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RESEARCH MEMORANDUM

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A MODEL OF JOB CHOICE, LABOUR SUPPLY AND WAGES

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Abstract

In this paper a structural model of job choice, labour supply and wages is developed. The analysis is carried out in a neoclassical framework and the restrictions implied by microeconomic theory are imposed.

An individual is assumed to maximize a utility function with leisure, nonpecuniary job characteristics and consumption as arguments. Moreover it is assumed that one's wage depends on human capital variables and the characteristics of the job actually chosen. As a result the wage rate is endogenous.

We simultaneously estimate labour supply, the demand for job characteristics and the wage equation, taking into account that job characteristics are qualitative variables.

The results suggest that there is a wage premium on the jobs with bad characteristics

1. Introduction

The major objective of this paper is to develop a model of job choice, wages and labour supply, and to use this model to estimate the magnitude of the compensating wage differentials for qualitative differences in jobs (such as pleasentness, riskiness, dirtiness etc.).

The theory of compensating wage differentials refers to observed wage differentials required to equalize monetary and nonmonetary compensation associated with different jobs. The theory can be used to explain the allocation of workers to labour activities that differ in various attributes, such as quality of the working environment. Activities that offer favourable working conditions attract labour at lower than average wage rates, and jobs offering unfavourable working conditions must pay a premium, as a compensation, to attract workers.

Most prior empirical work on compensating wage differentials has been based on the estimation of a single wage equation (cf. Hamermesh[1977], Duncan[1976]). One major disadvantage of these studies is that information on labour supply is neglected. Since we believe that the labour supply decision is taken jointly with the choice of a particular job and its associated wage, it is essential that this information is incorporated in the analysis. Analyses that ignore the (self) selection of individuals into different occupations, may produce misleading results. Only in a few papers a model is developed in which labour supply, job choice and the determination of wages are analysed jointly. Examples are Atrostic[1982], Zimmerman[1987] and Killingsworth[1984]. Killingsworth developed a model of labour supply and discrete job choice, and used it in an empirical analysis of the compensating wage differential between white and blue collar work. This approach is slightly different from ours, since we consider the joint determination of labour supply and a continuous job characteristic.

Jobs with qualitative differences can be interpreted as differentiated products, described by a vector of objectively measurable characteristics. The observed product price (this is the wage rate if we are dealing with the labour market) and the amounts of characteristics define a set of implicit or hedonic prices (in our case the prices of job characteristics). See for example Rosen[1974], or Brown and Rosen[1982].

In this study it is assumed that an individual maximizes a utility function with leisure, a nonpecuniary job characteristic and consumption as its arguments. Nonpecuniary job characteristics are defined as nonmonetary benefits accruing to individuals as a consequence of their particular occupation (e.g. working conditions). Notice that in this model job choice is not discrete.

One's wage is assumed to depend on human capital variables and the characteristics of the job chosen. The idea behind this relation is that the rewards for working can be both pecuniary (money wage) and nonpecuniary (compensation by means of desirable job characteristics). In fact employees sell the services of their labour, but simultaneously purchase utility bearing job characteristics. Employers purchase the services of labour, and jointly sell job characteristics. The observed relation between wages, human capital of the employee and job characteristics is determined by the market in such a way that employees and employers are matched correctly. For example, assume that individuals have homogeneous preferences for different kinds of work, say all individuals dislike dirty work. Furthermore assume there is a continuum of jobs, then if there is no wage differential between dirty and clean jobs, nobody will be working in dirty jobs. So individuals working in jobs with undesirable characteristics have to be paid extra.

By including a job characteristic in the wage equation, the wage rate becomes endogenous. Demand functions for leisure and job characteristics are derived by applying Roy's Identity to the indirect utility function.

A common problem in the literature on job characteristics is the measurement of job characteristics. In most studies a single, composite, measure of job characteristics is constructed from responses to a series of questions (cf. Atrostic[1982]). This approach assumes that those responses are commensurable. In this paper only one, objectively measurable, job characteristic is taken into consideration. In principle it is possible to extend the model by considering more than one job characteristic at a time, but this complicates the estimation of the model quite a bit.

The most important contribution of this paper is the formulation of a model of job choice and labour supply, that is consistent with neoclassical theory and that can be tested empirically.

In Section 2 a simultaneous model of job choice, labour supply and wages is developed. In Section 3 the data are described and estimation results are presented. Finally, in Section 4 some concluding remarks are given.

2. The model

As a convenient framework to present the basic ideas, we adopt the home production approach to the theory of consumption, which takes goods and services as inputs in a production process that generates utility bearing outputs usually called "commodities" (cf. Becker[1965], Lancaster[1966], Gronau[1986]). Let Z_i be the quantity of commodity i and let the production of each commodity require a combination of time inputs T_j $(j=1,..,p)$ and goods X_l $(l=1,..,n)$:

$$Z_i = f_i(X_1^i,...,X_n^i,T_1^i,...,T_p^i), \quad i=1,..,m. \tag{1}$$

Here X_l^i is the amount of the l-th good used in the production of the i-th commodity and T_j^i is the amount of the j-th time input used in the production of the i-th commodity; f_i is the production function of the i-th commodity. The utility function is:

$$\Phi(Z_1,..,Z_m). \tag{2}$$

The total number of goods and the total number of time inputs used in the production of all commodities jointly are respectively:

$$X_l = \sum_i X_l^i, \qquad l=1,..,n \tag{3}$$

$$T_j = \sum_i T_j^i, \qquad j=1,..,p. \tag{4}$$

Let unearned income of the individual (or household) be equal to μ and assume for simplicity that the individual can hold only one paid job; the amount of time spent on the job is T_p. Restrictions on behaviour are:

$$\sum_l p_l X_l = \mu + w(q)T_p \tag{5}$$

where $w(q)$ is the wage rate and

$$\sum_j T_j = T \tag{6}$$

where T is the total time endowment. The wage rate corresponding to a job depends on a vector q of job characteristics. For the moment we take q as given.

