participation decision

The theory discussed in the previous chapter focused on the hours-of-work decision. However, in many situations the decision whether or not to work at all may be as important as the decision regarding the number of hours. Such decisions may be particularly relevant at the beginning and end of the work career and also for females with young children. The basic model can be used in a straightforward manner to analyse the labour force participation decisions of Finnish women, which as argued in chapter 2, has been a matter of major macro-economic importance in Finland.

The participation decision is usually analysed in terms of wage – reservation wage comparisons. The reservation wage (sometimes also called the shadow wage) is the wage rate at which the individual is indifferent between working and not working. In the basic model the reservation wage can be calculated as the slope of the indifference curve at zero working hours, i.e. as the marginal rate of substitution between consumption and leisure at zero hours of work. If the actual wage rate offered is greater than the reservation wage, the individual chooses to work; if it is below the reservation wage, she does not work.

Denote the market wage offer of individual i as w_i and her reservation wage as w_i^r. Then

if $w_i > w_i^r$, the individual chooses to work and
if $w_i < w_i^r$, the individual chooses not to work.

By specifying the functions for w_i and w_i^r, we can estimate the participation decision as a standard probit model. This simple model can be used to analyze many important aspects of female labour supply behaviour. For example, labour force participation rates of married women are usually much lower than the rates for other groups of the same age. One obvious reason for this could be that because of housework, childcare etc., married women obviously have quite high preferences for nonmarket time. In terms of the above model, their indifference curves are steep and their reservation wages are high. Another possible reason for the low participation rates of married women is that the wife treats her husband's earnings as exogenous income when she makes labour supply decisions. Then the husband's earnings have only a negative income effect on the wife's labour supply, and must therefore reduce the participation probability. Thirdly, married women might have lower market wages because of interruptions in labour force participation.

4.2 Estimation techniques for the basic model

The Tobit and Heckit models

We begin with the simplest possible model under the (unrealistic) assumption that measures of the wage rate w are available for all individuals in the population, including nonworkers. Our labour supply function is of the form

$$h_i = \alpha_0 + \alpha_1 w_i + \alpha_2 y_i + Z_i\beta + \varepsilon_{hi} \tag{4.1}$$

where Z_i is a vector of observable taste factors that influence the marginal rate of substitution between leisure and consumption (the reservation wage). Factors such as number of children, education and age are included in Z. The random term ε_{hi} includes unobservable taste factors and measurement errors. We assume ε i.i.d. $N(0, \sigma_h^2)$. Let $J_i = \alpha_0 + \alpha_1 w_i + \alpha_2 y_i + Z_i\beta$.

In our simple model labour supply refers to two intimately connected relationships: a work – not work function based on a comparison between the offered wage and the reservation wage, and an hours-of-work function. In estimating the model we must take account of the fact that there is a lower limit of zero on the dependent variable h_i, i.e. the distribution of h_i is censored. So our complete model is

$$\begin{aligned} h_i &= J_i + \varepsilon_{hi}, \quad \text{if } w_i > w_i^r \text{ or RHS} > 0, \\ h_i &= 0 \text{ otherwise.} \end{aligned} \tag{4.2}$$

Our model can be easily estimated using the standard Tobit analysis (Tobin, 1958). Suppose we have a random sample of $N_1 + N_2$ individuals, N_1 working and N_2 not working. The Tobit likelihood function is given by:

$$L = \pi_{N_1}(1/\sigma_\varepsilon) * \phi\left(\frac{h_i - J_i}{\sigma_h}\right) \pi_{N_2}(1 - \Phi(J_i/\sigma_h)), \tag{4.3}$$

where ϕ denotes the standard normal density function and Φ the standard normal cumulative density function. Thus our basic model can be estimated with the standard algorithms for the Tobit model (for details, see Maddala 1983, pp. 151—156).

Thus far we have ignored the problem of missing wages, i.e. wage data are available for workers only. The most obvious and often used solution to this problem is the "imputed" wage procedure.

We can assume that the wage rate that a given individual i earns (or is capable of earning) is given by a wage function $w_i = w(X_i, \varepsilon_{wi})$, where X_i is a vector of personal characteristics and regional macroeconomic variables which arise from an economic model of wage determination. The wage equation can be estimated for working women and predictions generated by the model can be used for both working and non-working women.

Unfortunately, this procedure entails a potential selectivity bias problem since the imputed wage is based on a least-squares regression using data on workers only. Assume that ε_{hi} and ε_{wi} are joint normally distributed with zero mean. Then the expected value of the wage is (Heckman 1979)

$$\begin{aligned} E(w_i | h_i > 0) &= E[X_i\theta + \varepsilon_{wi} | \varepsilon_{hi} > -J_i] \\ &= X_i\theta + E[\varepsilon_{wi} | \varepsilon_{hi}/\sigma_h > (-J_i/\sigma_h) \\ &= X_i\theta + (\sigma_{wh}/\sigma_h) * \Omega_i, \end{aligned} \tag{4.4}$$

where $J_i = \alpha_0 + \alpha_1 w_i + \alpha_2 y_i + Z_i\beta$,
$\Omega_i = \phi(-J_i/\sigma_h)/[1 - \Phi(-J_i/\sigma_h)]$,
σ_h = standard deviation of h,
$\sigma_{wh} = E(\varepsilon_h \varepsilon_w)$ = covariance between ε_h and ε_w.

A detailed derivation of the above formula is presented in Ilmakunnas & Lahdenperä (1986, appendix 2). We see that unless $\sigma_{wh} = 0$, the least-squares estimates θ of the parameters of the wage function will suffer from sample selection bias.

Another restrictive assumption implicit in the Tobit procedure is that the parameters that determine participation or non-participation are identical to the parameters that determine the hours that participants work. This assumption may be quite unrealistic in estimating labour supply functions.

A more general model of labour supply was suggested by Heckman (1979) and estimated with Finnish data by Ilmakunnas & Lahdenperä (1986). This Heckit procedure extends Tobit to a simultaneous equations system. In Heckman's model of labour supply, wages and hours worked are the two endogenous variables. The model consists of the shadow wage (marginal rate of substitution) equation.

$$w_i^r = \pi_0 + \pi_1 h_i + \pi_2 y_i + Z_i \Gamma + \varepsilon_{ri} \tag{4.5}$$

and the market wage equation

$$w_i = X_i \theta + \varepsilon_{wi}. \tag{4.6}$$

Heckman assumed that hours worked h_i adjust so that $w_i^r = w_i$. Hence we obtain

$$h_i = \frac{X_i \theta - \pi_0 - \pi_2 y_i - Z_i \Gamma}{\pi_1} + \frac{\varepsilon_{wi} - \varepsilon_{ri}}{\pi_1} \tag{4.7}$$

If $h_i \leq 0$ and $(\pi_1 > 0)$

$$\varepsilon_{di} = \varepsilon_{wi} - \varepsilon_{ri} < \pi_0 + \pi_2 y_i + Z_i \Gamma - X_i \theta. \tag{4.8}$$

Assume $\varepsilon_d \sim N(0, \sigma_d^2)$. Then the probability that individual i does not work is

$$\text{Prob }(h_i \leq 0) = \Phi\left(\frac{\pi_0 + \pi_2 y_i + Z_i \Gamma - X_i \theta}{\sigma_d}\right) = \Phi(0) \tag{4.9}$$

Let w_i^r be the reservation wage, as before. Then for the i^{th} working woman the conditional joint distribution of observed hours and wages is

$$j(h_i, w_i | w_i > w_i^r) = \frac{n(h_i, w_i)}{Pr(w_i > w_i^r)}, \tag{4.10}$$

where j(.) is the conditional distribution, n(.) is the unconditional distribution and Pr(.) is the probability of working.

Suppose we have a sample of $N_1 + N_2$ married women, as before, with N_1 working and N_2 not working. Then the likelihood function for Heckman's model can be written as:

$$L = \pi_{N_1} j(h_i, w_i | w_i > w_i^r) * Pr(w_i > w_i^r) * \pi_{N_2} Pr(w_i < w_i^r) \tag{4.11}$$

Using (4.9) and (4.10) we get

$$L = \pi_{i=1}^{N_1} n(h_i, w_i) * \pi_{i=1}^{N_2} \Phi(0). \tag{4.12}$$

By maximizing this likelihood function one obtains consistent, asymptotically unbiased and efficient parameter estimates which are asymptotically normally distributed (see Heckman 1974).

The two-stage estimation method

Heckman (1976, 1979, 1980) has suggested a two-stage method of estimating the model (4.12).

Stage 1. Estimate a probit model for participation. The probit likelihood function is given by

$$L = \underset{\text{workers}}{\pi(1-\Phi(0))} * \underset{\text{non-workers}}{\pi\Phi(0)}, \tag{4.13}$$

$$\text{where } 0 = \frac{\pi_0 + \pi_2 y_i + Z_i\Gamma - X_i\theta}{\sigma_d}.$$

From the probit maximum likelihood estimation we get consistent estimates of the parameters in 0.

Stage 2. Estimate (consistently) the wage equation and the hours-of-work equation. The expected value of the wage rate is

$$\begin{aligned} E(w_i|h_i>0) &= X_i\theta + E(\varepsilon_{wi}|\frac{\varepsilon_{wi}-\varepsilon_{ri}}{\sigma_d}>0) \\ &= X_i\theta + \frac{\sigma_w^2 - \sigma_{wm}}{\sigma_d} * \frac{\Phi(0)}{1 - \Phi(0)}, \end{aligned} \tag{4.14}$$

where $var(\varepsilon_w) = \sigma_w^2$ and $cov(\varepsilon_w,\varepsilon_m) = \sigma_{wm}$. The wage equation can be estimated consistently by using the estimates of the parameters in 0 from the first stage probit maximum likelihood estimation.

Thus the wage equation to be estimated is

$$w_i = X_i\theta + \frac{\sigma_w^2 - \sigma_{wm}}{\sigma_d} * \frac{\Phi(\hat{O})}{1 - \Phi(\hat{O})} + \varepsilon_w^*, \tag{4.15}$$

where ε_w^* is a mean-zero random term.

Similarly, we can derive the expected value of hours worked as follows

$$\begin{aligned} E(h_i) &= -\frac{\pi_0}{\pi_1} + X_i\frac{\theta}{\pi_1} - \frac{\pi_2}{\pi_1}y_i - Z_i\frac{\Gamma}{\pi_1} + E\left(\frac{\varepsilon_{wi}-\varepsilon_{ri}}{\pi_1}|h_i>0\right) \\ &= -\frac{\pi_0}{\pi_1} + X_i\frac{\theta}{\pi_1} - \frac{\pi_2}{\pi_1}y_i - Z_i\frac{\Gamma}{\pi_1} + \frac{\sigma_d}{\pi_1}\frac{\Phi(\hat{O})}{1 - \Phi(\hat{O})}. \end{aligned} \tag{4.16}$$

We estimate the hours-of-work equation in the following form:

$$h_i = \alpha_0 + \alpha_1 w_i + \alpha_2 y_i + Z_i\beta + \alpha_4 \frac{\Phi(\hat{O})}{1 - \Phi(\hat{O})} + \varepsilon_h^*, \tag{4.17}$$

where ε_h^* is a mean-zero random term.

4.3 Estimation with non-linear budget constraint (progressive taxation)

Blomquist (1988) noted that it may be very misleading to draw conclusions about the effects of taxation on the basis of models such as that of the previous section, where the effects of non-linear taxes are not correctly taken into account. Blomuist utilizies the following example to demonstrate this very pedagogically:

Suppose we have the following model:

$$\begin{array}{lll} \max\ u(c,l) = c^{\alpha}(z-h)^{1-\alpha} & & \\ \text{s.t.} & \text{a) budget constraint} & c = wh+y = x \\ & \text{b) tax function} & tax = x-x^{\beta},\ x\geq 1, \\ & 0<\beta\leq 1. & \end{array} \tag{4.18}$$

The so-called basic supply function generated by the linear budget constraint is:

$$h = \alpha z - (1-\alpha)*y/w. \tag{4.19}$$

The so-called mongrel supply function generated by the nonlinear budget constraint is:

$$h = \frac{\alpha\beta z}{1 - \alpha + \alpha\beta} - \frac{(1 - \alpha)y}{1 - \alpha + \alpha\beta)w} \tag{4.20}$$

If we estimate a linearized labour supply function

$$h = b_0 + b_1w + b_2y, \tag{4.21}$$

the conclusions that can be drawn on the basis of the estimated coefficients are clearly not the same in models (4.19) and (4.20). The cofficients b_0, b_1 and b_2 will depend on individuals' preferences, the functional form of the tax function, and the tax parameters.

The problem of estimating labour supply functions in the case of nonlinear taxation is a complicated task which imposes some technical and statistical problems. Several different approaches have been suggested and applied in the literature. In the following, we will review some of these methods and indicate where they have been applied.

The Instrumental Variables Approach

The pioneering study on the effects of taxation on labour supply was the study by Kosters (1969), who assumed a proportional individual income tax. Hall (1973) was one of the first researchers to take progression explicitly into account. Hall replaced the true nonlinear budget constraint with a straight line tangent to the true constraint at the point of actual hours of work. Instead of the gross wage rate and non-labour income, he included the marginal tax rate and virtual income, defined as the intercept of the linearised budget set at zero hours of work, in his regressions. This methodology was used in several other studies in the 1970s, e.g. Boskin (1973), Wales & Woodland (1976). It has also been applied to Finnish data by Pulli (1985).

