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Estimating Earnings In An Employment Status Model With Banded Data

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1. Introduction

In this paper we consider the estimation of earnings equations for individuals who are either self employed or are in paid employment, and who are assumed to have freely chosen their employment status. The key aspect of the available data is that we do not observe an individual's earnings. Instead we only know in which of several bands an individual's earnings are located. This has implications for the choice of econometric technique and implies that the ordered probit, or the ordered probit with selectivity, are the statistical models that appear most appropriate. Commonly used estimation techniques such as the two-step estimator due to Heckman (1979) are inappropriate. However, there is an important difference between the ordered probit model as defined in this paper and as defined in, for example, Greene (1997). The Greene definition of the ordered probit assumes that the band separations are unknowns to be estimated, whereas they are known in our data set. This situation is not uncharacteristic of survey data where individuals, or firms, are reluctant to disclose their precise income. Knowledge of the band separations implies that the parameters in the earnings equation are identified and can therefore be estimated[1]. Parameter estimation is discussed in detail in section 2. The data and the economic framework are discussed in section 3. The estimation results are presented and discussed in section 4. Our conclusions are presented in section 5.

2. The statistical model

The employment status of an individual is assumed to be determined as follows : The latent variable I_i^* is assumed to be determined by the equation

$$I_i^* = Z_i'\theta + u_i \tag{1}$$

where self employment is chosen by individual i if and only if I_i^* is positive, and paid employment is chosen otherwise. If u_i is assumed to be independently $N(0,1)$ across i, and the vector of explanatory variables, Z_i, is observed for all i, then (1) defines a probit and θ can be estimated by maximum likelihood (ml).

The level of an individual's earnings is determined by

$$\ln(E_{se,i}) = \beta_{se}' X_{se,i} + u_{se,i} \tag{2}$$

if individual i is self employed, and by

$$\ln(E_{pe,i}) = \beta_{pe}' X_{pe,i} + u_{pe,i} \tag{3}$$

[1] Stewart (1983) examines the same problem but does not consider sample selection issues.

if individual i is in paid employment. However, the level of an individual's earnings, E, is never observed. Instead, we know in which of the following J+1 bands, indexed by the variable EB, earnings are located :

$$\begin{array}{llll}
EB = 0 & \text{iff } E \in (0, u_1) & \text{iff } \ln(E) \in (-\infty, c_1) \\
EB = 1 & \text{iff } E \in [u_1, u_2) & \text{iff } \ln(E) \in [c_1, c_2) \\
EB = 2 & \text{iff } E \in [u_2, u_3) & \text{iff } \ln(E) \in [c_2, c_3) \\
 & \vdots & \vdots \\
EB = J-1 & \text{iff } E \in [u_{J-1}, u_J) & \text{iff } \ln(E) \in [c_{J-1}, c_J) \\
EB = J & \text{iff } E \in [u_J, \infty) & \text{iff } \ln(E) \in [c_J, \infty)
\end{array}$$

where $c_j = \ln(u_j)$, $j = 1, 2, \dots, J$, are known.

An approach to estimation involves estimating the two earnings equations in isolation, assuming that the disturbance term in either (2) or (3) and u_i in (1) are bivariate normal. For example, the components of the likelihood function when the earnings equation for self employed individuals is estimated are

$$\Pr(I_i^* \leq 0) = \Phi(-Z_i'\theta) \tag{4}$$

and

$$\Pr(I_i^* > 0 \text{ and } EB = 0) = \Phi_2(Z_i'\theta, ((c_1 - \beta_{se}' X_{se,i})/\sigma_{se}), -\rho_{se}) \tag{5}$$

and

$$\begin{aligned}\Pr(I_i^* > 0 \text{ and } EB = j) = {} & \Phi_2(Z_i'\theta, ((c_{j+1} - \beta_{se}' X_{se,i})/\sigma_{se}), -\rho_{se}) \\ & - \Phi_2(Z_i'\theta, ((c_j - \beta_{se}' X_{se,i})/\sigma_{se}), -\rho_{se}),\end{aligned} \tag{6}$$

for $j = 1, 2, \dots, J-1$, and

$$\Pr(I_i^* > 0 \text{ and } EB = J) = \Phi_2(Z_i'\theta, ((\beta_{se}' X_{se,i} - c_J)/\sigma_{se}), \rho_{se}), \tag{7}$$

where σ_{se} is the standard deviation of u_{se}, ρ_{se} is the correlation between u and u_{se}, Φ is the cumulative distribution function for a standard normal, and Φ_2 is the cumulative distribution function for a standard bivariate normal[2]. It is convenient to write the implied log-likelihood function, $\ell(\theta, \beta_{se}, \sigma_{se}, \rho_{se})$, as

$$\ell(\theta, \beta_{se}, \sigma_{se}, \rho_{se}) = \sum_{i=1}^{i=n} \sum_{j=1}^{j=J+2} D_{ij} \ln(\Pr(D_{ij} = 1)) \tag{8}$$