In principle, behaviour follows from maximization of (2) subject to (1), (3), (4), (5), (6). It has been noted by various authors (e.g. Pollak and Wachter[1975]) that without further assumptions and without information about commodities, this model cannot be distinguished from a model in which utility is defined directly in terms of goods and time inputs. Examples of papers with specific implications are Gronau[1977,1980] and Graham and Greene[1984].

In this paper we consider a static model in which relative prices of consumption goods are constant across consumers. Furthermore, the structure of the production functions f_i is as follows:

$$Z_i = f_i(X_1^i,..,X_n^i,T_1^i,..,T_p^i, q), \qquad i=1,..,m. \tag{7}$$

The vector q appears in the production function because we want to allow for the possibility that at least some commodities are being influenced by the type of the job one is holding. An example might be that a commodity is an amenity of a job and that the job characteristic q describes the working conditions of the job. In this paper it is assumed that q is one-dimensional.

Given that relative prices of consumption goods are assumed to be constant across consumers, perfect aggregation over goods is possible. Similarly, we can aggregate the time inputs $T_1,..,T_{p-1}$ perfectly. Denote the aggregate of the consumer goods by c, the aggregate of the first p-1 time inputs by l and let $h := T_p$. If we are only interested in three commodities, namely leisure (Z_1), an amenity of a job (Z_2) and consumption (Z_3), we can then, without loss of generality, restrict our attention to the following maximization problem:

$$\text{max.} \quad \tilde{U}(Z_1,Z_2,Z_3) \tag{8}$$

$$\text{s.t.} \quad p_c c = w(q)h + \mu \tag{9}$$

$$Z_i = f_i(c,l,q), \qquad i=1,2,3. \tag{10}$$

We assume that the production functions f_1 and f_3 are trivial, that is

$$Z_1 = l \tag{11}$$

$$Z_3 = c. \tag{12}$$

For f_2 we take a simple, multiplicative, specification, namely

$$Z_2 = (T-l)q. \tag{13}$$

For the function $w(q)$ we adopt the following linear specification:

$$w = a'k + bq \tag{14}$$

where k := vector of individual characteristics
a, b are parameters.

The variable q is assumed to be a continuous variable. Equation (14) reflects the fact that the wage rate is dependent on individual characteristics, such as age and education, as well as on job characteristics such as working conditions. If q is defined as a "good", the expected sign of b is negative. For, a job with desirable job characteristics must be paid less than a job with undesirable job characteristics, according to the equalizing wage differentials literature. The parameter b can be interpreted as a compensating wage differential.

Combining equations (8),(9),(11),(12),(13) and (14), the utility maximization problem can be written as follows:

$$\max \quad U(Z_1,Z_2,Z_3)$$

$$\text{s.t.} \quad \begin{aligned} Z_1 &= l \\ Z_2 &= (T-l)q \\ Z_3 &= c \\ p_c c &= (a'k + bq).(T-l) + \mu. \end{aligned} \tag{15}$$

The output level of commodity Z_2 (to be interpreted as an amenity of a job) does not only depend on the type of job one is holding with associated characteristic q, but also on the number of hours one is working. The interpretation of this specification is the following: The disutility derived from working only a few hours in an unpleasant job is less than the disutility of working a lot of hours in the same job. In this interpretation both Z_2 and q are closely connected with working. If you don't work, then q no longer affects utility. Hours of work affect utility through two channels. Assuming that both Z_2 and q are valued positively, more hours of work yield more utility, if one is working in a nice type of job. On the other hand, more hours of work means less leisure time and thus less utility. If q is less than zero, that is, one is working in an unpleasant job, both effects work in the same direction.

The necessary conditions for a maximum of the utility maximization problem (15) are:

$$a'k/p_c = \frac{\partial U}{\partial Z_1} / \frac{\partial U}{\partial Z_3} \tag{16}$$

$$-b/p_c = -\frac{\partial U}{\partial Z_2} / \frac{\partial U}{\partial Z_3}. \tag{17}$$

Notice that, since consumption is assumed to be a "good" (that is $\frac{\partial U}{\partial Z_3} > 0$), b less than zero implies that Z_2 is a "good", and b greater than zero implies that Z_2 is a "bad". This can also be seen in Figure 1 , in which the shape of the budget set is shown for different values of b, in respectively the (Z_1,Z_2)-plane, the (Z_1,Z_3)-plane and the (Z_2,Z_3)-plane, where $a'k>0$ and $p_c=1$.

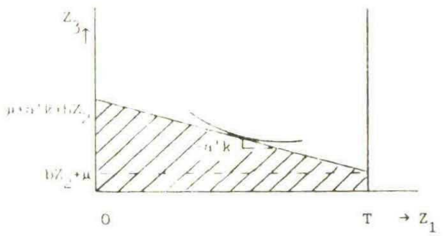


Figure 1A. The optimum situation in the (Z_3, Z_1)-plane, given a value of Z_2

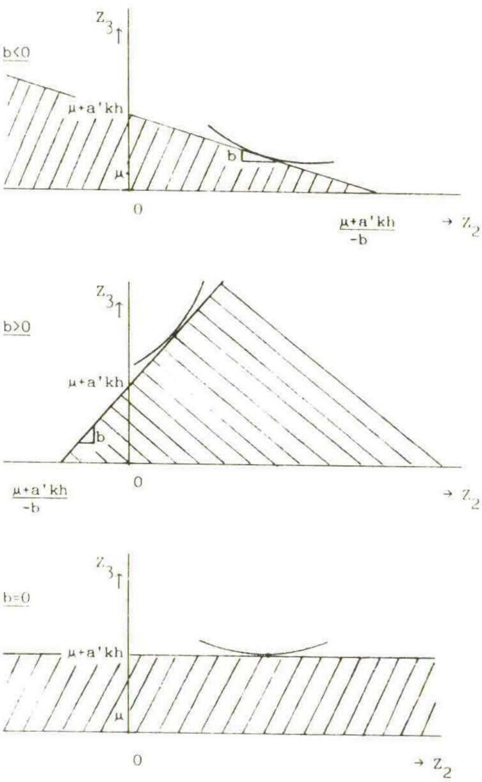


Figure 1B. The optimum situation in the (Z_3, Z_2)- plane, given a value of $h=(T-Z_1)$.