Although this procedure is appropriate for the non-stochastic case it introduces two problems in the stochastic case (Wales & Woodland, 1979):

1) The observed net wage rate is itself endogenous, since it depends on the number of hours worked, and is therefore correlated with the disturbance term. Thus OLS will give inconsistent parameter estimates.
2) Although an individual may be observed to be on a given segment of a piecewise-linear constraint, this observed position is the sum of two components — the utility maximizing position plus a random disturbance. Hence her true utility maximizing position may be on a segment of the piecewise linear constraint other than the observed one. In this case the net wage rate that should be

used in the labour supply equation is the one corresponding to the utility maximizing position, not the observed one.

A straightforward way to try to solve the endogeneity problem is to estimate a simultaneous equation model relating hours worked to the marginal (net) wage rate. Taking into consideration the participation decision we are faced with the following simultaneous equations model with selectivity:

$$w_{ni} = X_i\theta + \alpha_1 y_i + \varepsilon_{wi}, \tag{4.22}$$

$$y_i = G_i\Gamma + \alpha_2 w_{ni} + \varepsilon_{yi}, \tag{4.23}$$

$$h_i = Z_i\beta + \alpha_3 w_{ni} + \alpha_4 y_i + \varepsilon_{hi}, \tag{4.24}$$

if $h_i > 0$,

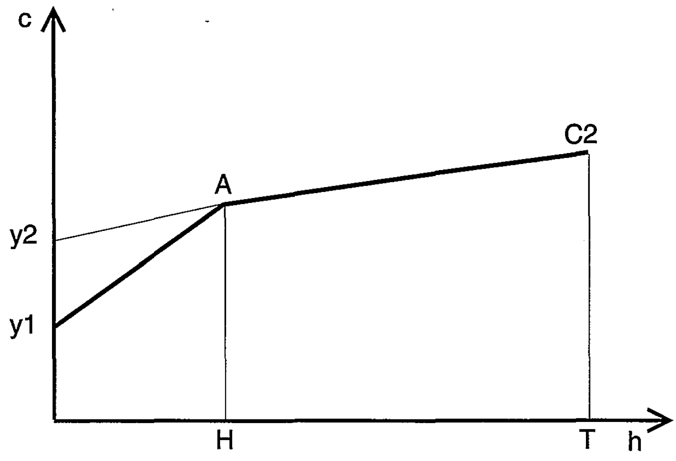
where w_{ni} is the net marginal wage,
y_i is the corresponding virtual income and
h_i is the hours worked by individual i.

Simultaneous equation models to estimate labour supply have been used by e.g. Leuthold (1985) and Merz (1989). However, Leuthold ignores the selectivity rule in her study. Merz takes selectivity into account but ignores endogeneity of virtual income.

The ordered probit model

To simplify the exposition, we consider a budget constraint with only two segments (figure 4.1). A consumer may occupy one of the four states of the world in this model: zero hours of work at point y_1, the first budget segment y_1A, the kink point A or the second budget segment Ac_2.

Figure 4.1 **The two-segment budget constraint**



As a consequence of convexity of preferences and the constraint set, a local comparison of the marginal rate of substitution function and the net wage at the kink points determines the location of an individual on the budget set. The individual chooses not to work if

$$m(y_1,0,\varepsilon) \geq (1-t_1)w. \tag{4.25}$$

The consumer works in the interval (0,H) if

$$m(y_1,0,\varepsilon) < (1-t_1)w \text{ and } m(y_2,H,\varepsilon) > (1-t_1)w. \tag{4.26}$$

The consumer is in equilibrium at kink A if

$$(1-t_1)w \geq m(y_2,H,\varepsilon) \geq (1-t_2)w. \tag{4.27}$$

Finally, the consumer is at an interior solution in the interval (H,T) if

$$(1-t_2)w > m(y_2,H,\varepsilon). \tag{4.28}$$

Thus the hours of work corresponding to each state i (i = 1,2,3,4) are:

$$
\begin{aligned}
h_1 &= 0, \\
h_2 &= H(y_1,(1-t_1)w,\varepsilon), \\
h_3 &= H, \\
h_4 &= H(y_2,(1-t_2)w,\varepsilon).
\end{aligned}
$$

To set up an explicit econometric model we assume:

$$
m(y,H,\varepsilon) = m_0 + m_1y + m_2H + \varepsilon. \tag{4.29}
$$

Then the conditions above can be rewritten:

$$
\begin{aligned}
&\varepsilon \geq -m_0-m_1y_1+(1-t_1)w, \\
&(1-t_1)w-m_0-m_1y_2-m_2H < \varepsilon < (1-t_1)w-m_0-m_1y_1, \\
&(1-t_1)w-m_0-m_1y_2-m_2H > \varepsilon > (1-t_2)w-m_0-m_1y_2-m_2H, \\
&\varepsilon < (1-t_2)w-m_0-m_1y_2-m_2H.
\end{aligned} \tag{4.30}
$$

Assume $\varepsilon \sim N(0,\sigma_m^2)$. Then the likelihood function for this sample is:

$$
L = \pi\Phi(\theta_0)*\pi[\Phi(\theta_1)-\Phi(\theta_0)]*\pi[\Phi(\theta_2)-\Phi(\theta_1)]*\pi[1-\Phi(\theta_2)], \tag{4.31}
$$

where
$$
\begin{aligned}
\theta_0 &= [m_0+m_1y_1-(1-t_1)w]/\sigma_m, \\
\theta_1 &= [m_0+m_1y_2+m_2H-(1-t_1)w]/\sigma_m, \\
\theta_2 &= [m_0+m_1y_2+m_2H-(1-t_2)w]/\sigma_m.
\end{aligned}
$$

The model is known as an ordered probit model (see Maddala 1983, pp. 46–49). The ordered probit model does not utilize any data on hours of work as such; all that is required for the analysis is categorical data on the individual's location on the budget constraint. As such, this approach wastes information and hence is inefficient.

The model can be extended to utilize hours-of-work information too. Assume that $m(y,H,\varepsilon)$ is monotonically increasing in ε. Define ε_1^*, ε_2^* and ε_3^* as those values of ε satisfying

$$
\begin{aligned}
m(y_1,0,\varepsilon_3^*) &= (1-t_1)w, \\
m(y_2,H,\varepsilon_2^*) &= (1-t_1)w, \\
m(y_2,H,\varepsilon_1^*) &= (1-t_2)w.
\end{aligned} \tag{4.32}
$$

By the monotonicity assumption, $\varepsilon_1^* < \varepsilon_2^* < \varepsilon_3^*$. Thus conditions (4.32) define the regions:

$$S_1 = [\varepsilon:\varepsilon_3^* \leq \varepsilon]; \qquad S_2 = [\varepsilon:\varepsilon_2^* < \varepsilon < \varepsilon_3^*]:$$
$$S_3 = [\varepsilon:\varepsilon_1^* \leq \varepsilon \leq \varepsilon_2^*]; \qquad S_4 = [\varepsilon:\varepsilon \leq \varepsilon_1^*].$$

Define the density of ε as $f(\varepsilon)$. The probability that a consumer is in state i is:

$$Pr(\varepsilon_{Si}^{in}) = \int_{S_i} f(\varepsilon)d\varepsilon. \tag{4.33}$$

The expected hours of work of a consumer who is known to be in state i are:

$$E(h|\varepsilon_{S_i}^{in}) = E(h_{(i)}|\varepsilon_{S_i}^{in} = \frac{\int h_{(i)} f(\varepsilon)d\varepsilon}{Pr(\varepsilon_{S_i}^{in})} \tag{4.34}$$

The expected hours of work for a randomly chosen individual are:

$$E(h) = \sum_{i=1}^{4} E(h_{(i)}|\varepsilon_{S_i}^{in}) * Pr(\varepsilon_{S_i}^{in}). \tag{4.35}$$

This model has a very close similarity to the Heckman model presented in section 4.2. In order to avoid sample selection bias in estimating structural labour supply functions, one must account for the conditioning that generates the observations (i.e. the particular branch or corner on which an observation is situated). In this case, correcting for potential sample selection bias means correcting for the endogeneity in tax rates and unearned income levels. A straight forward modification of Heckman's two-step procedure can be used for this.

The crucial assumption behind the two-step procedure in this case is that hours worked are measured without error, i.e. measured hours are also optimal hours. If this assumption is violated, we can no longer place the individual on the correct segment of the budget constraint, i.e. a misspecification error is present. For this reason this approach is feasible only with a small number of budget segments. The assumption behind this procedure becomes more and more doubtful as the number of budget segments increases. This approach has been utilized by Zabalza (1983) in a model with only two budget segments.

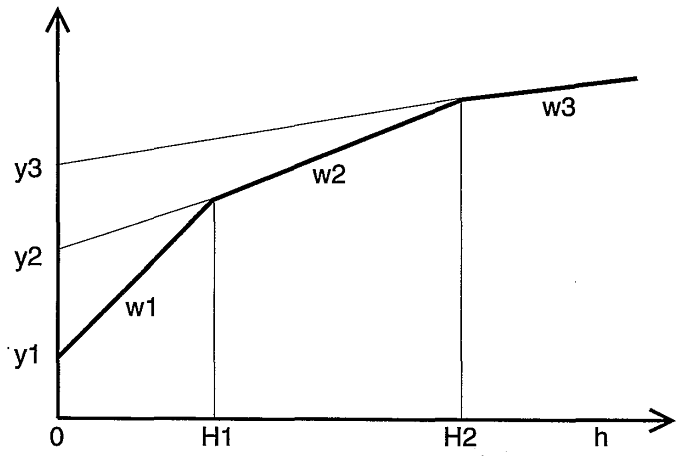
The Hausman-Blomquist approach

All the models presented above are vulnerable to the criticism presented particularly by Hausman (1979, 1981) and Blomquist (1983, 1988) that such models fail to take into account the nature of the entire budget constraint. With semi-linear, progressive taxation, an individual's optimum labour supply can be located at one of the budget segments, at zero hours of work, at a corner point or at one of the kink points. Therefore, we should look for procedures that locate the individual's optimum by checking the entire budget constraint, including both flat segments and kink points.

Hausman (1979) has presented a straightforward econometric estimation procedure in the case of purely convex budget sets. These are created by strictly progressive income tax systems. However, certain social programs, transfer payment systems, negative income tax schemes and entry costs generate nonconvex budget constraints. These are considerably more difficult to estimate than the convex case because of the possibility of joint tangencies between an indifference curve and the budget set.

For the convex case, consider the budget constraint in figure 4.2, where the net wage on segment i is $w_i = w(1-t_i)$, the corresponding virtual nonlabour income is y_i, constructed by extending the budget segment back to the vertical axis.

Figure 4.2 **The convex budget constraint**



Following Hausman (1979) consider the econometric specification of labour supply

$$h_i = \alpha_0 + \alpha_1 w_i + \alpha_2 y_i + Z\beta + \varepsilon = h_i^* + \varepsilon, \tag{4.36}$$

where w_i is net hourly wage on budget segment i, y_i is virtual income of budget segment i, Z is a vector of socioeconomic variables, $\alpha_0,\alpha_1,\alpha_2,\beta$ unknown coefficients and ε is a stochastic term which represents the divergence between desired hours h^* and actual hours. We assume the individual's preferences are strictly convex. Since the budget set is also convex, this assumption quarantees that there exists a unique global utility maximum.

We now study how the optimum can be found. For each extended segment of the individual's budget constraint we compute $h_i^* = g(w_i,y_i)$, where h_i^* is optimum hours given the budget line (w_i,y_i). If $H_{i-1} \leq h_i^* \leq H_i$, h_i^* is feasible and represents a tangency of the indifference curve with the budget segment i. It must also be the unique global optimum. If h_i^* is not on budget segment i, then the optimum must be on some other segment, at a corner or at one of the kinks.

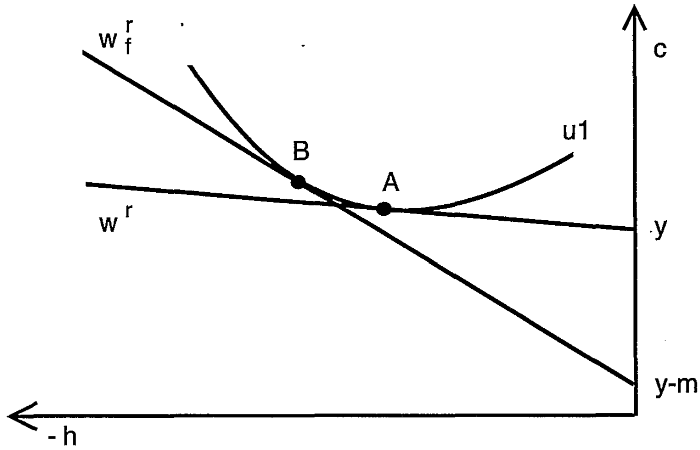
Due to the uniqueness of the optimum, we don't have to compute all the h_i^*. First, compute $h_1^* = g(w_1,y_1)$. If $h_1^* < 0$, then we have a corner solution at zero, and $h^* = 0$. If $0 \leq h_1^* \leq H_1$, then h_1^* is the global optimum h^*. If $h_1^* > H_1$, we go to segment 2 and compute h_2^*. If $h_2^* < H_1$, then we have a kink solution and $h^* = H_1$. If $H_1 \leq h_2^* \leq H_2$, then $h^* = h_2^*$. If $h_2^* > H_2$, we go to the next segment and continue the search for the optimum in a similar fashion. We need to compute all the h_i^* only when the tangency occurs on the last segment or at maximum hours T.