[2]Thus

$$\Phi_2(a, b, c) = \Pr(X_1 \leq a \text{ and } X_2 \leq b)$$

where X_1 and X_2 are bivariate normal with $\mathrm{E}(X_1) = \mathrm{E}(X_2) = 0$, $\mathrm{var}(X_1) = \mathrm{var}(X_2) = 1$ and $\mathrm{corr}(X_1, X_2) = c$.

where $D_{i1} = 1$ iff $I_i^* \leq 0$, $\Pr(D_{i1} = 1)$ is given in (4), $D_{i2} = 1$ iff $I_i^* > 0$ and $EB = 0$, $\Pr(D_{i2} = 1)$ is given in (5), $D_{ij} = 1$ iff $I_i^* > 0$ and $EB = j - 2$, with $\Pr(D_{ij} = 1)$ given in (6), for $j = 3, \ldots, J + 1$, and $D_{i,J+2} = 1$ iff $I_i^* > 0$ and $EB = J$ with $\Pr(D_{i,J+2} = 1)$ given in (7)[3].

It follows from (8) that

$$\mathrm{d}\ell(\theta, \beta_{se}, \sigma_{se}, \rho_{se}) = \sum_{i=1}^{i=n} \sum_{j=1}^{j=J+2} D_{ij} \frac{1}{\Pr(D_{ij} = 1)} \mathrm{dPr}(D_{ij} = 1) \tag{9}$$

where d indicates differentiation with respect to the vector of unknown parameters, and analytical expressions for the score vector in (9) can be obtained using the relationship between $\Pr(D_{ij} = 1)$, $j = 1, 2, \ldots, J + 2$, and the expressions in (4) to (7), and the derivatives

$$\frac{\partial \Phi_2(a, b, c)}{\partial a} = \phi(a)\Phi((b - ca)/\sqrt{1 - c^2}) \tag{10}$$

$$\frac{\partial \Phi_2(a, b, c)}{\partial c} = \frac{\phi(b)\phi((a - cb)/\sqrt{1 - c^2})}{\sqrt{1 - c^2}}. \tag{11}$$

The same approach allows an analytical expression for the matrix

$$\sum_{i=1}^{i=n} \sum_{j=1}^{j=J+2} D_{ij} \frac{1}{\Pr(D_{ij} = 1)} \mathrm{dPr}(D_{ij} = 1)(\mathrm{dPr}(D_{ij} = 1))' \tag{12}$$

to be obtained. Since this is $-\mathrm{E}[\mathrm{D}\ell(\theta, \beta_{se}, \sigma_{se}, \rho_{se})]$, where $\mathrm{D}\ell$ is the second derivative matrix of $\ell(\theta, \beta_{se}, \sigma_{se}, \rho_{se})$, it follows that analytical asymptotic standard errors for the ml estimators are available.

There are alternatives to the estimator outlined above. From both modelling and computational points of view an attractive alternative involves maximising $\ell(\theta, \beta_{se}, \sigma_{se}, \rho_{se})$ over β_{se}, σ_{se}, and ρ_{se}, with θ fixed at the probit ml estimate. The computational advantage of this two-step estimator lies in the considerable reduction in the number of parameters over which $\ell(\theta, \beta_{se}, \sigma_{se}, \rho_{se})$ is maximised. The two-step estimator will be consistent but inefficient relative to the estimator that maximises $\ell(\theta, \beta_{se}, \sigma_{se}, \rho_{se})$ over all the unknown parameters. Further, as with the Heckman estimator in the

[3] The ordered probit with selectivity model implemented in the Limdep package treats $c_1, c_2, \ldots, c_J$ in (8) as unknowns to be estimated. If there are three earnings bands the Limdep estimation is simply a reparameterisation of that implied by the maximisation of the log-likelihood in (8) over $\theta, \beta_{se}, \sigma_{se}, \rho_{se}$ only, so that estimates of these parameters can be obtained from Limdep output and knowledge of c_1 and c_2. If there are more than three earnings bands then the Limdep estimation ignores valid parameter restrictions which allow the identification of the parameters of the earnings equation.

case where earnings are observed, the fact that θ is estimated at an earlier stage needs to be taken into account in defining standard errors for the estimated β_{se}, σ_{se}, and ρ_{se} which are obtained at the second stage. The result needed to correctly define these standard errors is derived in the appendix. The estimation results presented in section 4 use the two-step estimator[4].