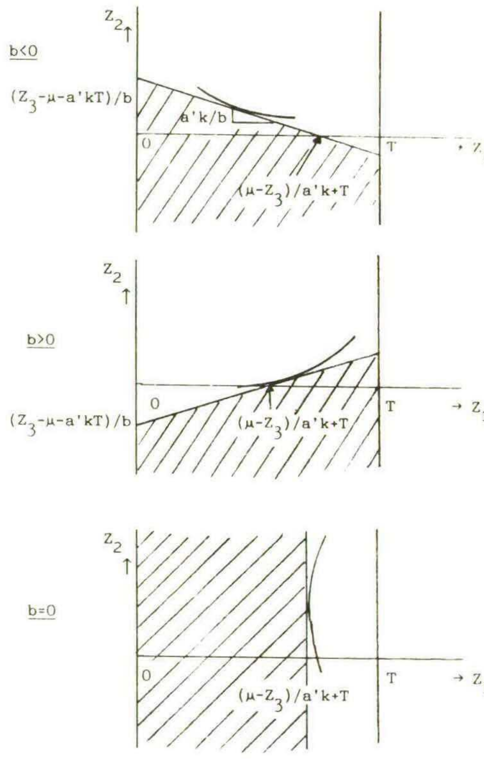


Figure 1C. The optimum situation in the (Z_2, Z_1)- plane, for a given value of Z_3.

Figure 1. The budget set.

In all these planes the budget line is a straight line. In the (Z_1,Z_3)-plane the slope of the budget line is independent of the value of b. Different values of b only yield different positions of the budget curve. In both other planes, the slope of the budget line does depend on the value of b. In the (Z_2,Z_3)-plane the slope of the budget line is negative for negative values of b, and positive for positive values. For b>0, the optimum point is on the rising part of the indifference curve. For b=0, the budget line is horizontal; in this case the existence of a satiation point of Z_2 is required. The same applies to the optimum situation in the (Z_1,Z_2)-plane.

Following the approach taken by Pollak and Wachter(1975), we define a cost function C(P,Z) as the cost of the least expensive bundle of goods, required to produce the commodity vector $Z=(Z_1,Z_2,Z_3)$ when good prices are $P=(w,p_c)$.

$$C(P,Z) := -wh+p_c c$$

$$= - a'k.(T-Z_1)-bZ_2+p_c Z_3 \quad (18)$$

Implicit commodity prices $\pi=(\pi_1,\pi_2,\pi_3)$ are defined as the marginal costs of producing commodities:

$$\pi_1(P,Z) = \frac{\partial C(P,Z)}{\partial Z_1} = a'k \quad (19)$$

$$\pi_2(P,Z) = \frac{\partial C(P,Z)}{\partial Z_2} = -b \quad (20)$$

$$\pi_3(P,Z) = \frac{\partial C(P,Z)}{\partial Z_3} = p_c \quad (21)$$

Further, full implicit income (I) is defined as the cost of the commodity bundle Z, evaluated at the implicit commodity prices:

$$I(P,Z) := \pi_1 Z_1 + \pi_2 Z_2 + \pi_3 Z_3 \quad (22)$$

$$= \mu + a'k.T.$$

Maximization problem (15) can be rewritten as

$$\max \quad U(Z_1,Z_2,Z_3)$$

$$\text{s.t.} \quad \pi_1 Z_1 + \pi_2 Z_2 + \pi_3 Z_3 = I(P,Z) \tag{23}$$

Since, in this case, the commodity prices are independent of the commodity bundle chosen by the individual, the analogy with traditional demand theory is preserved. Thus, we can proceed with the specification of the indirect utility function.

For our specification of the indirect utility function we adopt a variant of the Hausman-Ruud model (cf. Hausman and Ruud[1984]):

$$V(\pi,I) = \exp((\beta_1\pi_1 + \beta_2\pi_2)/\pi_3)\mu^* \tag{24}$$

$$\mu^* = I/\pi_3+\vartheta+\delta_1\pi_1/\pi_3+\delta_2\pi_2/\pi_3+1/2\gamma_1\pi_1^2/\pi_3^2+1/2\gamma_2\pi_2^2/\pi_3^2 \tag{25}$$

Application of Roy's Identity yields demand functions for the commodities Z:

$$Z_1 = -\beta_1\mu^* - \delta_1 - \gamma_1\pi_1/\pi_3 + T \tag{26}$$

$$Z_2 = -\beta_2\mu^* - \delta_2 - \gamma_2\pi_2/\pi_3 \tag{27}$$

$$Z_3 = (\beta_1\pi_1/\pi_3+ \beta_2\pi_2/\pi_3+ 1)\mu^* - \vartheta + 1/2\gamma_1\pi_1^2/\pi_3^2 + 1/2\gamma_2\pi_2^2/\pi_3^2 \tag{28}$$