4.4 Estimation with non-convex budget constraint (fixed costs of working)

The Tobit and Heckman models, if not estimated by multi-step procedures, can be quite restrictive because they constrain the sorting equation to have the same parameters as the equations describing the continuous parameters. This can be seen from the Tobit and Heckit likelihood functions (4.3) and (4.11), where the probability that a woman works depends only on the parameters from the wage and hours equations. If there are costs of entry into the labour market this assumption is no longer valid.

Assume that if a woman works, she must pay a fixed entry cost f; if she doesn't work, she doesn't have to pay it. This case is depicted in Figure 4.3. In the diagram w^r is the reservation wage without fixed costs and w_f^r is the reservation wage with fixed costs. We see that there are two significant implications of fixed working costs. First, a woman is not willing to work below some minimum number of hours per period, termed reservation hours. Secondly, the reservation wage is no longer equal to the shadow price (value) nonworkers assign to their time. It is obvious that $w_f^r > w^r$. We see that fixed costs impose a discontinuity on the labour supply schedule and we no longer have a tight relationship between the participation rule and the hours and wage equations.

Figure 4.3 **Labour supply with entry cost**



The effects of money costs of entry on participation and hours of work among workers are obvious. A fixed entry cost acts as a tax on participation and reduces the participation probability. An increase in the entry cost has a pure income effect on labour supply and will therefore increase the hours of work, assuming leisure is a normal good. However, we are also interested in the effects of money costs of entry on reservation hours. Cogan (1981) has established that in the case of an upward sloping labour supply curve an increase in the money cost of work will increase the reservation hours.

If the amount of entry costs is known, the analysis of labour supply is quite simple. With fixed costs f, we define the indirect utility v(y-f,w,p) as

$$v(y-f,w,p) = \max \{u(c,l);\ pc+wl \leq y-f+wT\}. \tag{4.37}$$

A woman will work if the maximum utility attainable when she works, given wage rate w and exogenous income net of fixed costs y-f, is greater than the utility attainable if she does not work, $u^0(y,p)$. Given the indirect utility function v(y-f,w,p), the hours of work function h(y-f,w,p) can be solved using Roy's identity. Thus, the complete model of labour supply under fixed costs would consist of a participation equation and a pair of equations for hours of work, that is,

$$
\begin{aligned}
&\Pr(\text{i works}) = \Pr[v_i(y-f,w,p)>u_i^0(y,p), \\
&h_i = h_i(y-f,w,p) \quad \text{if } v_i>u_i^0 \text{ and} \\
&h_i = 0 \quad \text{if } v_i \leq u_i^0.
\end{aligned} \tag{4.38}
$$

As noted in section 4.2, this kind of a model can be estimated by a two-stage method where the participation equation is first estimated by a probit model and then the selectivity corrected hours-of-work equation is estimated by ordinary least squares. Given information on the amount of entry costs we can estimate the structural parameters of not only the labour supply function but also the costs-of-work function.

On the other hand, if information on costs of work is not available, one can only obtain estimates of a quasi-reduced form labour supply function. However, Cogan (1981) has shown that under some not so restrictive assumptions it is possible to estimate labour supply functions and the mean reservation hours, even when entry costs are not directly observable in the data. Heckman (1974) and Hausman (1980) have also analyzed labour supply under fixed costs, but their models are based on stricter assumptions than Cogan's model.

There are several possible ways to characterize the labour force participation decision in the case of fixed costs of working. One can compare the utility of working with the utility of not working, actual wage with reservation wage or actual hours with reservation hours. The approach used by Cogan (1981) is to formulate the model in terms of a comparison between actual hours of work h^s and reservation hours h^r. The reduced form hours, reservation hours and wage equations can be written as

$$
\begin{aligned}
&h^s = \alpha_0 + \alpha_1 w + Z_1\beta + \varepsilon_s, \\
&h^r = \tau_0 + Z_1\Gamma + \varepsilon_r, \\
&w = Z_2\theta + \varepsilon_w.
\end{aligned} \tag{4.39}
$$

If the labour supply curve is upward sloping, we observe

$$
\begin{aligned}
&h = h^s \qquad h^s>h^r \\
&h = 0 \qquad \text{otherwise.}
\end{aligned}
$$

The likelihood of the data consisting of N_1+N_2 observations, N_1 of them nonworking women, is

$$L = \pi_{N_1} \{1 - \Pr[(1/\sigma_u)[u<(\alpha_0-\tau_0)+Z_2(\alpha_1\theta)+Z_1(\beta-\Gamma)]]\}$$

$$\pi_{N_2} \{\Pr[(1(\sigma_u)[u<(\alpha_0-\tau_0)+Z_2(\alpha_1\theta)+Z_1(\beta-\Gamma)], \qquad (4.40)$$

$$h=\alpha_0+Z_2(\alpha_1\theta)+Z_1\beta+\alpha_1\varepsilon_w+\varepsilon_s,\ w=Z_2\theta+\varepsilon_w]\},$$

where $u = \varepsilon_r+\alpha_1\varepsilon_w+\varepsilon_s$ and

$$u \sim N(0,\sigma_r^2+\sigma_s^2+\beta^2\sigma_w^2-2\sigma_{rs}-2\alpha_1\sigma_{rw}+2\alpha_1\sigma_{sw}).$$

The likelihood function with a trivariate density in the second part is extremely burdensome to estimate. However, estimation of the model can be simplified by using Heckman's multi-step procedure. We first estimate the probit equation for participation which is the first term in each part of the likelihood function and calculate lambda (Mill's ratio term). Next, we estimate the wage equation using lambda — this gives consistent estimates of θ. The likelihood function conditional upon estimated values of the wage equation parameters collapses to one which is identical to that proposed by Nelson (1977) for models with unobserved stochastic censoring thresholds. This is the model Cogan estimated. The key condition for identification in this case is that there is at least one variable in Z_2 not included in Z_1.

However, we can also estimate the hours-of-work equation by Heckman's method. Given θ from the wage equation, we estimate the hours-of-work equation using lambda by TSLS. Finally, given consistent estimates from probit and wage and hours equations, we can identify Γ for the reservation hours equation. For identification we need at least two variables in Z_2 not included in Z_1 — one to identify w and one to identify lambda.

5 Data

The empirical analysis is based on two data files, the Labour Force Survey (LFS) of 1980 and the Population and Housing Census (PHC) of 1980, which were merged by the Central Statistical Office of Finland. The LFS provides information on labour force participation, employment, unemployment and hours worked. It is a random sample stratified by region, age group and sex. The gross sample contains information on 9330 individuals. The PHC provides information on components of income, taxation and personal characteristics, not only on persons included in the sample but also on those who share the same dwellings. The variables measuring income are collected for the most part from registers, the principal one being the register on tax-files.

In this study we concentrate on a subsample of married women aged 25—54 years. As was shown in chapter 2, the increase in labour force participation rates in Finland has been especially pronounced for married women in the most active working age group. Our primary data consists of 1656 married women, who were not self-employed, pensioners or disabled.[1]

In a cross-section survey the question of data accuracy is always of prime importance. In our data this concern arises mainly in regard to the variable measuring hours worked during the year, which was constructed from the number of hours worked during the survey week and number of months spent working during the year. It is to be expected that substantial error is present in this variable due to misunderstanding of the survey, coding errors etc. It is not possible to detect even the most serious measurement errors by simply examining the data on hours worked because the only a priori boundaries we have for the variable are zero and some maximum amount of time available for work and leisure for the whole year.

Measurement errors in hours worked also taint the wage data because hourly wages were calculated by dividing yearly earnings by the calculated working hours for the year. Careful inspection of the calculated hourly wage data reveals several potential outlier observations which have either unrealistically high or low hourly wages. If

[1] We have also excluded from our sample some logically impossible observations, i.e. those who have reported no hours worked but have a substantial amount of labour income.

we plot hourly wage rates against hours worked we see that there are some observations with very high wage rates, particularly at the lower end of the hours distribution. The effect of these observation can also be seen in table 5.1, which contains sample statistics on computed hourly wage rates and unearned income by hours worked for the original 1309 observations. The mean hourly wage rates among those working less than 800 hours during the year are unrealistically high.

Table 5.1 **Sample statistics by hours worked (means, standard deviations)**

distribution of hours worked	cases	hourly wage	unearned income
not working	347	...	4394.8
			(8250)
0–400	35	94.32	4628.8
		(122.7)	(4194)
400–800	51	33.07	6138.6
		(19.25)	(15932)
800–1200	101	22.95	3985.7
		(10.15)	(11182)
1200–1600	110	23.85	2326.2
		(13.55)	(2300)
1600–2000	357	22.48	1758.4
		(8.10)	(1638)
2000–2400	632	17.12	1608.2
		(4.58)	(1983)
2400–	23	11.84	1764.2
		(4.79)	(1053)
all workers	1309	22.19	2153.0
		(24.81)	(4903)

The effect of these outlier observations can also be seen from the results of an estimated wage equation for this sample. A typical human capital-type wage function is presented in appendix 2. Hourly wage rate is assumed to depend on education, age, work experience, occupation and place of residence. The fit of this wage equation is poor, and the standard errors of estimates are large. Further, some variables behave strangely, e.g. hourly wages decrease when work experience increases.

The problem of outlier observations can also be seen by looking at the plot of wage distribution. The actual wage distribution in our sample seems to range from about 6 marks per hour to nearly 60 marks per hour, with observations outside this range qualifying as outliers. The distribution of unearned income also shows some peculiarities. It would be expected that mean unearned income would fall more or less monotonically as hours worked increase, but in our sample there is a big jump in mean unearned income for those working 400–800 hours per year. This is difficult to explain.

Because the problems with our data are due to unsystematic measurement errors we can hardly utilise a heteroscedasticity model to improve the quality of our estimates. However, we can use supplemental information on hourly wage rates to remove at least the most obvious outlier observations from the data.

The average hourly wage rate in our sample of 1309 individuals is 22.19 marks which is high compared to average earnings per hour of female industrial workers, which was 16.22 marks in 1980 according to the wage statistics of the Central Statistical Office of Finland. Part of this difference could be due to conceptual differences and underestimation of working hours. It is likely that hours worked are underestimated in our data because there is no separate information on overtime work. However, it is also likely that the average wage in our sample is overestimated because of outliers with unrealistically high actual wages.

We can use government and municipality salary tables to get reasonable estimates of the lowest and highest hourly wages in the public sector in 1980. According to these tables, the maximum wage rate that could be paid in the public sector was in the range of 60–70 marks per hour. Even this wage level is rather high since females with doctor's degrees had average wages in the range of 41–50 marks per hour in general government, depending on the degree field. The lowest reasonable wage in general government (paid to a temporary worker) was about 10 marks an hour. However, in the private sector even lower wages could be paid. There was no legislated minimum wage in Finland in 1980. Earlier in the 1970s the labour market organizations had agreed on minimum wages, the last being 6.90 marks per hour, set in 1976.

We have rejected outliers with hourly wages greater than 60 marks or less than 6.90 marks or, if employed in general government, less than 10 marks. Using supplemental information on hourly wages in 1980 as presented above, all these observations could be classified as having unreasonably high or low wage rates. After these deletions, we were left with 1 588 observations, of which 1 241 (78 %) work and 347 (22 %) have zero hours of work.

Table 5.2 **Sample statistics by hours worked: corrected data (means, standard deviations)**

distribution of hours worked	cases	hourly wage	unearned income
not working	347	...	4394.8
			(8250)
0—400	17	30.08	5680.6
		(11.57)	(4873)
400—800	46	30.84	4185.9
		(13.26)	(5531)
800—1200	98	22.77	3976.4
		(8.88)	(11338)
1200—1600	103	24.33	2324.6
		(11.54)	(2357)
1600—2000	351	22.60	1741.7
		(7.65)	(1643)
2000—2400	611	17.45	1569.7
		(4.26)	(1991)
2400—	19	13.85	1431.2
		(4.71)	(1098)
all workers	1241	20.53	2022.7
		(8.01)	(3931)

Sample statistics by hours worked for our final data are presented in table 5.2. Over 60 per cent of those in our sample work between 1 600 to 2 400 hours a year, which usually means working about 35—40 hours per week for the whole year. This is a typical feature of the Finnish labour market. According to the 1984 Labour Force Sample Survey, only about 13 % of employed women were working part-time (1—29 hours per week). However, according to recent surveys, one third of married female wage-earners were willing to work part-time. Thus it seems clear that individuals in the Finnish labour market face restrictive constraints on their choice of working hours. Nonetheless, in this particular subsample the variation in hours worked is considerably greater than for unmarried women or men.

The mean wage rate among workers in our sample is 20.53 marks per hour, which is more in line with supplemental statistical information about female wage rates in 1980 than is the original data set. The mean wage rates among those working less than 800 hours per year are still considerably higher than for those working more than 2 000 hours per year. Part of this strong negative correlation between hours worked and hourly wage rates may be due to further measurement error in our data. One problem we have is that for part-time and irregular workers hours worked yearly are normally effective working hours, whereas for full-time workers our hours worked variable includes vacation hours. This will probably introduce a spurious negative bias in the estimated wage elasticity.

Another problem arises when we calculate the average hourly wage by dividing yearly labour income by hours worked during the year. If there are errors in measured hours worked, this procedure introduces a spurious negative relationship between measured hours worked and measured wage rate that is independent of the labour supply model, i.e. the measurement problem probably adds further negative bias to the estimated wage elasticity.