3. The economic model and the data

A standard argument is to regard the equation in (1) as being the result of combining the earnings equations in (2) and (3) with the 'structural' equation

$$I_i^* = \delta_1(\ln(E_{se,i}) - \ln(E_{pe,i})) + \delta_2' X_i + \varepsilon_i \tag{13}$$

where δ_1 is positive. This interpretation of the 'reduced form' equation in (1) implies that the variables in Z_i include those in $X_{se,i}$, $X_{pe,i}$, and X_i, so that no variables appear in $X_{se,i}$ or $X_{pe,i}$ that do not appear in Z_i [5]. However the definition of some of the variables in our data set does not fit well with this implication of (13), (2) and (3), and as a consequence we work with the model defined by (1), (2) and (3) rather than that defined by (13), (2) and (3). An example of a variable which leads to this decision is **parttime** which is defined in Table 1 as recording whether an individual works full time or part time. It seems likely that part time workers will have lower earnings than full time workers so that this variable should be included in $X_{pe,i}$. Further, a preference for working a smaller than average number of hours might influence an individual's decision regarding self, as opposed to paid, employment, but it isn't clear that this preference is what our variable actually records[6]. Similar comments apply to the variables which record the size of the company in which individuals in paid employment work (**large**, **small**, and **medium** in Table 1), and to the variable indicating whether or not the individual is a member of a trade union (**union**).

[4] The estimation results reported in this paper were obtained using the optimisation routines in Gauss which were supplied with analytical first derivatives. σ_{se} was estimated via $\sigma_{se} = \exp(a_1)$ since σ_{se} must be positive, and ρ_{se} was estimated via $\rho_{se} = (\exp(a_2) - 1)/(\exp(a_2) + 1)$ since ρ_{se} must lie between -1 and 1. It turned out that we needed to deal with the problem that expressions of the type $\Phi_2(a, b+\delta, c) - \Phi_2(a, b, c)$, for positive δ, see (6) in the text, were sometimes calculated to be negative (and small). When this problem arose the routines switched to calculating $\Phi_2(a, b+\delta, c) - \Phi_2(a, b, c)$ by numerical integration of the appropriate density function.

[5] Further, $u_i = \varepsilon_i + \delta_1(u_{se,i} - u_{pe,i})$ and if ε_i, $u_{se,i}$, and $u_{pe,i}$ are uncorrelated then both $\rho_{se} = \text{corr}(u_i, u_{se,i}) = \delta_1 \text{var}(u_{se,i})$ and $\rho_{pe} = \text{corr}(u_i, u_{pe,i}) = -\delta_1 \text{var}(u_{pe,i})$ will be non-zero.

[6] Nor is it clear whether individuals are part time workers by choice. The discussion in the text suggests it might be useful to think of (1) as following from an equation of the form in (13) in which expected or potential earnings, rather than actual earnings as determined in (2) and (3), are compared.

The complete set of variables used in this paper is listed in Table 1. The data are a subset of that used elsewhere by the same authors (Ashcroft, Holden, and Low (2004)). The full data set was constructed from the records of interviews of a representative set of individuals in the UK conducted by the MORI organisation for Scottish Enterprise in 1992 as part of the preparatory work for its Business Birth-rate Strategy. An interesting feature of the data set is the presence of a number of variables which record the individual's attitudes and perceptions. The usefulness of these variables in explaining the choice between paid and self employment, and earnings, is an interesting, and potentially important, issue. Government policy directed towards the creation of an 'enterprise culture' might be interpreted as attempting to make self employment a more attractive alternative to the individual, and thus as working via an individual's attitudes. A necessary condition for such an approach to be successful is that an individual's attitudes affect their behaviour. The use of subjective variables relating to an individual's attitudes and perceptions is further discussed in Ashcroft, Holden, and Low (2004). There are a number of disadvantages of the data set : the age of the individual and of the individual's children are not continuously observed, nor are variables relating to the education and work experience of the individual available.

As in Ashcroft, Holden, and Low (2004) it is useful to collect the full set of variables into six groups which are defined as follows : objective human capital (OHC) variables, location (L) variables, self-perceived human capital (PHC) variables, attitudes towards risk (RA) variables, preferences towards entrepreneurship and self-employment (PFE) variables, and two sets of variables which describe the social attitudes of the individual : SA1 contains variables which measure the 'communitarian' aspects of an individual's attitudes, whereas SA2 contains variables which measure the 'individualistic' aspects of an individual's attitudes.