The price of consumption π_3 is used as a numeraire.Translating system (26)-(28) back into the goods-space, the following goods demands functions are derived:

$$h = \beta_1\mu^* + \delta_1 + \gamma_1(a'k) \tag{29}$$

$$hq = -\beta_2\mu^* - \delta_2 + \gamma_2 b \tag{30}$$

$$c = (\beta_1 a'k-\beta_2 b+1)\mu^* -\vartheta + 1/2\gamma_1(a'k)^2 + 1/2\gamma_2 b^2 \tag{31}$$

where $\mu^* = \mu+\vartheta+\delta_1(a'k)-\delta_2 b+1/2\gamma_1(a'k)^2+1/2\gamma_2 b^2.$ (32)

2.1. Estimation

Notice that the above described system of goods demand functions is nonlinear; the nonlinearity comes in in equation (30). In principle such a nonlinear system of demand equations can be estimated. However, in our data-set the information about job characteristics is dichotomous (e.g. a certain job is reported to be dirty or not). Thus, for q we only have a binary indicator. To estimate the model, we therefore need an explicit expression for the probabilities that the binary indicator q is one or zero. This, in turn, requires the reduced form of the system, which in this case is quite straightforward. See Appendix A.

The necessary condition for a utility maximum is that the slope of the indifference curve equals the slope of the budget constraint. Since the implicit prices are independent of Z_1, Z_2, and Z_3, the budget constraint is linear, and the second order condition for a utility maximum is that the indifference curves are convex. In Appendix A a condition for quasi-concavity of the Hausman-Ruud direct utility function is given, (see also Kapteyn, Kooreman and Van Soest [1986]) as well as a discussion of how this can be checked in estimation.

Estimation of the reduced form parameters requires information on the exogenous variables k and μ, the endogenous variables c, h, q and all (implicit) prices. Prices are functions of observables and unknown parameters which are estimated simultaneously with the system of demand functions.

We specify a stochastic version of the reduced form system by adding a disturbance term to each equation. Due to the adding-up restriction one of the equations may be dropped in estimation. We drop the equation for consumption and obtain all the parameter estimates from the other equations.

To deal with demographic variation we have parameterized δ_1 as

$$\delta_1 = \delta_{10} + \delta_{11}fs + \delta_{12}dchild6 \quad (33)$$

where fs := log of family size

dchild6 := dummy for the presence of children younger than six.

The exact specification of the wage equation is:

$$
\begin{aligned}
w = {} & a_{11} + a_{12}ed2 + a_{13}ed3 + a_{14}ed4 + a_{21}age \\
& + a_{22}ed2.age + a_{23}ed3.age + a_{24}ed4.age \\
& + a_{31}age^2 + a_{32}ed2.age^2 + a_{33}ed3.age^2 \\
& + a_{34}ed4.age^2 + a_5 for + bq
\end{aligned} \tag{34}
$$

where ed2 := 1 if the education level is 2
0 else

ed3 := 1 if the education level is 3
0 else

ed4 := 1 if the education level is 4 (highest)
0 else

for := 1 if the individual's home country is not Holland
0 else

Solving h, q, and w from (29)-(34) yields the reduced form solutions $\hat{h}$, $\hat{q}$, and $\hat{w}$ (see Appendix A). Let $\tilde{h}$ and $\tilde{w}$ be the observed values of h and w and let q^o be the binary indicator for q. Then we specify the following stochastic model for $\tilde{h}, \tilde{w}$ and q^o:

$$\tilde{h} = \hat{h} + \varepsilon_h \tag{35}$$

$$\tilde{w} = \hat{w} + \varepsilon_w \tag{36}$$

$$\tilde{q} = \hat{q} + \varepsilon_q \tag{37}$$

$$q^o = \begin{cases} 1 & \text{if } \tilde{q} > 0 \\ 0 & \text{if } \tilde{q} \leq 0 \end{cases} \tag{38}$$

$$\begin{bmatrix} \varepsilon_h \\ \varepsilon_w \\ \varepsilon_q \end{bmatrix} \sim N \left[\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, V \right] \tag{39}$$

$$V = \left[\begin{array}{cc|c} \sigma_h^2 & \rho_{hw}\sigma_h\sigma_w & \rho_{hq}\sigma_h \\ & \sigma_w^2 & \rho_{wq}\sigma_w \\ & & 1 \end{array}\right]. \tag{40}$$

The likelihood contribution for working individuals with $q^o = 1$ is

$$f_1(\tilde{h},\tilde{w}) . \int_0^\infty f_c(\tilde{q}|\ \tilde{h},\tilde{w})d\tilde{q} \tag{41}$$

and for working individuals with $q^o = 0$

$$f_1(\tilde{h},\tilde{w}) . \int_{-\infty}^0 f_c(\tilde{q}|\ \tilde{h},\tilde{w})d\tilde{q} \tag{42}$$

where f_c is the conditional density of $\tilde{q}$, and f_1 the marginal density of $\tilde{h}$ and $\tilde{w}$. The likelihood for non-working individuals, for whom q and w are not known is:

$$\int_{-\infty}^0 f_2(\tilde{h})d\tilde{h}. \tag{43}$$

where f_2 is the marginal density of $\tilde{h}$.

The model, developed above, is referred to as the "extended" model. We will contrast the extended model with a "standard" model, describing the case where q is excluded from the direct utility function, i.e. q is no longer a choice variable, but enters exogenously into the wage equation. Due to its mode of measurement, q is then taken as a binary variable. Then the maximization problem becomes :

$$\max \quad U(c,l) \tag{44}$$

$$\text{s.t.} \quad p_c c = w(T-l) + \mu. \tag{45}$$

Starting from the indirect utility function, written in terms of goods-prices,

$$V(w,p_c,\mu) = \exp(\beta_1 w/p_c)\mu^* \tag{46}$$

$$\mu^* = \mu + \vartheta + \delta_1 w/p_c + 1/2\gamma_1(w/p_c)^2 \tag{47}$$

the following demand functions for h and c can be derived:

$$c = (\beta_1 w + 1)\mu^* - \vartheta + 1/2\gamma_1 w^2 \tag{48}$$

$$h = \beta_1 \mu^* + \delta_1 + \gamma_1 w. \tag{49}$$

For the rest, the standard model is specified similar to the extended model (equations (33)-(36)).