One possible way of correcting these spurious correlations is to use the hourly wage rate as an instrument in the labour supply equations. The natural instruments to use for wages are predictions from a typical wage equation based on human capital theory. Another reason for using predicted wages is that we do not know the market wages of women who don't work. For non-participants we use predictions from a participants' wage equation as an instrument for the actual wage in the labour supply equations.

The results of the estimated wage equation are given in Appendix 3. The inverse of Mills' ratio (lambda) has been included in this equation to correct for possible sample selection bias. The fit and the efficiency of the estimates is much better in this case where outliers have been deleted from the sample. Selectivity has such an important effect on the parameters in the wage equation that we use estimates from the selectivity-corrected regression to calculate predicted wages, which are used in place of actual wages as an explanatory variable in the hours-of-work regressions.

The main explanatory variables behave in the expected way. Hourly wage rates rise with education and work experience. The effect of education is large. Women with graduate education earn over 15 marks an hour more than women with only basic education. The effect of work experience on hourly earnings seems to be highest at the beginning of the work career. During the first 6—9 working years the hourly wage rises by over 4 marks an hour. After that the rise in hourly wages slows down considerably.

The major difference between the selectivity-corrected and uncorrected (not shown) equations is that in the former work experience has a much greater influence on hourly wage rates. This is probably due to work experience having a concave effect on hourly wage. When the probability of participating increases significantly with work experience in the uncorrected regression we estimate the higher part of work experience only. The effect of education on hourly wages also increases when selectivity is taken into account.

Regional differences in wage rates seem to be quite insignificant. Technical, pedagogic, administrative, transport and communications work are highly paid, whereas hourly wages in the textile and private service sectors are low.

6 Estimation Results

6.1 Results from estimating the basic model

Table 6.1 shows the results of the probit analysis, which gives the probability that a woman works. We have estimated with two different specifications, an overidentified labour supply function and an exactly identified one. The first model is overidentified in the sense that more than one variable that appears in the wage equation does not appear in the structural labour supply equation. Mroz (1985) finds that estimated wage elasticities tend to be higher in exactly identified labour supply functions than in overidentified ones. Our results are the opposite and hence cast some doubt on the generality of Mroz's results.

The results of probit equation agree with the simple reservation wage model presented above. The probability of participating increases with wages in both specifications, and the coefficient of unearned income has the expected negative sign (i.e. leisure is a normal good).

As might be expected, having children reduces the participation probability considerably, with children under three years having an additional negative effect. However, this model does not allow us to identify the exact link between children and participation. The presence of children may reduce participation probability if it changes the woman's preferences between work and leisure. But children also bring about costs of day-care which may also reduce the participation probability. It is also to be expected that both these effects are strongest when children are young. Further, it woud seem that the higher the socio-economic status of husband, the lower the participation probability of the wife. The socio-economic status of husband may be interpreted as a proxy for his income, which would be expected to reduce the participation probability. It may also be the case that husbands with higher socio-economic status have better career possibilities and this is reflected in the division of labour within the family.

Increases in work experience have a very large positive effect on the probability of participating. Furthermore, we can clearly reject the hypothesis that work experience can be treated as an exogenous variable in the participation decision. This result is similar to that of Heckman (1977, 1978, 1980) and Mroz (1985). This result probably points to the dynamic nature of labour supply decisions. As already argued in chapter 2, persons employed in period t-1 have a very high probability of being employed also in period t.

Table 6.1 **Analysis of participation**

	probit1		probit2	
constant	-0.835	(4.56)	-0.876	(3.59)
wage (pred.)	0.132	(12.51)	0.078	(3.41)
unearned income (1000 Fmk)	-0.031	(4.18)	-0.022	(3.21)
no. of children	-0.106	(2.52)	-0.110	(2.49)
youngest child				
0–2 years	-0.807	(7.89)	-0.703	(6.26)
3–6 years	-0.230	(2.17)	-0.130	(1.16)
socioeconomic status of husband				
employer	-0.702	(2.66)	-0.728	(2.75)
own-account worker	-0.357	(2.02)	-0.347	(1.92)
upper-l. employee	-0.624	(5.19)	-0.401	(3.02)
lower-l. employee	-0.137	(1.33)	-0.134	(1.24)
education				
upper 1st level			0.077	(0.45)
2nd level: lower			0.253	(2.29)
2nd level: upper			0.415	(1.81)
3rd level: lower			0.511	(1.74)
3rd level: undergr.			-0.183	(0.41)
3rd level: graduate			0.367	(0.62)
work experience				
6–9 years			0.414	(2.50)
10–14 years			0.917	(4.63)
15–19 years			0.983	(4.35)
20– years			1.164	(4.54)
region				
inner Helsinki area			-0.063	(0.54)
outer Helsinki area			-0.067	(0.25)
other great towns			0.040	(0.33)
number of observations	1588		1588	
log-likelihood	-651.49		-619.35	
chi-squared (9/22)	364.48		428.76	
correct predictions, %	82.4		82.9	

estimation procedure	wage elasticity	income elasticity
probit1	+ 0.841	- 0.027
probit2	+ 0.498	- 0.020

At the bottom of Table 6.1 we present wage and income elasticities calculated from the probit equations. The formulas for the probit and tobit elasticity calculations are given in Appendix 6. All elasticities are evaluated at sample means.

The wage elasticity in the participation equation is 0.84 in the first and 0.50 in the second equation. The wage elasticity is similar or somewhat greater in magnitude to those typically found in Sweden (Gustafsson & Jacobsson, 1983), Great Britain (Layard & Barton & Zabalza, 1980, Greenhalgh, 1980) and in the United States (Schultz, 1980). In Ingberg & Lahdenperä & Pulli & Skurnik (1986) the estimated wage elasticity for married women is 0.74. In that study it was shown that an estimated wage effect of this magnitude can explain most of the increase in women's participation in Finland since 1970.

On the other hand, income elasticity is very low compared to those obtained in international studies. The low income elasticity obtained in this as well as other Finnish studies may result from several factors. In our data the nonlabour income variable is underestimated because we have no data on tax-free capital income. Furthermore, the mean level of unearned income in Finland is so low that in practice very few are able to live outside the labour force without substantial social security benefits.

Next we look at hours worked by participants and non-participants, i.e. the tobit model. Estimates in the tobit equation have the same sign as the logit estimates. In the first model the wage coefficient is large and positive; the exogenous income coefficient is negative and also highly significant.

The uncompensated wage elasticity in the first tobit model is 0.637 and the income elasticity is -0.056. With regard to the estimated wage elasticity the results are in line with many other studies (Rosen (1976)–Cogan (1980)–Schultz (1980)–Layard, Barton & Zabalza (1980)) which also yield large estimates for the uncompensated wage effect. Rosen's wage elasticity was as high as 2.3 for yearly hours. In Schultz also the wage elasticities are larger than in this study for all age groups except women aged 35–44 years. In Layard & Barton & Zabalza the estimated wage elasticity is 0.49, and income elasticity is -0.04. Thus we note that our tobit estimates of wage and income elasticities are well in line with international studies.

Table 6.2 **Analysis of hours of participants and non-participants**

	tobit1		tobit2	
constant	642.54	(6.79)	286.45	(2.15)
wage (pred.)	63.66	(13.17)	18.27	(1.61)
unearned income (1000 Fmk)	-40.41	(6.59)	-30.52	(5.36)
no. of children	-51.98	(1.97)	-58.77	(2.30)
youngest child				
0—2 years	-713.30	(10.28)	-558.76	(7.94)
3—6 years	-224.83	(3.46)	-100.93	(1.57)
socioeconomic status of husband				
employer	-556.87	(3.21)	-531.45	(3.23)
own-account worker	-334.10	(2.99)	-310.29	(2.91)
upper-l. employee	-545.22	(7.27)	-322.73	(4.27)
lower-l. employee	-148.48	(2.46)	-148.93	(2.54)
education				
upper 1st level			43.93	(0.47)
2nd level: lower			152.58	(2.44)
2nd level: upper			375.32	(3.21)
3rd level: lower			396.82	(2.59)
3rd level: undergr.			244.08	(1.07)
3rd level: graduate			381.73	(1.38)
work experience				
6—9 years			617.35	(5.84)
10—14 years			1132.83	(9.71)
15—19 years			1200.40	(9.32)
20— years			1241.85	(8.87)
region				
inner Helsinki area			-15.73	(0.25)
outer Helsinki area			-26.98	(0.17)
other great towns			21.26	(0.32)
sigma	922.48	(46.63)	872.21	(46.77)
number of observations		1588		1588
log-likelihood		-10595		-10510

estimation procedure	wage elasticity	income elasticity
tobit1	+ 0.637	- 0.056
tobit2	+ 0.183	- 0.043

As in the probit model, the inclusion of work experience in the tobit model changes the parameter estimates of hourly wage and non-labour income significantly. The significant effect of the exogeneity assumption on work experience in the probit and tobit models appears to arise from the fact that previous labour market experience is an excellent predictor of whether or not a woman is in the labour force in the survey year. The effect of experience on the tobit coefficients in our study is similar to that of Mroz (1984). In his study, as in ours, the estimated wage coefficient fell dramatically and the income coefficient rose considerably in the tobit model when the experience variables were included as separate regressors in the structural labour supply equation as well as in the reduced form wage equation.

The presence of young children reduces both the participation probability and hours worked by participants and non-participants. Besides this, the socioeconomic status of the husband has a negative effect on both the participation probability and the hours worked by participants.

The estimated tobit elasticities should be viewed with some caution for two reasons. First, the endogeneity of experience is clearly a problem which is hard to control in cross-section analysis. Secondly, in the tobit model we implicitly assume a continuous labor supply schedule so that labour supply falls continuously to zero in response to increases in hourly wage and unearned income. In other words, tobit assumes that the parameters which determine participation are the same as the parameters which determine hours of work for people who participate. If this assumption is violated, the tobit estimates may be biased.

To relax the tobit assumptions we can utilize procedures that allow for the possibility that the least number of hours a worker will work may be substantially in excess of zero. These procedures estimate the participation equation and the hours of work equation separately. In many studies it has been found that estimation methods that assume a continuous supply schedule typically produce greater female labour supply elasticities than do techniques that allow for a discontinuous labour supply schedule.

Table 6.3 contains the two stage least squares estimates, where predictions from the wage equation in Appendix 3 have been used as instruments for actual wages. After some preliminary testing we chose to exclude the number of children and the region variables from the labour supply model, as they appeared to have no significance. We have also included two industry dummies to account for institutional arrangements that could constrain individual labour supply decisions in some types of economic activity. A detailed examination of the data indicated that particularly in the manufacturing and public sectors it was normal to work full time (35—40 hours per week); part-time jobs were practically non-existent. The results from labour force surveys conducted by the Central Statistical Office of Finland also indicated that many individuals are constrained to work more than their optimal hours due to the shortage of part-time work. The estimated coefficients for industry dummies give strong support to this view.

In the first equation the wage coefficient is positive but of small magnitude. As in the tobit model, the wage coefficient falls considerably (even becomes negative) when work experience is included as a separate regressor in the model. In the second model higher education is positively associated with hours of work — even when the effect of education on the wage is held constant. This might be due to educational attainment being positively associated with nonpecuniary compensation — better working conditions, more interesting work, better career possibilities etc. Contrary to the wage effect, the income effect is quite similar in both models. In TSLS estimation income elasticity is less than half that of the tobit estimates.

According to TSLS estimation, the presence of young children reduces the optimal hours for working women. And, the higher the socioeconomic status of the husband the lower the working hours of the wife.

Table 6.3 **Analysis of participants' hours of work: two stages least squares estimates**

	TSLS1		TSLS2	
constant	1761.57	(34.85)	1673.57	(21.24)
wage (pred.)	6.77	(2.59)	-12.09	(2.03)
unearned income (1000 Fmk)	-21.61	(6.85)	-18.66	(5.92)
youngest child				
0–2 years	-190.53	(5.09)	-144.89	(3.69)
3–6 years	-80.99	(2.53)	-43.78	(1.33)
socioeconomic status of husband				
employer	-135.16	(1.45)	-113.29	(1.24)
own-account worker	-133.89	(2.29)	-140.79	(2.44)
upper-l. employee	-163.06	(4.12)	-121.45	(3.02)
lower-l. employee	-63.98	(2.07)	-66.34	(2.15)
education				
upper 1st level			-3.29	(0.07)
2nd level: lower			15.12	(0.45)
2nd level: upper			138.40	(2.27)
3rd level: lower			160.02	(2.00)
3rd level: undergr.			230.56	(1.92)
3rd level: graduate			309.71	(2.16)
work experience				
6–9 years			191.98	(2.95)
10–14 years			392.95	(5.72)
15–19 years			447.71	(6.06)
20– years			443.91	(5.61)
industry				
manufacturing	159.06	(5.07)	155.54	(5.01)
general government	51.06	(1.74)	78.93	(2.68)
number of observations		1241		1241
R-squared		0.11		0.15
(F(10,1230/20,1220)		14.91		10.84
mean of dep. variable		1816.67		1816.67

estimation procedure	wage elasticity uncomp.	wage elasticity compensated	total income elasticity
TSLS1	+ 0.07	+ 0.48	- 0.41
TSLS2	- 0.13	+ 0.23	- 0.36

6.2 Selectivity bias-corrected estimation

In Tables 6.2 and 6.3 above it was shown that the elasticities of hours worked by participants with respect to the principal variables from the tobit procedure were quite different from those obtained by traditional TSLS estimation. There may be several reasons for this. All these estimation procedures, Tobit, OLS and TSLS, mistreat the zero observations. The sample selection problem may be important here because about 22 % of our sample does not work. Another obvious reason for the difference in the tobit and OLS estimates is the presence of a large discontinuity in the hours distribution. As was shown in Table 5.2 above, there are very few individuals working between zero and 800 hours per year. The tobit procedure in effect assumes that the labour supply schedule is continuous, and is therefore not suitable for estimating labour supply functions with large discontinuities (see Killingsworth 1983, pp. 145—148).