The earnings of an individual are known to be in one of three bands. The bands, and the distribution of individuals across the bands, are as follows :

Earnings (E) in pounds	self employment	paid employment
$E < 11499$	16	106
$11500 \leq E < 17499$	24	170
$E \geq 17500$	57	240

so that there are 613 individuals in the sample, 97 of whom are self employed, with the remaining 516 individuals being in paid employment.

4. The results

A natural approach to adopt is to model the participation decision, as a probit, before moving on to consider the issue of earnings determination using the two-step estimator defined in section 2 and the appendix. Thus, some estimated probits are reported in Table 2. The results in the first column are obtained by including all but the final set of variables defined in Table 1[7]. On the basis of the likelihood ratio tests reported in Table 2 the PHC variables and the SA2 variables are each jointly insignificant and might therefore be excluded. The ml estimates of the resulting specification are reported in the second column of Table 2. The third column reintroduces the **entrepreneur** variable, since it is the single individually significant variable in the SA2 group in the results in the first column of Table 2.

Similar findings emerge when the three different specifications in Table 2 are considered. Concentrating on the variables which achieve statistical significance : females are less likely to be self employed than males; the widowed/divorced/separated are most, and the single least, likely to be self employed, when marital status is considered; the probability of being self employed is smallest for individuals residing in Scotland/North/Wales and largest for individuals residing in E Midlands/S West/E Anglia. As far as the significant attitudinal variables are concerned an expressed willingness to take risks (ie **pchard2** = 1) increases the probability of being self employed, as does an expressed liking for independence (**pchard10** = 1), and an expressed belief that entrepreneurs contribute a good deal to society (**entrepreneur** = 1). Finally, individuals who place importance on job security (**pchard7** = 1) are less likely to be self employed.

4.1. Earnings in paid employment

The initial specification of an earnings equation for individuals who opt for paid employment includes the following variables : the sex, age, and social class variables from the OHC group, the locational variables, and the variables **union**, **parttime**, **large**, **medium**, and **small** which describe aspects of the job the individual ends up with. In addition we include the ten attitudinal variables which make up the sets RA, PFE, and PHC.

The two-step estimator can be implemented using any of the estimated probits reported in Table 2. Since similar results emerge whichever specification of the probit is chosen we only report the results for two-step estimation when the restricted probit specification in the second column of Table 2 is used. The first column of Table 3 gives the two-step estimates of the unrestricted specification of an earnings equation for individuals in paid employ-

[7]**nochild5** is not included because it is always 0.

ment. The age and social class variables, as well as **small**, are individually significant. The estimated correlation between u in (1) and u_{pe} in (3), ρ_{pe}, is positive but the null hypothesis that ρ_{pe} is zero cannot be rejected. The statistics for the joint significance of groups of variables[8] indicate that all the attitudinal variables (groups RA, PFE, and PHC) might be excluded as might the locational variables. The two-step estimates of the resulting specification are reported in the second column of Table 3. The sign of the estimated coefficient attached to **large** is the only one to change when the results in columns 1 and 2 of Table 3 are compared. However, this variable is insignificant, and the two sets of estimation results in Table 3 are very similar : the age and social class variables and **small** are significant explanatory variables.

A useful way of considering the magnitude of the estimated coefficients is to use the equation in (3) to obtain predicted earnings. A set of predictions, based on the results in the second column of Table 3, is as follows[9] :

[8]These statistics are Wald statistics based on the estimated variance matrix for the two-step estimator, as defined in the appendix. The OHC set of variables differs between Tables 2 and 3 so that χ^2(OHC) in Table 2 has 28 degrees of freedom whereas χ^2(OHC) in Table 3 has 13 degrees of freedom.