3. Empirical Results

In Appendix A the complete specification of the extended model and standard model is given. We have considered only one job characteristic, namely cleanliness of work. It is possible to extend the model by considering more job characteristics, but this is left for the future. The model has been estimated by means of maximum likelihood for data from a mobility survey in The Netherlands, conducted in 1985. The sample contained 932 males in families, of which 884 are working and 48 are not working. Sample information is given in Table 1. From this table it can be seen that 73% of the males report to work in clean jobs. Notice that non-labour income also includes labour income of the spouse.

The first column of Table 2 shows results for an Ordinary Least Squares Regression of wages on a vector of human capital variables, on a dummy variable "foreigner" and on a dummy variable for the job characteristic cleanliness of work. The dummy equals one if the work is reported by the individual to be clean, and zero otherwise, which means that the job characteristic is defined to be a "good". The results of the maximum likelihood estimation of the standard and the extended model are presented in the other two columns of Table 2. As was discussed in Section 2, job choice was assumed to be exogenous in the standard model. This model consists of two equations, an hours equation and a wage equation. In the extended model job choice was made endogenous, thus extending the model with a job choice equation.

The coefficient of the job characteristic (b) in the OLS-regression is 0.01 and in the standard model -0.11. Although the specification of the wage equation is identical for the standard model and the single wage equation model, the estimates differ for two reasons. First, the estimation methods differ (OLS versus SURE). Secondly, the OLS-regression has only been done for working individuals (without correction for selection bias). As in much empirical research on wage differentials the estimated wage difference is very small and statistically not significant. According to the theory of compensating wage differentials, one would expect a negative sign for this coefficient. However it could be argued that the coefficient should not be interpreted as a compensating wage differential, but as a measure of the impact of omitted variables, such as ability and motivation. Whatever the interpretation, the two estimates of this coefficient are biased if one believes that the job characteristic is an endogenous variable. In the extended model the interpretation of the wage differential is different, since b is the coefficient of the latent variable $\tilde{q}$ and not of the observed variable q^o. A reasonable measure of the wage differential might be

$$(E(\tilde{q}|q^o=1) - E(\tilde{q}|q^o=0)).b = 6.02 \text{ guilders per hour.}$$

Figure 2 presents, for the different models, wages as a function of age, for different levels of education. As one can see from this figure, age has a positive but decreasing effect on wages, for all levels of education. The higher the level of education the steeper the curve. With respect to the wage curves, all three models look very similar.

Turning to the economic interpretation of the other parameters in the last two columns one should bear in mind that the extended model is nonlinear and that the estimated parameters are just particular parameters of the utility function and of the budget constraint. For simplicity we will nevertheless mainly use conventional terminology to describe the parameters. In both the standard and the extended model family size has a negative, though insignificant effect on the male's labour supply ($\delta_{11}<0$). On the other hand, the more children younger than six there are, the higher is the male's labour supply (this effect is also insignificant) ($\delta_{12}>0$). In all three models being a foreigner has a negative, though insignificant effect.

Furthermore, we notice that both last columns show negative income effects on labour supply ($\beta_1<0$). The income effect on the demand for the job characteristic, $-\beta_2$, is positive, as one would expect since individuals with a high income can best afford nonpecuniary job characteristics.

With respect to the standard model and the extended model, we should note that for numerical reasons the models have been reparameterized. We have estimated directly the constant term, the linear wage coefficient and the quadratic wage coefficient of the hours equation and the constant term in the job characteristic equation. For the exact specification, see Appendix A. Thus, we circumvented the numerical problem of identifying ϑ, when β_1 is small. The linear wage effect is negative and insignificant in the standard model (-0.49), but positive in the extended model (0.59). The quadratic wage coefficient is positive in the standard model and negative in the extended model. In Figure 3 the labour supply curves for both models are shown.

Table 1 Definitions, Means and Standard Deviations of Variables used in the Analysis

Variable Definition	Mean (Standard Deviation)			
	working		not working	all
	clean	dirty		
clean :=1 if the job is clean 0 else	1	0	—	0.73(0.45)*
h := working hours	42.5(7.8)	42.8(7.7)	0	40.4(12.1)
w := after tax wage rate	16.2(6.7)	16.1(6.1)	—	16.2(6.5)*
μ := non-labour income	219(243)	203(216)	501(188)	230(242)
ed2 := 1 if education level is 2 0 else	0.19(0.39)	0.22(0.42)	0.31(0.47)	0.20(0.40)
ed3 := 1 if education level is 3 0 else	0.39(0.49)	0.38(0.49)	0.25(0.44)	0.38(0.49)
ed4 := 1 if education level is 4 (highest) 0 else	0.27(0.48)	0.23(0.42)	0.15(0.36)	0.25(0.43)
age	39.4(10.1)	39.5(9.8)	41.5(10.0)	39.5(10.0)
for := 1 if foreigner 0 else	0.05(0.23)	0.03(0.18)	0.13(0.33)	0.06(0.25)
fs := log of family size	1.2(0.4)	1.3(0.4)	1.22(0.35)	1.2(0.4)
dchild6 := 1 if there are children in the family younger than 6 0 else	0.29(0.45)	0.32(0.47)	0.02(0.14)	0.28(0.45)
number of observations	641	243	48	932

* := These numbers apply to working males only.