The multi-stage procedure of Heckman (1979) provides us with a more suitable estimation method in the case of discontinuous labour supply functions. In the case of selection bias-corrected-regression, the parameters that determine participation will not necessarily be the same as the parameters that determine hours of work for people who participate, whereas in the case of tobit these two sets of parameters are treated as proportional. Moreover, the use of selection bias-corrected regression permits a simple empirical test of the hypothesis that the labour supply schedule is discontinuous. Finding very different parameters for participation than for hours of work for participants implies a discontinuity in the labour supply schedule (Killingsworth 1983, pp. 145—148).

However, even the use of the two-step procedure doesn't precisely take account of all possible reasons for labour supply discontinuities. Discontinuities in the labour supply schedule may arise because of fixed costs of labour force entry, demand-side restrictions with respect to working times or poverty traps generated by social security and taxation. If, for example, the discontinuity arises from demand-side restrictions with respect to working times, the normality assumption used throughout this study may be violated, and fundamentally different estimation methods should be applied (see Dickens & Lundberg, 1985, for an application in the case where individuals may face constraints on their choice of work hours).

In the first stage a reduced form equation for labour force participation was estimated by probit. Variables included in the probit equation were: husband's earnings, number of children in the family, children's age dummies, education, age, age squared, husband's socioeconomic status, wife's work experience, municipality tax rate. The probit coefficients were used to compute a selection bias correction variable (inverse of Mill's ratio), which was included in the structural wage equation. The exogenous variables in the wage equation were the same as in the probit equation. Finally, the predicted wage and the inverse of Mill's ratio were included in the ordinary least squares estimation of the structural labour supply equation.

The results of the selectivity bias-corrected hours-or-work equation are given in Table 6.4. The formula for the least squares variance-covariance matrix has been adjusted as suggested by Heckman (1980).

Selectivity correction à la Heckman changes the parameter estimates in the hours-of-work equation as compared to equations without it (Table 6.3). The wage coefficient is negative and smaller than in TSLS estimation. Total income elasticity is, in absolute terms, only half that of TSLS estimates. It is interesting to note that both wage and income coefficients are very robust to the inclusion of other variables into the model. In this respect the selectivity model clearly differs from TSLS estimation.

Compared to studies in other countries our wage elasticity estimates are low. According to the survey by Killingsworth & Heckman (1986), estimates of the uncompensated wage elasticity of annual hours in various studies range from -0.30 to +14.00. Our estimates are at the lower bound of this range. The total income elasticities noted in the same survey typically range from 0 to -0.50. The estimated total income elasticity in our study falls well within this range.

The coefficient of Mills' Ratio is significant. This suggests that it is important to control for self-selection in regard to participation when estimating a labour supply equation for those who participate. It should be noted that the effect of children and the wife's work experience is small or even insignificant when selection bias is taken into account.

Table 6.4 **Analysis of hours of participants: selectivity bias-corrected regressions**

	SBC1		SBC2	
constant	2097.16	(28.18)	2052.04	(17.92)
wage (pred.)	-8.21	(2.26)	-10.32	(1.70)
unearned income (1000 Fmk)	-10.64	(1.63)	-11.68	(2.92)
youngest child				
0–2 years	-4.71	(0.09)	-1.28	(0.03)
3–6 years	-23.44	(0.60)	-14.01	(0.39)
socioeconomic status of husband				
employer	19.76	(0.17)	6.43	(0.06)
own-account worker	-75.97	(1.08)	-85.99	(1.35)
upper-l. employee	-60.74	(1.24)	-61.98	(1.36)
lower-l. employee	-48.65	(1.32)	-48.47	(1.43)
education				
upper 1st level			-56.55	(1.03)
2nd level: lower			-43.61	(1.14)
2nd level: upper			-7.97	(0.11)
3rd level: lower			-16.35	(0.18)
3rd level: undergr.			54.38	(0.41)
3rd level: graduate			61.99	(0.39)
work experience				
6–9 years			-2.55	(0.03)
10–14 years			91.07	(0.95)
15–19 years			129.78	(1.27)
20– years			87.78	(0.78)
industry				
manufacturing	166.34	(5.29)	160.44	(5.25)
general government	82.16	(2.75)	88.63	(3.05)
lambda	-537.64	(6.65)	-458.45	(4.72)
number of observations		1241		1241
R-squared		0.16		0.17
(F(11,1229/21,1219)		20.70		11.60
mean of dep. variable		1816.67		1816.67

estimation procedure	wage elasticity		total income
	uncomp.	compensated	elasticity
SBC1	- 0.09	+ 0.11	- 0.20
SBC2	- 0.11	+ 0.11	- 0.22

This is in accordance with the view that selectivity bias is primarily associated with children and work experience, which, together with wage and unearned income, are the main predictors of the wife's labour force participation. Our results are similar to those of Mroz (1984) who, without controlling for self-selection, finds work experience to be endogeneous to the labour supply function.

The sign of the wage effect is different vis-à-vis the tobit estimates in the selectivity-corrected regression, and the estimated coefficients of other variables are not in line with the tobit estimates. This suggests the possibility of a discontinuity in our labour supply schedule.

The results presented thus far give rise to reservations against using Tobit. The assumption of a continuous labour supply schedule is clearly violated in our sample. However, even the use of Heckman's procedure may not be any more satisfactory, because the simple assumptions behind the basic model may not be met. First, individuals may not be completely free in their choice of working hours, because of unemployment for example. Secondly, the assumption of a linear budget constraint may be violated because of the fixed costs of working, progressive income taxes and social security. In the next chapter we will discuss and present some tests of the presence and significance of some of these factors, which are not properly treated in the basic model.

6.3 Results of estimating the model with fixed costs of working

Our data set is somewhat special in the sense that we have detailed data on two major types of costs of labour market entry for married women; the costs of transportation to and from work and the costs of child day-care. The mean level of these costs was slightly over 2 000 marks a year in our sample of married working women. This amounts to 5,4 % of mean gross wage income and 7,5 % of mean wage income after taxes. Among participants, the mean entry costs are of the same magnitude as mean nonlabour income, which, however, must be due here to underestimation of exogenous income.

With entry costs we are faced with the same problem as with the wage variable, i.e. that data on these costs are in most cases not observable for nonparticipants. Our solution for this problem is exactly the same as for wage data. A linear equation for entry costs, conditional on participation, was first estimated, and then predictions from this equation were used in the labour supply equations for participants and non-participants. The variables included in the probit equation which was used to calculate lambda are: husband's earnings, number of children in the family, children's age dummies, education, age, age squared, husband's socioeconomic status, wife's work experience and regional dummies.

The results of entry costs equation are presented in appendix 4. The variables used to predict entry costs are: number of children, children's age dummies, education, husband's socioeconomic status and regional dummies. According to our results, the high costs of labour market entry are associated with young children and high education. A child under 3 years of age increases entry costs by about 4 000 marks a year. The effect of education on entry costs is probably due to the fact that fees for communal day-care rise with income (and thus with education) and many high income families must utilize more expensive private day-care services. The coefficient of lambda is negative and significant. This is in accordance with the expectation that the mean entry costs are lower among participants than for the whole sample because those with high entry costs tend not to participate.

The results of labour supply equations with entry costs are presented in Table 6.5. An increase in the money costs of labour market entry has the expected (significant) negative effect on the probability of participation. Entry costs raise the reservation wage and hence decrease the probability of participating. The effect of entry costs on participation probability is significant. An increase in entry costs reduces female participation probability over ten times more than a corresponding increase in nonlabour income. When costs of labour market entry are included in the probit model, the presence of young children as such has no effect on participation probability. The participation equation with entry costs also has considerably greater predictive power than equations without entry costs. In the hours of work equation, entry costs have no significant effect.

With respect to participation, our results differ from those of Lappalainen & Magnusson (1989), who estimated the effects of child day-care expenses on female labour supply. In a logit model for participation they estimated a positive, statistically insignificant coefficient for entry costs. However, they do not control for selectivity with respect to entry costs, which probably biases their estimation results.

Table 6.5 **Analysis of participation and hours of participants with entry costs**

	probit		SBC	
constant	-0.756	(3.87)	1984.20	(19.67)
wage (pred.)	0.136	(10.26)	-7.24	(2.10)
unearned income (1000 Fmk)	-0.025	(3.38)	-12.84	(3.19)
no. of children	0.025	(0.53)	12.78	(0.85)
socioeconomic status of husband				
employer	-0.853	(2.93)	-10.54	(0.11)
own-account worker	-0.435	(2.34)	-89.30	(1.44)
upper-l. employee	-0.355	(2.63)	-64.07	(1.48)
lower-l. employee	-0.073	(0.64)	-53.73	(1.62)
work experience				
6–9 years	0.188	(1.35)	-15.94	(0.25)
10–14 years	0.571	(3.87)	76.45	(1.09)
15–19 years	0.438	(2.62)	116.26	(1.59)
20– years	0.420	(2.35)	76.23	(1.01)
industry				
manufacturing			166.32	(5.47)
general government			86.00	(2.99)
entry costs, 1000 Fmk	-0.342	(12.70)	-5.57	(0.62)
lambda			-446.32	(5.82)
number of observations		1588		1241
log-likelihood		-552.39		
chi-squared (12)		562.69		
R-squared				0.16
F(15,1255)				16.02
mean of dep. variable				1816.67
correct predictions, %		84.8		

Next we turn to the estimation of the reservation hours-of-work model. The variables included in the hours-of-work equation are: wife's wage, nonlabour income, number of children, age of youngest child, socioeconomic status of husband, education and regional dummies. The reservation hours were assumed to depend on the same variables except for the wage and nonlabour income variables. We estimated the model as likelihood function (4.40) using Heckman's multi-stage procedure. First, the probit model was estimated. This yields consistent estimates of $\alpha_1\theta/\sigma_u$ and $(\beta-\Gamma)/\sigma_u$. Then both the hourly wage equation and hours of work equation with lambda (Mills' ratio) were estimated. Given the wage, the hours-of-work equation and the reservation hours equation can be written;

$$\begin{aligned} h^s &= \alpha_0 + Z_1\beta - \sigma_{su}*\text{lambda}_s + \varepsilon_s, \\ h^r &= \tau_0 + Z_2\Gamma - \sigma_{ru}*\text{lambda}_r + \varepsilon_r, \end{aligned} \tag{6.1}$$

where lambda_s and lambda_r are the Mills' ratio terms and ε_s and ε_r are the new residuals, with zero conditional means (see Maddala 1983, pp. 224-225):

$$\begin{aligned} \varepsilon_s &= u_s + \sigma_{su}*\text{lambda}_s, \\ \varepsilon_r &= u_r + \sigma_{ru}*\text{lambda}_r. \end{aligned} \tag{6.2}$$

From the OLS estimation of the hours-of-work equation we get consistent estimates of θ and σ_{su}. However, in the estimation of standard errors we must take account of the fact that σ_s^2 and σ_r^2 are heteroscedastic (see Maddala, p. 225).

If there is at least one variable included in X_1, which is not included in X_2, then from the estimate of θ_j corresponding to this variable we get a consistent estimate of σ_u and hence consistent estimates of all the elements of ß, i.e. the coefficients in the reservation hours equation. Then, given estimates of σ_{su}, σ_s^2 and σ_u, we can obtain an estimate of σ_{sr} using $\sigma_{su} = (\sigma_{sr} - \sigma_s^2)/\sigma_u$. Finally, from $\sigma_u^2 = \sigma_s^2 + \sigma_r^2 - 2\sigma_{sr}$ we get an estimate of σ_r^2 and can estimate the variance-covariance matrix of the reservation hours equation.

Table 6.6 presents estimates of the parameters of the hours-of-work and reservation hours functions. The asymptotic t-values are given in parentheses. The estimated coefficient of unearned income in the probit and hours-of-work equations was used to identify σ_u.

In the reservation hours-of-work equation, the presence of young children, higher education and higher socioeconomic status of the husband all significantly decrease the minimum number of hours a woman is willing to supply to the labour market. Because we have a negatively sloped labour supply schedule, these same factors which decrease reservation hours also increase reservation wages, i.e. the minimum wage at which the woman would be willing to participate. The estimation results are reasonable even if the interpretation of these results s complicated by the fact that the same factors can affect reservation hours both directly and via reservation wages which are inversely related to reservation hours.