[9]The equation $\mathrm{E}(\ln(E_{pe,i})/I_i^* \leq 0) = \beta_{pe}' X_{pe,i} - \rho_{pe}\sigma_{pe}\lambda(-Z_i'\theta)$ implies that the expected earnings of an individual are increased (decreased) when that individual is known to be in paid employment if ρ_{pe} is negative (positive). The predictions reported in the text do not assume knowledge of an individual's employment status.

			pounds	
default earnings		:	7796	
sex = 1 earnings		:	7417	(-4.9%)
age1 = 1 earnings		:	13329	(+71%)
age2 = 1 earnings		:	12717	(+63.1%)
age3 = 1 earnings		:	11944	(+53.2%)
age4 = 1 earnings		:	12551	(+61%)
age5 = 1 earnings		:	14165	(+81.7%)
age6 = 1 earnings		:	15964	(+105%)
age7 = 1 earnings		:	12209	(+56.6%)
age8 = 1 earnings		:	12706	(+63%)
age9 = 1 earnings		:	13540	(+73.7%)
sclassab = 1 earnings		:	15381	(+97.3%)
sclassc1 = 1 earnings		:	11494	(+47.4%)
sclassc2 = 1 earnings		:	9994	(+28.2%)
union = 1 earnings		:	7377	(-5.4%)
parttime = 1 earnings		:	7000	(-10.2%)
large = 1 earnings		:	7752	(-0.6%)
medium = 1 earnings		:	7580	(-2.8%)
small = 1 earnings		:	6560	(-15.9%)

where the default earnings are of a male aged between 60 and 64, who is in social class D or social class E, works full time in the public sector, and is not a member of a trade union. If an otherwise identical female is compared to the default individual then we see that predicted earnings fall by £379 (ie by 4.9% of default earnings). Some of the predicted effects are substantial. For example, comparing **sclassab** = 1 earnings to default earnings implies an difference in predicted earnings of £7585, which is 97.3% of default earnings[10].

The results in the second column of Table 3 imply that the average level of predicted earnings across all 613 individuals in the sample is £17426, and that the average level of predicted earnings across the 516 individuals who are in paid employment is £17411.

The comparison between predicted and actual outcomes, where each individual is predicted to be self employed, in paid employment with earnings not exceeding £11499, in paid employment with earnings between £11500 and £17499, or in paid employment with earnings exceeding £17500 accord-

[10]Default earnings are estimated by $\exp(\hat{c})$, where $\hat{c}$ is the estimated intercept. Small changes in the estimated intercept can produce substantial changes in estimated default earnings. A 95% confidence interval for default earnings is £5451 to £10140.

ing to a maximum predicted probability rule, in the following array :

40	8	21	28
9	41	39	17
7	24	63	76
18	9	34	179

(where the rows (columns) correspond to actual (predicted) behaviour[11]) shows that the behaviour of 52.7% of individuals is correctly predicted.

4.2. Earnings in self employment

Given the small number of individuals in self employment compared to paid employment it is perhaps not surprising that the estimated earnings equations for self employed individuals are not especially encouraging. As an initial specification we include age, sex, and social class variables from the OHC set, as well as the locational (L) variables, and the attitudinal variables that make up the RA, PFE and PHC sets. The first column in Table 4 contains the results of the two-step estimation of such an earnings equation for individuals in self employment[12]. On the basis of tests for individual significance and joint significance it is worth considering the simpler specification that is obtained by excluding the RA and PFE groups of variables. The resulting specification is reported in the second column of Table 4. The third column of Table 4 contains the results of estimating an earnings equation with the PHC variables removed from the specification in the second column of the table. This group is collectively insignificant but contains an individually significant variable (**pchard4**).

In each of the estimations reported in Table 4 there is evidence to suggest that social class and regional location have a role to play in explaining earnings. In addition the attitudinal variable indicating whether an individual considers that they put work before family (**pchard4**) is significant, and positively signed, in the two specifications in which it is included. Whilst the restrictions required to obtain the third specification from the second specification are acceptable on statistical grounds there does appear to be a greater degree of similarity between the first and second set of results as compared to the second and third set of results[13]. Given this we might take

[11]For example there are 18 individuals who are in paid employment and earning at least £17500 who are predicted to be self employed.

[12]For consistency with the estimated earnings equations reported in Table 3 the probit is again specified as in the second column of Table 2. The alternative specifications of the probit lead to similar conclusions to those in the text. **age1** is not included because it is always 0.