Table 2 Parameter Estimates (Standard Errors in parentheses)

Exogenous Variable	Coefficient(Standard Error)		
	OLS Wage Regression	Standard Model	Extended Model
a_{11}(constant)	0.89(7.01)	-3.61(7.58)	-0.31(8.14)
a_{12}(ed2)	-0.60(9.56)	0.68(10.19)	0.58(10.19)
a_{13}(ed3)	-5.09(9.07)	-4.32(9.15)	-4.70(8.76)
a_{14}(ed4)	-17.54(10.59)	-14.92(12.46)	-13.63(11.98)
a_{21}(age)	0.68(0.36)	0.94(0.38)	0.93(0.39)
a_{22}(age.ed2)	0.03(0.49)	-0.04(0.52)	-0.04((0.52)
a_{23}(age.ed3)	0.19(0.46)	0.16(0.45)	0.18(0.44)
a_{24}(age.ed4)	0.87(0.53)	0.74(0.60)	0.69(0.58)
a_{31}(age-squared)	-0.008(0.004)	-0.010(0.005)	-0.01(0.005)
a_{32}(age-sq.ed2)	0.0002(0.006)	0.0008(0.0065)	0.0007(0.0065)
a_{33}(age-sq.ed3)	-0.0004(0.006)	-0.0004(0.0054)	-0.0006(0.0052)
a_{34}(age-sq.ed4)	-0.008(0.006)	-0.0065(0.0070)	-0.0057(0.0069)
a_4(foreigner)	-1.70(0.96))	-1.63(1.06)	-1.57(1.09)
b(wage diffential)	0.01(0.46)	-0.11(0.43)	-5.47(6.63)
c_1(constant)		42.95(8.58)	32.45(3.21)
c_2(linear wage coef.)		-0.49(1.07)	0.59(0.16)
c_3(quadratic wage coef.)		0.03(0.326)	-0.0006(0.0006)
δ_{11} (family size)		-0.97(0.89)	-0.80(0.89)
δ_{12} (dchild6)		0.93(0.69)	0.86(0.68)
β_1 (income)		-0.0020(0.0012)	-0.0016(0.0012)
c_4(constant)			11.68(13.84)
β_2 (income)			-0.0076(0.0085)

Table 2 Continued

σ_h		7.63(0.12)	7.64(0.12)
σ_w	6.07	6.04(0.09)	6.03(0.09)
ρ_{hw}		-0.21(0.03)	-0.21(0.03)
ρ_{hq}			-0.02(0.05)
ρ_{wq}			0.002(0.052)
log(likelihood)		-5875.5	-6394.3

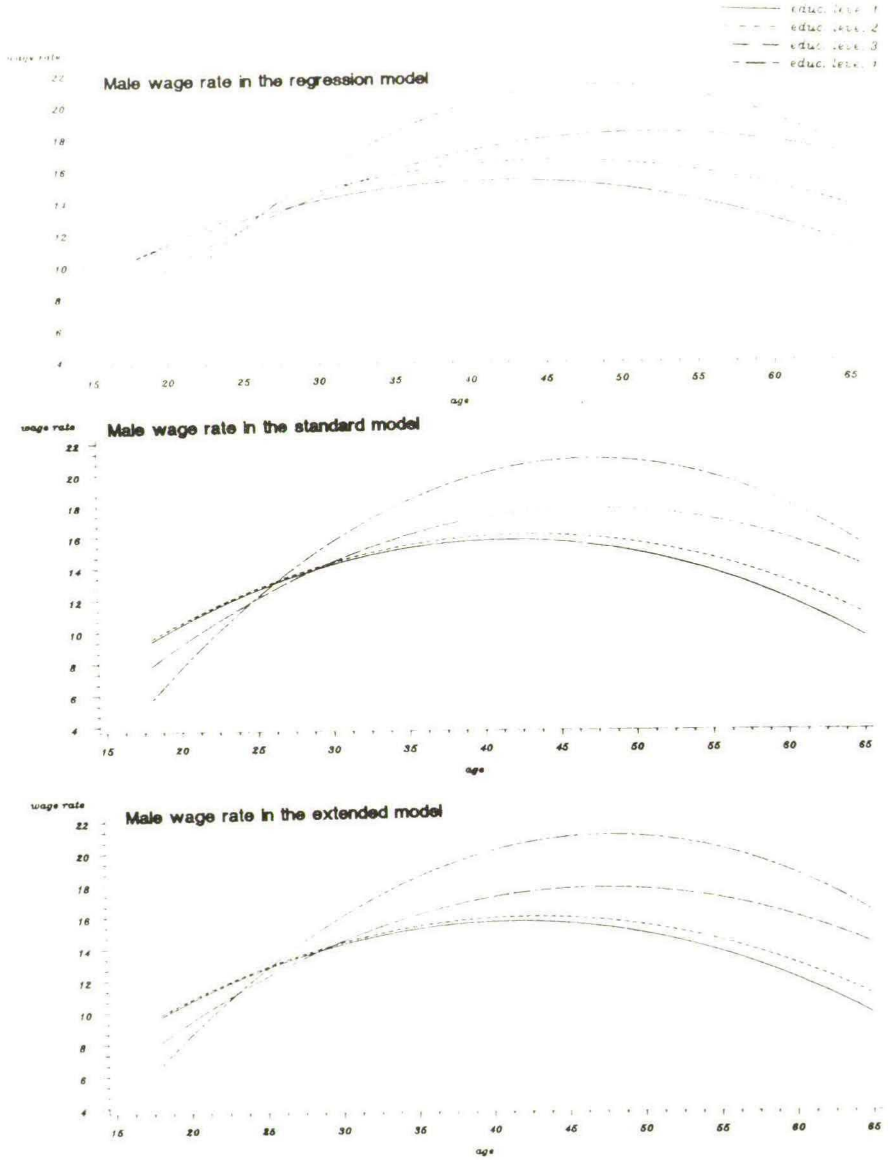
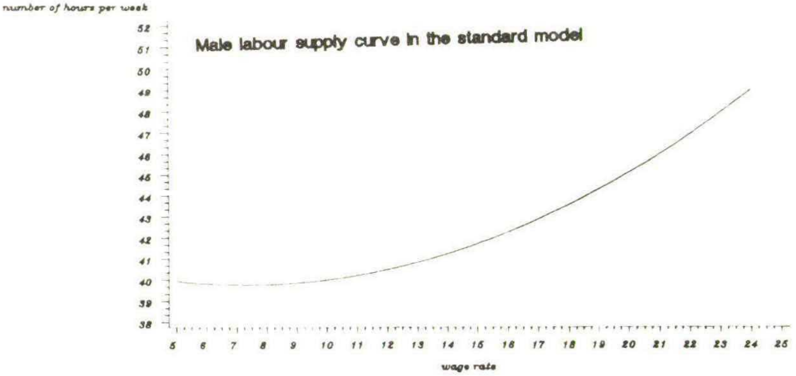