Table 6.6 **Parameter estimates of entry costs model**

	hours of work function		reservation hours function	
constant	2231.75	(20.44)	1559.55	(28.02)
wage (pred.)	-10.32	(1.82)		
unearned income (1000 Fmk)	-11.99	(1.77)		
no. of children	21.47	(1.21)	-27.39	(0.98)
youngest child				
0–2 years	-17.05	(0.32)	-303.22	(3.64)
3–6 years	-28.91	(0.71)	-108.32	(1.51)
socioeconomic status of husband				
employer	-12.43	(0.11)	-222.64	(1.13)
own-account worker	-78.97	(1.13)	-202.00	(1.62)
upper-l. employee	-59.09	(1.19)	-223.80	(2.57)
lower-l. employee	-55.37	(1.51)	-85.25	(1.29)
education				
upper 1st level	-92.23	(1.63)	-166.52	(1.69)
2nd level: lower	-64.24	(1.70)	-44.47	(0.67)
2nd level: upper	-48.55	(0.80)	-195.18	(2.11)
3rd level: lower	-59.40	(0.75)	-199.34	(1.70)
3rd level: undergr.	37.55	(0.31)	-565.47	(3.59)
3rd level: graduate	18.25	(0.14)	-482.95	(2.89)
region				
inner Helsinki	-10.46	(0.27)	-51.74	(0.75)
outer Helsinki	15.72	(0.15)	13.29	(0.07)
other great towns	5.16	(0.12)	26.54	(0.36)
lambda	-520.39	(7.14)	-913.43	(12.53)
σ	504.64		904.6	
number of observations		1241		1241
R-squared		0.14		

The effect of young children on reservation hours is consistent with survey data information which shows that women with young children are more willing to work part-time than other women. It is also reasonable that higher education raises the reservation wage and hence lowers the reservation hours. It is more difficult to see the connection between the husband's socioeconomic status and reservation hours. If the husband's socioeconomic status is seen as a proxy for his income, it may be that women with high income husbands are more ready to accept part-time work. The effect of regional variables is not significant in either the hours-of-work or reservation hours equation.

The estimated mean reservation hours for workers and non-workers is large, about 1 280 hours a year, which indicates that the money costs of labour market entry are of prime importance in a married woman's labour supply decisions. The estimated size of discontinuity in the labour supply schedule is surprisingly near Cogan's (1980) results for American females. The estimated mean reservation hours for workers is about 1 060 hours a year and for non-workers about 2 090 hours a year. This great difference between reservation hours of workers and non-workers has some interesting implications. The results so far have pointed to that non-monetary variables (children, education, unmeasured factors etc.) that affect labour supply via preferences between consumption and leisure do not have significant effects on hours supplied by participants. However, the results from the entry costs model indicate that these same factors may have a significant effect on hours worked via reservation wage and reservation hours.

Even if the results from the entry cost model seem quite reasonable care should be taken in the interpretation of the results, for two reasons. First, the results are extremely sensitive to the specification of hours-of-work and reservation hours functions. Second, in the entry cost model above we have assumed that the discontinuity in the labour supply schedule is entirely due to money and time costs of labour market entry. It may be the case that discontinuities in labour supply are often created by demand side restrictions, e.g. there may be a shortage of part-time jobs.

6.4 Results from estimating the model with progressive taxation

The income tax in Finland consists of two parts. There is both a proportional income tax imposed by local authorities and the national pension system and a progressive income tax imposed by the central government. With some minor exceptions the tax base is the same for the two cases, although deductions allowed differ considerably.

Finnish and Swedish studies of nonlinear income taxation have normally assumed a common local tax rate for all individuals in order to simplify the analysis. However, in Finland tax rates between communities differ considerably. In 1980, the lowest community tax rate was 14 per cent and the highest was 19.25 per cent. Moreover, tax rates tend to be higher in communities with lower income levels. For the participants in our sample, the correlation between taxable income and local tax rate was -0.07. Therefore, the assumption of a common local tax rate may introduce spuriously steep progressivity and bias the estimation results. To avoid this we calculated the actual local tax rate for all participants in our data. To this was added the church income tax rate (1 %), the national pension insurance contribution (1,5 %) and the national health insurance contribution (0.5 %).

The income tax is based on each person's taxable income, which is computed as assessed income minus certain deductions. We have data on taxable income in local income taxation but not on taxable income in central government taxation. However, we have data on taxes paid to the central government from which we can calculate taxable income and marginal tax rates under central government taxation.

The central government income tax schedule in 1980, expressed in terms of taxable income, is shown in Table 6.7.

Table 6.7 **Central government tax schedule, 1980**

Taxable income, Fmk (A_i-A_{i-1})			tax at the lower end of the income interval	marginal tax rate, % (t_i)
9300	—	12400	11	6
12400	—	15000	197	13
15000	—	19000	535	19
19000	—	23000	1295	23
23000	—	31000	2215	28
31000	—	44000	4455	29
44000	—	60000	8225	33
60000	—	92000	13505	38
92000	—	153000	25665	45
153000	—	275000	53115	50
275000	—		114115	51

The central government income tax schedule was highly progressive in 1980 with marginal tax rates ranging from 0 % to 51 %. The number of tax brackets (12) was large, and especially at the lower end of the schedule the rates changed for small differences. To simplify the computation and analysis we combined brackets for central government income taxation, reducing the number to six. We have combined brackets 2 and 3, 4 and 5, 6 and 7 and the four highest brackets (there were no observations in two highest segments and only two observations in the third highest segment). The central government tax schedule applied, with the frequencies, observed is given below.

Table 6.8 **Central government tax schedule applied in this study**

Taxable income, Fmk $(A_i - A_{i-1})$			marginal tax rate, % (t_i)	number of observations
not working				347
0	—	9300	0	100
9300	—	15000	9.5	154
15000	—	23000	21	393
23000	—	44000	28.5	513
44000	—	60000	33	63
60000	—		38	18

In order to calculate net marginal wages and virtual incomes, we have linearized the budget constraint using tax brackets where individual's observed hours were situated. Then the wage and income variables can be calculated using the formulas in chapter 3.2. The key assumption behind the linearizing of budget sets through observed hours is that individuals' observed working hours are also optimal working hours.[1]

[1] Rosen (1976) has suggested a simple test to analyze whether marginal taxes are important for labour supply behavior. We write our labour supply model with taxes as follows:

$$h_i = a_0 + a_1(1-\delta t_i)w_i + a_2 y_i + Z_i\alpha + \varepsilon_i. \quad (1)$$

We have included into the model a parameter δ, which is the coefficient of the marginal tax rate. Following Rosen, we interpret δ as a coefficient of tax perception. In the studies which ignore marginal tax rates, it is implicitly assumed that $\delta = 0$. For those who assume that individuals react rationally to net marginal wages, the assumption is $\delta = 1$. We can estimate δ by rewriting equation (1) as

$$h_i = a_0 + a_1 w_i - a_1\delta(t_i w_i) + a_2 y_i + Z_i\alpha + \varepsilon_i. \quad (2)$$

An estimate of δ is obtained by dividing the coefficient of $t_i w_i$ by the coefficient of w_i and multiplying the result by minus one: $\delta = -(-a_1\delta/a_1)$. Thus equation (2) allows a test of the hypothesis that net rather than gross marginal wages are important in the work decision.

We estimated equation (2) by ordinary least squares and by selectivity-bias-corrected estimation procedures. The estimates of δ obtained were 1.552 (s.d. = 0.065) and 1.579 (s.d. = 0.154). With these results we can clearly reject the alternative hypothesis that $\delta = 0$, i.e. that the individual ignores taxes when making labor supply decisions. However, we must also reject the hypothesis that $\delta = 1$, i.e. the hypothesis that individuals take taxes rationally into account. In any case the power of this test is rather weak, because w and t*w are highly correlated and it is therefore difficult to disentangle their separate effects.

(continued...)

In the table below we have presented sample statistics on net marginal wages and virtual incomes by hours. The table shows that the negative correlation between net marginal wages and hours worked is even higher than between gross wages and hours worked. This spurious negative correlation is due to steep progressivity of the tax schedule. With a given gross wage, the marginal tax rate rises and the net marginal wage falls as hours worked increase. So, the observed net wage rate that appears as an explanatory variable in the labour supply function is itself endogeneous and therefore correlated with the disturbance term. The same problem applies to the virtual income variable, which also depends on hours worked.

Table 6.9 **Sample statistics by hours worked**

distribution of hours worked	cases	net marginal wage		virtual income	
not working	347	...		4394.8	(8250)
0 - 400	17	24.67	(9.48)	5680.6	(4873)
400 - 800	46	22.30	(7.64)	4713.3	(5092)
800 - 1200	98	15.65	(4.10)	4831.4	(8558)
1200 - 1600	103	14.19	(4.44)	5309.3	(3077)
1600 - 2000	351	12.36	(2.94)	6076.3	(2473)
2000 - 2400	611	9.96	(1.71)	5158.7	(2134)
2400 -	15	8.17	(1.87)	4572.3	(1550)
all workers	1241	12.08	(4.47)	5388.4	(3458)

Table 6.9 clearly shows the sharp rise in virtual income among workers due to the steep progressity of tax schedule. The mean non-labour income for workers is even higher than for non-workers, whereas the actual non-labour income of workers is less than half that of non-workers.

[1](...continued)

Our results differ from those of Rosen who in several different specifications obtained estimates of δ which were within one standard deviation of one. On the other hand, Mroz (1984) could not reject either the hypothesis that the women optimally take taxes into account or the hypothesis that the women fail to take taxes into consideration. Mroz used a semilogarithmic form of the labour supply function whereas in Rosen's as well as in our study a linear form was used. Another major difference between these studies is that Rosen calculated marginal earnings and marginal tax rates using standard number of hours per week and per year, whereas in our and Mroz's study the budget constraint was linearized through actual hours worked.

The estimation results for the labour supply equations with linearized budget sets are presented in Table 6.10. These results are not promising. The coefficients of virtual income are slightly positive but not statistically different from zero in either tobit and TSLS estimation. The uncompensated wage effect is negative and of very large magnitude, especially in the tobit model. Together these results imply that, contrary to what theory would indicate, the compensated wage elasticity is negative.

These results are mainly due to high spurious correlations between hours worked and net marginal wage and between hours worked and virtual income. When net marginal wage and virtual income are calculated using observed hours worked, progressive taxation introduces a large negative correlation between working hours and marginal wage and a positive correlation between working hours and virtual income. These correlations are reflected in the estimated coefficients of the labour supply equations in Table 6.10.

Our results differ from most other studies, where positive income elasticity is a rare exception. The differences are probably due mainly to differences in tax systems. In countries like United States and Great Britain, where joint filing has been the rule, the spurious correlations introduced by the tax system are not so severe. In tax systems with joint filing, the husband's and wife's earnings and other income are taxed as one. Usually the wife does not immediately face the marginal tax rate applicable to her husband's last increment of earnings for her first increments because of her earned income allowance. Moreover, because the wife's earnings usually are much smaller than her husband's, there are fewer tax brackets and less progressivity in the US and UK tax systems than in the Finnish system and the endogeneity problem is not as severe in those countries.

In the United Kingdom married individuals who earn more than their allowance face a marginal tax rate which is determined by the combined income of the couple. In practice, the great majority of married individuals face the standard tax rate, since this covers a very large range of incomes. In the American tax system the frequency of changes in tax rates is greater than in the UK but the progressivity is still much less steep than in the Finnish system.

Table 6.10 **Analysis of hours of participants and non-participants (tobit) and hours of participants (TSLS)**

	tobit		TSLS	
constant	1693.65	(6.88)	2367.78	(14.36)
net marg. wage	-162.26	(5.01)	-47.58	(2.36)
virtual income (1000 Fmk)	32.83	(1.12)	12.83	(0.68)
youngest child				
0—2 years	-457.55	(6.09)	63.12	(1.05)
3—6 years	-117.68	(1.84)	-6.49	(0.16)
socioeconomic status of husband				
employer	-413.20	(2.50)	48.73	(0.43)
own-account worker	-147.79	(1.33)	-33.26	(0.47)
upper-l. employee	-80.18	(0.92)	9.37	(0.17)
lower-l. employee	-94.15	(1.57)	-30.46	(0.81)
education				
upper 1st level	290.95	(3.19)	-48.50	(0.82)
2nd level: lower	268.21	(4.49)	-52.92	(1.28)
2nd level: upper	765.50	(8.31)	-35.72	(0.51)
3rd level: lower	947.87	(7.96)	-40.65	(0.46)
3rd level: undergr.	1177.63	(6.59)	29.04	(0.22)
3rd level: graduate	1806.21	(7.94)	110.57	(0.70)
work experience				
6—9 years	812.81	(8.32)	-22.96	(0.25)
10—14 years	1314.79	(14.36)	22.54	(0.22)
15—19 years	1446.82	(14.94)	58.00	(0.55)
20— years	1596.15	(16.30)	15.20	(0.13)
industry				
manufacturing			140.03	(4.29)
general government			95.30	(3.20)
sigma	874.69	(46.75)		
lambda			-517.45	(4.32)
number of observations		1588		1241
log-likelihood		-10516		
R-squared				0.16
F(21,1219)				11.28
mean of dep. variable		1419.7		1816.67

estimation procedure	wage elasticity	income elasticity
tobit	-1.07	+0.12
TSLS	-0.31	+0.05

In Finland the income tax and marginal rate are based on each person's own taxable income. The separate taxation of spouses was introduced in 1976. With separate filing, steep progression and frequent tax brackets, the endogeneity problem becomes a central issue in the Finnish case. This is especially evident with respect to non-labour income, where the virtual component becomes dominant when it is calculated using observed working hours. The severity of the problem can be clearly seen from the correlation coefficient between working hours and wage and income variables. The correlation between hours worked and marginal wage changes from -0.39 to -0.68 and between hours worked and non-labour income from -0.22 to slightly positive when a budget set without taxation is replaced by one that is linearized through observed points.