[13]The equation $E(\ln(E_{se,i})/I_i^* > 0) = \beta_{se}' X_{se,i} + \rho_{se}\sigma_{se}\lambda(Z_i'\theta)$ implies that the expected

the results in the second column to be our preferred specification, and use it to produce the following predicted earnings figures :

		pounds	
default earnings	:	3336	
sex = 1 earnings	:	3063	(-8.2%)
age2 = 1 earnings	:	6698	(+101%)
age3 = 1 earnings	:	4174	(+25.1%)
age4 = 1 earnings	:	4536	(+36%)
age5 = 1 earnings	:	4716	(+41.4%)
age6 = 1 earnings	:	4670	(+40%)
age7 = 1 earnings	:	4148	(+24.3%)
age8 = 1 earnings	:	3286	(-1.5%)
age9 = 1 earnings	:	6996	(+109.7%)
sclassab = 1 earnings	:	6052	(+81.4%)
sclassc1 = 1 earnings	:	4869	(+46%)
sclassc2 = 1 earnings	:	3491	(+4.6%)
regdb = 1 earnings	:	7135	(+113.9%)
regdc = 1 earnings	:	5544	(+66.2%)
regdd = 1 earnings	:	8357	(+150.5%)
pchard1 = 1 earnings	:	4153	(+24.5%)
pchard3 = 1 earnings	:	3785	(+13.5%)
pchard4 = 1 earnings	:	5716	(+71.3%)
pchard5 = 1 earnings	:	5246	(+57.3%)
pchard6 = 1 earnings	:	3718	(+11.5%)
pchard8 = 1 earnings	:	2597	(-22%)

where default earnings apply to a male aged between 60 and 64 years of age, who is in social class D or social class E, resides in Scotland/North/Wales and whose attitudes are such that he perceives himself to be uncaring, unable to cope with pressure, not to put work before family, not to be dynamic, not to be able to think up new ideas, and not to have leadership qualities[14]. Some of the earnings differentials are quite substantial. For example, the earnings of an individual who matches the default conditions in all respects except for being a member of either social class A or social class B will be increased by £2716 (81.4% of default earnings), and the earnings of an individual who matches the default conditions in all respects except for being resident in London/S East will be increased by £5021 (150.5%). The average level of

earnings of an individual are increased (decreased) when that individual is known to be self employed if ρ_{se} is positive (negative). Given this we might expect that ρ_{se} will be positive. The estimated ρ_{se} is negative, allbeit insignificant, in the third column.

[14]A 95% confidence interval for default earnings is -£694 to £7366.

predicted earnings across all 613 individuals in the sample is £17621, and the average level of predicted earnings across the 97 individuals who are self employed is £20593.

The comparison between predicted and actual outcomes in the following array[15] :

510	1	1	4
16	0	0	0
21	0	0	3
43	0	0	14

shows that the behaviour of 85.5% of individuals is correctly predicted. However the ability of the estimated earnings equation and probit to correctly predict self employment is poor since 80 of the 97 self employed individuals are predicted to be in paid employment and only 23 individuals are predicted to be self employed.

5. Conclusions

When surveys are conducted of individual earnings or company turnover it is not always possible to obtain disclosure of the precise figures. However, individuals and companies are frequently more willing to locate their earnings within an income range, with the result that only banded data are available to the researcher. This is the situation with which we were confronted in our research on the self-employment choice decision, and for which we develop a two-step estimation procedure.

For earnings in paid employment, age, social class, and small firm employment were the significant variables in both sets of estimation results presented in the paper. There were no significant regional effects and neither union membership nor part-time working had a statistically significant effect. These results can be compared with those of others who have had the advantage of individual earnings data to estimate earnings equations as part of employment choice models. Support for the effect of age is given in Rees and Shah (1986) and Evans and Leighton (1989)[16], but not in Dolton and Makepeace (1990). Social class was also found to be significant in Dolton and Makepeace (1990) and in several other papers, such as Rees and Shah

[15]The rows (columns) correspond to actual (predicted) behaviour. Both the rows and columns are ordered as follows : paid employment, self employment with earnings not exceeding £11499, self employment with earnings between £11500 and £17499, self employment with earnings exceeding £17500. As an example, there are 21 self employed earning between £11500 and £17499 who are predicted to be in paid employment.

[16]In Evans and Leighton (1989) the variable *years of wage experience* was significant and this might be taken as a reasonable proxy for age.

(1986), Gill (1988) and Evans and Leighton (1989), where years in education, a likely proxy for social class, was found to be significant. In contrast, Dolton and Makepeace (1990) found both gender and part-time working to be significant, while Gill (1988) and Evans and Leighton (1989) found that a measure of location had a significant effect. None of these variables was significant in our model.

For earnings in self-employment, the preferred specification indicated that social class and regional location have a role to play in the explanation. In addition, the attitudinal variable that indicates whether an individual considers that they put work before family was also significant. No other study contains attitudinal variables, but some studies do confirm the importance of measures of, or proxies for, social class (Gill, 1988; and Evans and Leighton 1989) and location (Rees and Shah, 1986; and Evans and Leighton, 1989), while others do not (Rees and Shah, 1986; and Dolton and Makepeace, 1990 for social class; Gill, 1988 for location). Dolton and Makepeace (1990) also found that gender played no role in determining self-employment earnings.