Figure 2. Male wage predictions.



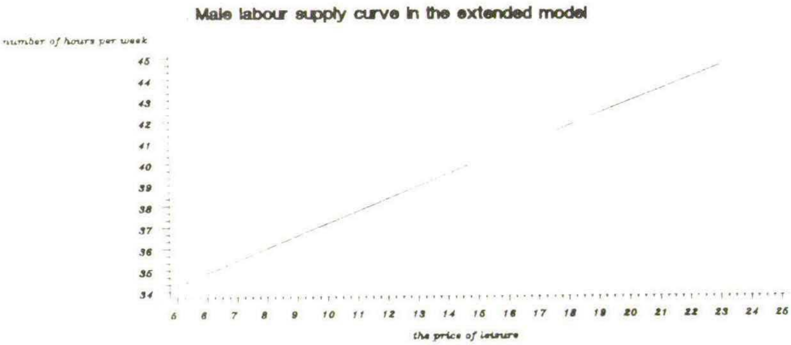


Figure 3. Male labour supply curves.

4. Conclusion

We have estimated a simultaneous model of job choice, labour supply and wages. Two main conclusions emerge from this analysis. First, nonpecuniary job characteristics (in this paper we have only analysed cleanliness of work) are important determinants of labour supply and wages. Second, the model yields estimation results that differ in sign and in magnitude from results obtained for models that do not take into account the endogeneity of job choice. Therefore, analyses of labour supply and wages that ignore the (self) selection of individuals into different occupations, may produce misleading results.

There are a few limitations to this analysis that deserve attention. First, the simple specification of the production function of job characteristics needs improvement. In particular we are considering a specification in which the production of job characteristics also depends on the number of hours one has to be on the job. The underlying idea is that it is worse to do dirty work for forty hours per week than for ten. Second, we have analysed only one job characteristic, while in this model it seems possible to analyse a number of job characteristics simultaneously.

Despite these limitations, it appears that the results so far justify further research of simultaneuos models of job choice, labour supply and wages.

Appendix A. Derivation of the reduced form and some theoretical implications of utility maximization.

In this Appendix, first the exact specifications of the standard model and the extended model will be given, that are used for estimation. Next some theoretical implications of utility maximization are discussed.

Let us start with the exact specification of the standard model, that consists of a wage equation and a labour supply equation:

$$h = \beta_1 \mu^* + \delta_1 + \gamma_1 w. \tag{A.1}$$

$$w = a'k + bq \tag{A.2}$$

where
$$\mu^* = \mu + \vartheta + \delta_1 w + 1/2\gamma_1 (w)^2 \tag{A.3}$$

$$\begin{aligned} a'k = {} & a_{11} + a_{12}ed2 + a_{13}ed3 + a_{14}ed4 + a_{21}age \\ & + a_{22}ed2.age + a_{23}ed3.age + a_{24}ed4.age \\ & + a_{31}age^2 + a_{32}ed2.age^2 + a_{33}ed3.age^2 \\ & + a_{34}ed4.age^2 + a_5 for \end{aligned} \tag{A.4}$$

$$\delta_1 = \delta_{10} + \delta_{11} fs + \delta_{12} dchild6 \tag{A.5}$$

and q exogenous.
We have rewritten equation (A.1) as follows:

$$h = c_1 + c_2 w + c_3 w^2 + \beta_1 \mu + \delta_1' + \beta_1 \delta_1' w \tag{A.6}$$

where
$$c_1 = \beta_1 \vartheta + \delta_{10} \tag{A.7}$$

$$c_2 = \beta_1 \delta_{10} + \gamma_1 \tag{A.8}$$

$$c_3 = =0.5\gamma_1 \beta_1 \tag{A.9}$$

$$\delta_1' = \delta_{11}fs + \delta_{12}dchild6 \tag{A.10}$$

Next we turn to the extended model. In section 2, the demand equations for the goods c,h, and q are derived from a variant of the Hausman-Ruud indirect utility function (equations (29)-(32)). From these equations the reduced form of the model can be obtained :

$$\hat{h} = \beta_1\mu^* + \delta_1 + \gamma_1(a'k) \tag{A.11}$$

$$\hat{q} = (-\beta_2\mu^* - \delta_2 + \gamma_2 b)/\hat{h} \tag{A.12}$$

$$\hat{w} = a'k + b\hat{q} \tag{A.13}$$

$$\mu^* = \mu+\vartheta+\delta_1(a'k)-\delta_2 b+1/2\gamma_1(a'k)^2+1/2\gamma_2 b^2 \tag{A.14}$$