In principle the problem of endogeneity could be solved by the instrumental variables method but in practice it is difficult to find good instruments, i.e. instruments that are highly correlated with explanatory variables but uncorrelated with the residual. It is also not likely that this problem could be solved by two stage least squares estimation, as would be true in the case of measurement problems in models without taxation. With taxation this method is not valid because taxation is present in the model that is used to calculate predicted values.

Rosen (1976) criticizes the use of actual number of hours worked in evaluating marginal wage and virtual income. This method will lead to biased results because individuals can be located in different tax brackets because of dissimilar indifference maps even though their budget sets are similar. This results in different marginal wages and virtual incomes for individuals who face the same budget set.

The effects of simultaneity and mis-specification biases on the estimator can be more clearly seen if we write the labour supply model in the following form

$$
\begin{aligned}
h_i &= \beta' Z_i + u_i, \\
h_i &= h_i^* + \varepsilon_i, \qquad i = 1,\ldots,N,
\end{aligned}
$$

where h_i is observed working hours and h_i^* is the solution to the true utility maximization problem. The model implies an estimation error of the form (see Pudney (1989), pp. 200–201):

$$\hat{\beta} - \beta = [(1/N)*\Sigma_i Z_i Z_i']^{-1}[(1/N)*\Sigma_i Z_i \varepsilon_i + (1/N)*\Sigma_i Z_i(h_i^* - Z_i'\beta)].$$

The first source of bias is a simultaneity problem: Z_i is endogenous because it depends on the tax rate t_i, but this tax rate is also affected by the chosen level of labour supply. Therefore, the correlation between ε_i and one or more of the elements in Z_i is non-zero, implying a non-zero probability limit for the term $(1/N)*\Sigma_i Z_i \varepsilon_i$.

The second problem concerns the mis-specification of the regression function h_i^*. The linearization approach is based on the assumption that the optimal working hours are located at an interior point of the same budget segment as observed working hours. However, for some individuals observed hours and optimal hours lie on different budget segments or optimal hours may also be at one of the kink points. In these cases h_i^* differs systematically from Z_i'ß and the term $(1/N)*\Sigma_i Z_i(h_i^* - Z_i'ß)$ converges to a non-zero probability limit.

Clearly, a satisfactory way to solve for the mis-specification problem is to utilize methods which properly account for the whole budget set. These methods have been proposed and applied by Hausman (1979), Hausman & Wise (1980) and Blomquist (1983). Later studies utilizing the same methodology in the treatment of piece-wise linear budget constraints are Moffitt (1986) and Soest & Woittiez & Kapteyn (1989). The major inconvenience in using these methods is the exhaustive computational burden that optimization requires.

For cases where these methods are not applicable, Rosen advocates that marginal wage and virtual income be calculated using some standard number of hours for all individuals in the sample. This method has also been utilized by Hausman and Wise (1976). In Finland Pulli (1985) used this method to analyze male labour supply.

Even if this method is somewhat 'ad hoc' in nature we utilize it because it takes into account the endogeneity and mis-specification problems, which are very important in our study. We have chosen to use the average number of hours worked per year by participants in evaluating marginal wage and virtual income. In this case the results are much more promising than in the case where linearization was done through observed points. The results from tobit estimations are presented in Table 6.11. The wage effect is positive and the income effect negative in both model specifications. Compared to tobit models without taxation, the wage elasticity is considerably greater and the income elasticity much smaller.

Table 6.11 **Analysis to explain hours of participants and non-participants (net marginal wage and virtual income evaluated at standard number of hours for all individuals)**

	tobit1		tobit2	
constant	408.69	(2.78)	396.86	(1.72)
net marg. wage	276.56	(14.43)	71.24	(2.19)
virtual income (1000 Fmk)	-241.25	(10.99)	-102.00	(4.19)
youngest child				
0–2 years	-597.08	(8.25)	-562.33	(7.78)
3–6 years	-172.23	(2.62)	-118.45	(1.84)
socioeconomic status of husband				
employer	-501.30	(2.86)	-514.81	(3.09)
own-account worker	-318.36	(2.80)	-305.38	(2.81)
upper-l. employee	-526.10	(6.35)	-347.58	(4.32)
lower-l. employee	-201.80	(3.25)	-178.19	(2.97)
education				
upper 1st level			68.24	(0.72)
2nd level: lower			186.61	(3.05)
2nd level: upper			456.09	(4.22)
3rd level: lower			514.69	(3.72)
3rd level: undergr.			533.32	(2.56)
3rd level: graduate			703.39	(2.90)
work experience				
6–9 years			584.67	(5.70)
10–14 years			1123.23	(10.74)
15–19 years			1212.45	(10.74)
20– years			1272.55	(10.59)
sigma	933.20	(46.62)	882.06	(46.75)
number of observations		1588		1588
log-likelihood		-10612		-10526
mean of dep. variable		1419.7		1419.7

estimation procedure	wage elasticity	income elasticity
tobit1	+1.571	-0.914
tobit2	+0.405	-0.387

The absolute values of tobit wage and income elasticities are surprisingly high, even though it is an acknowledged fact that tobit estimation tends to yield greater female labour supply elasticities than do techniques that allow for a discontinuous labour supply schedule (see Killingsworth (1983), pp. 185–206, Rosen (1976), Layard &

Barton & Zabalza (1980)). Compared to tobit models without taxation, the effects of other variables are similar except for education, which has a much higher positive effect on hours supplied in this study.

The TSLS and SBC estimation results for hours of participants are presented in Table 6.12. The coefficient of net marginal wage is not statistically different from zero in either model. Compared to models without taxation, the uncompensated wage elasticity is slightly higher. The greater uncompensated elasticity compared to gross wage elasticities is somewhat surprising because in methodologically comparable studies in other countries uncompensated wage elasticity usually falls when taxation is taken into account (Mroz 1986). The calculated compensated wage elasticities are positive in both cases. In both models the coefficient of virtual income is negative, and total income elasticity is of the same order of magnitude as in corresponding estimations of models without taxation. All in all, in contrast to tobit estimation, the results from the hours-of-work equations imply very small wage and income effects.

Because the estimated wage and income elasticities differ considerably from the tobit estimates, it is clear that the tobit assumption of a continuous labour supply schedule is violated and that multi-stage estimation procedures, such as Heckman's selectivity correction method, would be preferable. For this reason we should place more credence on the SBC estimation results, which imply small wage and income elasticities, than on the tobit estimates.

Although Rosen's method is useful in the treatment of simultaneity and mis-specification biases, interpretation of the results is difficult because the approach is not based on clear theoretical foundations. This problem is reflected in the fact that e.g. in our sample we linearize the budget segment by using tax brackets that differ from the observed ones for 55.5 % of the individuals when we apply Rosen's method. Secondly, Rosen's approach, like any simple linearization method, is unable to completely correct for the mis-specification bias that is inherent in models with piece-wise linear budget sets. In our case for about 13 % of the individuals, predicted (optimal) working hours are situated on a tax segment that differs from the one used in the calculation of wage and income variables.

Table 6.12 **Analysis of hours of participants (net marginal wage and virtual income evaluated at standard number of hours for all individuals)**

	TSLS		SBC	
constant	1826.73	(14.28)	2165.40	(13.33)
net marg. wage	-13.88	(0.81)	-10.02	(0.53)
virtual income (1000 Fmk)	-34.88	(2.68)	-12.24	(0.75)
youngest child				
0–2 years	-130.37	(3.19)	33.27	(0.53)
3–6 years	-33.96	(0.99)	-6.71	(0.16)
socioeconomic status of husband				
employer	-104.73	(1.13)	30.31	(0.26)
own-account worker	-114.83	(1.95)	-62.14	(0.84)
upper-l. employee	-94.91	(2.18)	-39.86	(0.74)
lower-l. employee	-68.05	(2.15)	-43.89	(1.12)
education				
upper 1st level	-8.03	(0.16)	-82.29	(1.33)
2nd level: lower	10.31	(0.31)	-66.14	(1.53)
2nd level: upper	122.84	(2.16)	-74.89	(0.96)
3rd level: lower	136.92	(1.89)	-101.03	(1.04)
3rd level: undergr.	220.37	(2.01)	-57.38	(0.40)
3rd level: graduate	297.88	(2.38)	-75.12	(0.47)
work experience				
6–9 years	163.69	(2.57)	-67.18	(0.72)
10–14 years	348.23	(5.56)	-12.97	(0.12)
15–19 years	401.43	(6.05)	17.87	(0.16)
20– years	388.89	(5.60)	-41.28	(0.34)
industry				
manufacturing	156.14	(4.97)	162.64	(5.07)
general government	81.38	(2.74)	88.48	(2.89)
lambda			-559.47	(4.47)
number of observations		1241		1241
R-squared		0.13		0.16
F(20,1220/21,1219)		9.37		10.91
mean of dep. variable		1816.67		1816.67

estimation procedure	wage elasticity		total income
	uncomp.	compensated	elasticity
TSLS	-0.08	+0.29	-0.37
SBC	-0.06	+0.07	-0.13

7 Conclusions

In this study we have estimated models of labour force participation and hours of work for married females aged 25—54 years. The results from the participation equations indicate high sensitivity of females to changes in hourly wage rates. On the other hand, the income effect on participation is small even though statistically significant. Both these results are familiar from labour supply studies done on other countries. Besides being affected by changes in budget constraints, the probability to participate is affected by the presence of young children, the socioeconomic status of the husband and previous labour market experience. The last effect clearly points to the life-cycle nature of labour-force-participation decisions and reminds us of the inevitable limitations of cross-section studies on participation.

With regard to hours of work during the year, we estimated several different model specifications. On the basis of statistical properties we must clearly reject the tobit specification. The implicit assumption in tobit of a continuous labour supply schedule is not satisfied in our data. The preferred specification is the sample-selectivity-corrected hours-of-work equation, which allows for a discontinuity in the labour supply.

The results from the selectivity-corrected equations point to a slightly backward-bending labour supply schedule. Compared with uncompensated wage elasticity estimates in studies done on other countries our estimates are at the lower end of the range. In most studies wage elasticities are positive, although negative estimates are not uncommon, especially in studies using non-US data. The total income elasticities are well in line with those of other studies.

Our cross-section wage and income elasticity estimates are roughly in accordance with time series trends in labour supply. The stylized facts of the last 20—30 years have been the gradual increase in participation rates and a slight decrease in average hours worked among married females. According to our results the rise in participation rates would be mainly due to the steady rise in average real wage rates. The rise in the price of leisure has decreased the demand for leisure and increased participation rates. Compared to the increasing effect of hourly wage, the decreasing effect of the rise in unearned income is small. The demographic changes also have some effect but our results clearly indicate that economic incentives are the dominant factors affecting participation decisions.

Compared to participation equations, we should be much more careful in interpreting the results of the hours-of-work equations in relation to real-life trends. It is true that the small negative wage elasticity is in accordance with the slight decrease in average hours worked among participants during the years. However it is hard to say what this small uncompensated wage elasticity indicates. In this study as well as in most similar labour supply studies it has been assumed that individuals can freely adjust their actual hours to correspond to their optimal yearly hours. As was pointed out at the beginning of our study this assumption is a rather strong one in the Finnish case. It may be the case that individuals' optimal working hours are more sensitive to wage rate changes than our results indicate, but adjustments in actual hours are limited because of institutional rigidities etc. This is clearly one of the problems which would be worth further research in Finland.

We have also estimated a model which takes into account costs of labour market entry for married women. The most important of these costs are child day-care expenses, which may account for a significant portion of female wage income. According to our results increases in the money costs of labour market entry have a large negative effect on participation probability. This result also seems to coincide with real life experience. In countries like Finland and Sweden, where subsidized communal child day-care services are widely available, female participation rates are significantly higher than in other industrialised countries. Our results also indicate that earnings- or participation-related social security benefits are much more important in participation decisions than are lump-sum benefits. During the last few years benefits for child home care have been raised considerably, especially in big cities, with the intention of lowering participation rates among married females.

The existence of fixed entry costs introduces a discontinuity to the labour supply schedule. This discontinuity can be measured by reservation hours, i.e. the minimum hours a year an individual is willing to work. Therefore we have estimated a model which allows us to identify the parameters of the reservation hours function. According to our results the presence of young children, higher education and higher socioeconomic status of the husband all significantly decrease the minimum number of hours a woman is willing to supply to the labour market and increase the reservation wages, i.e. the minimum wage at which the woman is willing to participate. These same non-monetary factors did not have significant effects on hours supplied by participants in the hours-of-work equation.

We have also estimated labour supply models which account for progressive income taxation. In Finland the income tax consists of a proportional income tax imposed by local authorities and the national pension system and a progressive income tax imposed by the central government. The changes in taxation can be decomposed into changes in the marginal tax rate, changes in the exemption level and changes in the tax bracket limit. A detailed analysis of the effects of tax reform would require a careful evaluation of all these effects which again can be reduced to the familiar income and substitution effects. In this study we have concentrated on the first half of the problem, i.e. the estimation of income and substitution effects.

The estimation of labour supply models with income taxation is difficult in the Finnish case for several reasons. The number of tax brackets is large and progressivity is steep compared to e.g. the US and UK income tax systems. The steep progressivity is further highlighted by the fact that the income tax and the marginal tax rate are based on each person's own taxable income.

The progressive, semi-linear income tax system introduces two statistical problems to the labour supply model. The first one is a simultaneity problem and the second one a mis-specification problem. The simultaneity problem arises from the fact that the net marginal wage and the virtual income depend on the tax rate t_i, but that tax rate is also affected by the chosen level of labour supply. The mis-specification problem is due to the assumption that optimal working hours is located at an interior point of the same budget segment as observed working hours. However, for some individuals observed and optimal hours lie on different budget segments or optimal hours may be at one of the kink points.