The average level of predicted earnings for the self-employed was £20,593 per annum and, as might be expected, this was higher than the predicted level for paid employment of £17,411. These figures compare with the April 1992 level of average earnings for paid employment in the UK of £15,850.

Appendix

Let p_1 be the vector of unknown parameters comprising $\beta_{se}, \sigma_{se}, \rho_{se}$ and let p_2 be θ. Then the 2-step estimator of p_1, $\overline{p}_1$, maximises $\ell(p_1, \overline{p}_2)$ over p_1, where $\overline{p}_2$ is the probit ml of p_2 obtained at the first stage. If $\mathrm{d}_1\ell(p_1, p_2)$ denotes the p_1 derivative of $\ell(p_1, p_2)$ then we have the expansion :

$$\mathrm{d}_1\ell(\overline{p}_1, \overline{p}_2) = 0 = \mathrm{d}_1\ell(p_1, p_2) + \mathrm{D}_{11}\ell(p_1, p_2)(\overline{p}_1 - p_1) + \mathrm{D}_{12}\ell(p_1, p_2)(\overline{p}_2 - p_2) + R \tag{a1}$$

where $\mathrm{D}_{11}\ell(p_1, p_2)$ and $\mathrm{D}_{12}\ell(p_1, p_2)$ are second derivative matrices, and the remainder term, R, will be negligable under standard assumptions. It follows from (a1) that $n^{1/2}(\overline{p}_1 - p_1)$ has the same limiting distribution as

$$-(n^{-1}\mathrm{D}_{11}\ell(p_1, p_2))^{-1}\{n^{-1/2}\mathrm{d}_1\ell(p_1, p_2) + n^{-1}\mathrm{D}_{12}\ell(p_1, p_2)n^{1/2}(\overline{p}_2 - p_2)\}. \tag{a2}$$

The terms $n^{-1}\mathrm{D}_{11}\ell(p_1, p_2)$ and $n^{-1}\mathrm{D}_{12}\ell(p_1, p_2)$ in (a2) will have probability limits which can be consistently estimated via (12) in the text. We also require the covariance terms in the joint limiting distribution of $n^{-1/2}\mathrm{d}_1\ell(p_1, p_2)$ and $n^{1/2}(\overline{p}_2 - p_2)$. These can be found using the probit expansion of Amemiya (1985, p. 366) which shows that $n^{1/2}(\overline{p}_2 - p_2)$ has the same limiting distribution as

$$-\left[\frac{1}{n}\sum_{i=1}^{i=n}\frac{\phi_i^2}{\Phi_i^+\Phi_i^-}Z_iZ_i'\right]^{-1}\frac{1}{\sqrt{n}}\sum_{i=1}^{i=n}Z_i\frac{\phi_i}{\Phi_i^+\Phi_i^-}(D_{i1} - \Phi_i^-) \tag{a3}$$

where D_{i1} is defined in the text, $\phi_i = \phi(Z_i'\theta)$, $\Phi_i^+ = \Phi(Z_i'\theta)$, and $\Phi_i^- = \Phi(-Z_i'\theta)$. Given this, the covariance terms will follow if we can evaluate

$$\mathrm{E}\left[\frac{1}{\sqrt{n}}\sum_{i=1}^{i=n}Z_i\frac{\phi_i}{\Phi_i^+\Phi_i^-}(D_{i1} - \Phi_i^-)\left(\frac{1}{\sqrt{n}}\mathrm{d}_1\ell(p_1, p_2)\right)'\right] \tag{a4}$$

which, using (9), is

$$\frac{1}{n}\sum_{i=1}^{i=n}Z_i\frac{\phi_i}{\Phi_i^+\Phi_i^-}\sum_{j=1}^{j=J+2}\mathrm{E}((D_{i1} - \Phi_i^-)D_{ij})\frac{1}{\Pr(D_{ij} = 1)}(\mathrm{d}_1\Pr(D_{ij} = 1))'. \tag{a5}$$

Using (i) $D_{i1}D_{ij} = 0$ whenever $j \neq 1$, and (ii) $\mathrm{E}(D_{ij}) = \Pr(D_{ij} = 1)$, the expression in (a5) can be shown to be

$$\frac{1}{n}\sum_{i=1}^{i=n}Z_i\frac{\phi_i}{\Phi_i^+\Phi_i^-}(\mathrm{d}_1\Pr(D_{i1} = 1))' - \frac{1}{n}\sum_{i=1}^{i=n}Z_i\frac{\phi_i}{\Phi_i^+}\sum_{j=1}^{j=J+2}(\mathrm{d}_1\Pr(D_{ij} = 1))'. \tag{a6}$$