In this model too, we have rewritten the demand equations somewhat:

$$\hat{h} = d_1 + d_2 a'k + d_3(a'k)^2 + \beta_1\mu + \beta_1\delta_1' a'k + \delta_1' \tag{A.15}$$

$$\hat{q} = d_4 - \beta_2\mu - \beta_2\delta_1 a'k - 0.5\gamma_1(a'k)^2/\hat{h} \tag{A.16}$$

where $d_1 = \beta_1(\vartheta - \delta_2 b + 0.5\gamma_2 b^2) + \delta_{10}$ (A.17)

$$d_2 = \beta_1\delta_{10} + \gamma_1 \tag{A.18}$$

$$d_3 = 0.5\beta_1\gamma_1^2 \tag{A.19}$$

$$d_4 = -\beta_2(\vartheta - \delta_2 b + 0.5\gamma_2 b^2) - \delta_2 + \gamma_2 b \tag{A.20}$$

Since the budget constraint is linear, a sufficient condition for a utility maximum is concavity of the direct utility function. This is equivalent with the condition for a cost minimum, namely concavity of the cost function. The cost function corresponding to the indirect Hausman-Ruud utility function is

$$C(\pi) = u.\exp(-\beta'\pi) - \vartheta - \delta'\pi - 1/2\pi' A\pi \tag{A.21}$$

where u denotes the individual's utility level. In this notation the price of consumption is set equal to one.
In the standard model β,π, and A are scalars,namely:

$$\beta := \beta_1$$

$$A := \gamma_1$$

$$\pi := a'k + bq$$

In the extended model β and π are two-dimensional vectors and A is a 2x2 diagonal matrix.

$$\beta := \begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix}$$

$$\pi := \begin{bmatrix} \pi_1 \\ \pi_2 \end{bmatrix}$$

where $\pi_1 = a'k$

$$\pi_2 = -b$$

$$A := \begin{bmatrix} \gamma_1 & 0 \\ 0 & \gamma_2 \end{bmatrix}$$

Concavity of the cost function requires that

$$E := (\mu + \vartheta + \delta'\pi + 1/2\pi'A\pi)\beta\beta' - A \tag{A.22}$$

is negative semi-definite. Since, however, a consideration of (A.17)-(A.20) shows that δ_2 is not identified, the concavity condition cannot (and does not have to) be imposed in estimation.

References

Atrostic, B.K. (1982), "The Demand for Leisure and Nonpecuniary Job Characteristics", American Economic Review , pp. 428-440.

Barnett, W.A (1977), "Pollak and Wachter on the Household Production Function Approach", Journal of Political Economy, vol. 85, pp. 1073-1081.

Becker, G.S. (1965), "A Theory of the Allocation of Time", Economic Journal, vol. 75, pp. 493-517.

Brown, J.R. and S. Rosen (1982), "On the Estimation of Structural Hedonic Price Models", Econometrica, vol. 50, pp.765-769.

Duncan, G.J. (1976), "Earnings Functions and Nonpecuniary Benefits", The Journal of Human Resources, vol. 11, pp. 462-483.

Graham, J. W. and C. A. Greene (1984), "Estimating the Parameters of a Household Production Function with joint Products", Review of Economic Statistics, vol. 66, pp.277-282.

Gronau, R. (1977), "Leisure, Home Production and Work-The Theory of the Allocation of Time revisited", Journal of Political Economy, vol. 85, pp. 1099-1123.

——— (1980), "Home Production- a forgotten Industry", Review of Economic Statistics, vol.62, pp.408-415.

——— (1986), "Home Production-A Survey", in: Handbook of Labor Economics, eds. O. Ashenfelter and R. Layard, Amsterdam: North-Holland.

Hamermesh D.S. (1977), "Economic Aspects of Job Satisfaction", in: Essays in Labor Market Analysis, eds. O. Ashenfelter and W. Oates, New York: Wiley.

Hausman, J. and P. Ruud (1984), "Family Labor Supply with Taxes", American Economic Review, vol. 74, pp. 242-248.

Kapteyn, A., P. Kooreman and A. van Soest (1986), "Non-convex budget sets, institutional constraints and imposition of concavity in a flexible household labor supply model", Working Paper, Tilburg University.

Killingsworth, M.R. (1984), "A Single Structural Model of Heterogeneous Preferences and Compensating Wage Differentials", Working Paper, Rutgers-The State University.

Lancaster, K.J. (1966), "A new Approach to Consumer Theory", Journal of Political Economy, vol. 74, pp.132-157.

Maddala, G.S. (1983), "Limited Dependent and Qualitative Variables in Econometrics", Cambridge: Cambridge University Press.

Pollak, R.A. and M. L. Wachter (1975), "The Relevance of the Household Production Function and its Implications for the Allocation of Time", Journal of Political Economy, vol. 83, pp. 255-277.

Rosen, S. (1974), "Hedonic Prices and Implicit Markets: Product Differentiation in PureCompetition", Journal of Political Economy, vol. 82, pp. 34-55.

Schmidt, P. (1981), "Constraints on the Parameters in Simultaneous Tobit and Probit Models", in: Structural Analysis of Discrete Data: With Econome tric Applications, ed. C.F. Manski and D. McFadden,Cambridge: The MIT Press.

Takayama, A. (1985), "Mathematical Economics", Cambridge: Cambridge University Press.

Wales, T.J. (1978), "Labour Supply and Commuting Time: An Empirical Study", Journal of Econometrics, vol. 8, pp. 215-226.

Zimmerman, K.F. (1987), "Wages and the Quantity and Quality of Labor", Working Paper, University of Pennsylvania and University of Mannheim.

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