We have tried to account for these problems using a method which calculates marginal wage and virtual income at a standard number of hours for all individuals. We have chosen to use the average number of hours worked per year by participants. The estimation results from a tobit specification yield very large positive wage elasticities and large negative income elasticities. However, just as in the non-taxation case, strong reservation against tobit is in order on the basis of statistical properties.

In the selectivity-corrected hours-of-work equation, which clearly is preferred to tobit, the wage elasticity is not statistically different from zero. The income elasticity is also very small in magnitude. Overall, our results imply very small wage and income effects in models with taxation. In this respect, again, we must be careful not to over-generalize our results. For firmer conclusions more research is needed. Of special importance would be the use of different data sets and different estimation techniques to cope with the statistical problems inherent in taxation models.

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Appendix 1. Means and standard deviations of variables used

Variable	workers	non-workers
annual hours of work	1816.7	...
	(449.7)	
wife's wage (in FIM)	20.53	...
(average hourly earnings)	(8.01)	
predicted wage	20.53	18.17
(in FIM)	(4.96)	(3.43)
unearned income	2022.7	4394.8
(in FIM)	(3931)	(8250)
husband's earnings	50641.0	49125.0
(FIM 1000)	(32569)	(34578)
education		
upper first level	0.086	0.086
	(0.28)	(0.28)
second level: lower	0.259	0.282
	(0.44)	(0.45)
second level: upper	0.114	0.110
	(0.32)-	(0.31)
third level: lower	0.064	0.040
	(0.24)	(0.20)
third level: undergraduate	0.033	0.029
	(0.18)	(0.17)
third level: graduate	0.029	0.009
	(0.17)	(0.09)
work experience		
3—5 years	0.048	0.245
	(0.22)	(0.43)
6—9 years	0.154	0.305
	(0.36)	(0.46)
10—14 years	0.264	0.193
	(0.44)	(0.40)
15—19 years	0.206	0.104
	(0.41)	(0.31)
20— years	0.320	0.075
	(0.47)	(0.26)
age	38.34	35.72
	(8.10)	(8.49)
no. of children	1.24	1.76
	(1.00)	(1.13)

Variable	workers	non-workers
youngest child	0.127	0.372
0–2 years	(0.33)	(0.48)
	0.189	0.231
3–6 years	(0.39)	(0.42)
socioeconomic status of husband		
employer	0.018	0.029
	(0.13)	(0.17)
own-account worker	0.048	0.061
	(0.22)	(0.24)
upper-level employee	0.156	0.184
	(0.36)	(0.39)
lower-level employee	0.223	0.205
	(0.42)	(0.41)
municipality tax rate, %	15.93	15.77
	(0.92)	(0.53)
part-time work	0.126	...
	(0.33)	
unemployed part of the year	0.044	0.124
	(0.21)	(0.33)
region		
inner Helsinki area	0.194	0.167
	(0.40)	(0.37)
outer Helsinki area	0.019	0.032
	(0.14)	(0.18)
other great towns	0.151	0.135
	(0.36)	(0.34)

Appendix 2. Regression to predict wife's hourly earnings

constant	20.94	(2.93)
education		
upper first level	-1.08	(0.41)
second level: lower	-1.90	(1.06)
second level: upper	1.43	(0.54)
third level: lower	4.93	(1.45)
third level: undergraduate	9.67	(2.03)
third level: graduate	18.84	(4.15)
work experience		
3–5 years	-3.48	(0.46)
6–9 years	-1.97	(0.27)
10–14 years	-2.04	(0.29)
15–19 years	-3.15	(0.44)
20– years	-1.83	(0.26)
region		
inner Helsinki area	1.31	(0.73)
outer Helsinki area	1.83	(0.39)
other great towns	-1.95	(0.98)
occupational status		
technical work	1.85	(0.62)
medical and nursing work	4.53	(1.60)
pedagogic work	8.98	(2.15)
administrative, manag. work	5.94	(1.35)
clerical, secretarial work	1.84	(0.84)
sales work	9.94	(3.73)
agricultural work	-1.83	(0.28)
transport and communic. work	9.29	(2.30)
textile work	-3.51	(1.12)
other manufacturing work	0.95	(0.39)
number of observations	1309	
R-squared	0.06	
F(24,1284)	3.66	
mean of dep. variable	22.19	

Appendix 3. Selectivity-corrected regression to predict wife's hourly earnings (corrected data)

constant	1.58	(0.31)
education		
upper first level	2.55	(3.38)
second level: lower	1.53	(2.94)
second level: upper	6.00	(7.84)
third level: lower	6.54	(6.67)
third level: undergraduate	8.72	(6.22)
third level: graduate	15.54	(11.21)
age	0.35	(1.33)
age squared	-0.004	(1.23)
work experience		
6–9 years	4.18	(4.18)
10–14 years	5.99	(5.19)
15–19 years	6.62	(5.17)
20– years	7.94	(5.54)
region		
inner Helsinki area	0.83	(1.63)
outer Helsinki area	-1.74	(1.26)
other great towns	-0.14	(0.26)
occupational status		
technical work	2.98	(3.78)
medical and nursing work	1.41	(1.86)
pedagogic work	10.52	(9.21)
administrative, manag. work	4.67	(3.92)
clerical, secretarial work	1.31	(2.23)
sales work	-0.33	(0.46)
agricultural work	-0.99	(0.62)
transport and communic. work	3.93	(3.66)
textile work	-2.02	(2.48)
other manufacturing work	0.94	(1.46)
lambda	5.46	(5.06)
number of observations		1261
R-squared		0.40
F(26,1214)		30.65
mean of dep. variable		20.52

Appendix 4. Regression to predict costs of labour market entry

constant	761.16	(5.33)
no. of children	-5.78	(0.08)
youngest child		
0–2 years	3966.34	(16.64)
3–6 years	3241.50	(17.50)
education		
upper first level	160.80	(0.65)
second level: lower	-2.28	(0.01)
second level: upper	1080.88	(4.50)
third level: lower	555.37	(1.84)
third level: undergraduate	1276.04	(3.18)
third level: graduate	1061.19	(2.45)
socioeconomic status of husband		
employer	51.70	(0.10)
own-account worker	-192.10	(0.61)
upper-level employee	147.14	(0.66)
lower-level employee	94.93	(0.57)
region		
inner Helsinki area	170.00	(1.00)
outer Helsinki area	199.29	(0.42)
lambda	-657.69	(2.28)
number of observations	1241	
R-squared	0.37	
F(16,1224)	45.15	
mean of dep. variable	2013.21	

Appendix 5. The direct and indirect utility functions corresponding to the linear labour supply specification

The linear labour supply specification has the form

$$h_i = \alpha_1 w_i + \alpha_2 y_i + Z\beta + \varepsilon_h, \qquad h \geq 0 \tag{1}$$

where w_i is the net wage, y_i is the virtual nonlabour income, Z is a vector of socioeconomic characteristics and ε is a stochastic term. For simplicity we set $s = Z\beta + \varepsilon_h$ and drop the i subscript.

The general indirect utility function is determined by the solution to the constrained utility maximization problem along a given budget segment of a nonlinear budget set

$$c = v(w,y) = \max[u(x,h):x-hw \leq y)], \tag{2}$$

where x is the composite commodity and h is labour supply.

By Roy's identity

$$h = -1 = \frac{dv/dw}{dv/dy} = \alpha_1 w + \alpha_2 y + s. \tag{3}$$

In the general n-good case, integration of Roy's identity raises the integrability problem that the function obtained must satisfy restrictions on the Slutsky matrix: rank n-1, symmetry and negative semidefiniteness. In this simple 2-good model, the integrability problem is simple. The only requirements imposed by the theory are that the compensated labour supply derivative with respect to the wage be greater than or equal to zero and that the indirect utility function be monotone nondecreasing in wage and nonlabour income. These requirements correspond to the properties of the indirect utility function in equation (3.18) above. The Slutsky restriction implies that $\alpha_1 - \alpha_2 h > 0$.

Along any given indifference curve we can consider y as a function of w, so that

$$c = c(w,y) = v(w,y(w)). \tag{4}$$

We differentiate (4) w.r.t. w

$$\frac{dv}{dw} + \frac{dv}{dy}\frac{dy}{dw} = 0 \quad \text{or} \quad \frac{dv/dw}{dv/dy} + \frac{dy}{dw} = 0. \tag{5}$$

From equations (3) and (5) it follows that

$$y' + \alpha_2 y = -(\alpha_1 w + s). \tag{6}$$

This is a first-order differential equation, whose solution is given by (Chiang 1974, p. 477):

$$\begin{aligned} y(w) &= (\exp(-\int\alpha_2 dw))(c+\int-(\alpha_1 w+s)(\exp(\int\alpha_2 dw))dw) \\ &= \exp(-\alpha_2 w)(c+\int-(\alpha_1 w+s)(\exp(\alpha_2 dw))dw). \end{aligned} \tag{7}$$

We use the constant of integration c as our cardinal utility index. We derive the following indirect utility function

$$c = v(w,y) = \exp(\alpha_2 w)(y + \frac{\alpha_1 w}{\alpha_2} + \frac{s}{\alpha_2} - \frac{\alpha_1}{\alpha_2^2}) \tag{8}$$

Derivation of the corresponding direct utility function follows from the solution of the constrained minimization problem

$$u(x,h) = \min_{w,y}(v(w,y):x-wh\leq y). \tag{9}$$

In many applications the primary purpose of a direct utility function is to evaluate utility for zero hours of work, $u_0 = u(x,0)$. A simple way to solve for u_0 is to find the wage, w^*, which for a given y causes zero hours of work. We have $w^* = -(\alpha_2 w + s)/\alpha_1$. Putting w^* into the indirect utility function gives us u_0 directly. This method can be used even if no closed form solution of the direct utility function exists. We have

$$u(x,0) = \exp\left[-\left(\frac{\alpha_2^2 y + \alpha_2 s}{\alpha_1}\right)\right]\left(\frac{-\alpha_1}{\alpha_2^2}\right) \tag{10}$$

Appendix 6. Expected values and derivatives of probit and tobit

Let the random variable y have a normal distribution with mean zero and variance σ^2. We shall use the symbol ϕ to denote the density function and Φ to denote the cumulative distribution function of the standard normal distribution. We have

$$f(y) = \frac{1}{(2\Pi)^{1/2}\sigma} \exp\left(\frac{y^2}{2\sigma^2}\right) = 1/\sigma \; \phi\left(\frac{y}{\sigma}\right)$$

$$F(y) = \int_{-\infty}^{y} \frac{1}{(2\Pi)^{1/2}\sigma} \exp\{-1/2(u/\sigma)^2\} \, du$$

$$= \int_{-\infty}^{y/\sigma} \frac{1}{(2\Pi)^{1/2}\sigma} \exp\{-1/2 * t^2\} \, \sigma dt = \Phi(y/\sigma)$$

Also

$$\frac{d\phi(y/\sigma)}{dy} = -\frac{y}{\sigma^2}\phi(y/\sigma)$$

$$\frac{d\Phi(y/\sigma)}{dy} = \frac{1}{\sigma}\phi(y/\sigma)$$

Our implicit model of labour supply for the whole population is

$$h_i^* = \beta' X_i + \varepsilon_i, \qquad \varepsilon_i \sim (0,\sigma^2)$$

and the observed hours of work is

$$h_i = h_i^* \text{ if } h_i^* > 0,$$
$$h_i = 0 \text{ otherwise.}$$

Then the probability of participating is

$$\Pr(h_i^* > 0) = 1-\Phi(-\beta'X_i/\sigma) = \Phi(\beta'X_i/\sigma)$$

The derivative of the probability of participating w.r.t. the x_k:th variable is

$$\frac{d\Pr(h_i^*>0)}{dx_k} = \frac{1}{\sigma} * \beta_k * \phi(\beta'X_i/\sigma)$$

The expected value of hours worked by participants is

$$\begin{aligned} E(h_i|h_i^*>0) &= \beta'X_i + E(\varepsilon_i|\varepsilon_i>-\beta'X_i) \\ &= \beta'X_i + \sigma\frac{\phi(\beta'X_i/\sigma)}{\Phi(\beta'X_i/\sigma)} \end{aligned}$$

The expected value of hours worked by participants and non-participants together is

$$\begin{aligned} E(h_i) &= \Pr(h_i>0) * E(h_i|h_i^*>0) + \Pr(h_i=0) * E(h_i|h_i^*<0) \\ &= \Phi_i(\beta'X_i + \sigma(\phi_i/\Phi_i) + (1-\Phi_i) * 0 \\ &= \Phi(\beta'X_i/\sigma) * \beta'X_i + \sigma\phi(\beta'X_i/\sigma) \end{aligned}$$

The derivatives for hours worked w.r.t. the x_k:th variable are

$$\frac{dE(h_i|h_i^*>0)}{dx_k} = \beta_k\left\{1 - \frac{\beta'X_i}{\sigma} * \frac{\phi(\beta'X_i/\sigma)}{\Phi(\beta'X_i/\sigma)} - \left(\frac{\phi(\beta'X_i/\sigma)}{\Phi(\beta'X_i/\sigma)}\right)^2\right\}$$

$$\frac{dE(h_i)}{dx_k} = \beta_k\Phi(\beta'X_i/\sigma)$$

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