The second term in (a6) will be 0 because $\Pr(D_{ij} = 1)$ sums to 1 across $j = 1, 2, \ldots, J + 2$, which implies

$$\sum_{j=1}^{j=J+2} \mathrm{d}_1 \Pr(D_{ij} = 1) = 0. \tag{a7}$$

The first term in (a6) is also 0 since $\Pr(D_{i1} = 1) = \Phi(-Z_i'\theta) = \Phi(-Z_i'p_2)$ and does not depend on p_1.

We have shown that the covariance terms in the joint limiting distribution of $n^{-1/2}\mathrm{d}_1\ell(p_1, p_2)$ and $n^{1/2}(\overline{p}_2 - p_2)$ are zero. It follows from (a2) that the limiting distribution of $n^{1/2}(\overline{p}_1 - p_1)$ is $N(0, V)$ where $V = A^{-1}(V_{11} + BV_{22}B')A^{-1}$, $A = \mathrm{plim}(n^{-1}\mathrm{D}_{11}\ell(p_1, p_2))$, $B = \mathrm{plim}(n^{-1}\mathrm{D}_{12}\ell(p_1, p_2))$, V_{22} is the variance matrix for the probit ml estimator, and V_{11} is the limiting variance matrix of $n^{-1/2}\mathrm{d}_1\ell(p_1, p_2)$, so that $V_{11} = -A$. It follows that V can be written as $A^{-1}BV_{22}B'A^{-1} - A^{-1}$.

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Table 1 : Definition of Variables

Objective Human Capital (OHC)

sex	:	is 1 iff female
age1	:	is 1 iff between 18 and 20 years old
age2	:	is 1 iff between 21 and 24 years old
age3	:	is 1 iff between 25 and 29 years old
age4	:	is 1 iff between 30 and 34 years old
age5	:	is 1 iff between 35 and 39 years old
age6	:	is 1 iff between 40 and 44 years old
age7	:	is 1 iff between 45 and 49 years old
age8	:	is 1 iff between 50 and 54 years old
age9	:	is 1 iff between 55 and 59 years old
age10	:	is 1 iff between 60 and 64 years old
sclassab	:	is 1 iff in social class A or social class B
sclassc1	:	is 1 iff in social class C1
sclassc2	:	is 1 iff in social class C2
marital1	:	is 1 iff married
marital2	:	is 1 iff living with a partner
marital3	:	is 1 iff divorced/separated/widowed
childage1	:	is 1 iff has children aged between 0 and 4
childage2	:	is 1 iff has children aged between 5 and 6
childage3	:	is 1 iff has children aged between 7 and 8
childage4	:	is 1 iff has children aged between 9 and 10
childage5	:	is 1 iff has children aged between 11 and 14
nochild1	:	is 1 iff has 1 child
nochild2	:	is 1 iff has 2 children
nochild3	:	is 1 iff has 3 children
nochild4	:	is 1 iff has 4 children
nochild5	:	is 1 iff has more than 4 children
contact1	:	is 1 iff knows someone who runs their own business
contact2	:	is 1 iff member of family runs their own business
contact3	:	is 1 iff used to run their own business

Table 1. Continued on next page

Table 1. Continued from previous page

Location (L)

regda	:	is 1 iff resides in Scotland/North/Wales
regdb	:	is 1 iff resides in N West/Y and H/W Midlands
regdc	:	is 1 iff resides in E Midlands/S West/E Anglia
regdd	:	is 1 iff resides in London/S East

Attitude to Risk (RA)

pchar2	:	is 1 iff judges that they are willing to take risks
pchar7	:	is 1 iff judges that they place importance on job security

Self-Percieved Human Capital (PHC)

pchar1	:	is 1 iff judges that they care about people
pchar3	:	is 1 iff judges that they are able to cope with pressure
pchar4	:	is 1 iff judges that they put work before family
pchar5	:	is 1 iff judges that they are dynamic
pchar6	:	is 1 iff judges that they often think up new ideas
pchar8	:	is 1 iff judges that they have leadership qualities

Preferences for Self Employment (PFE)

pchar9	:	is 1 iff judges that they place a high priority on making money
pchar10	:	is 1 iff judges that they like being independent

'Communitarian' attitudes (SA1)

busdriver	:	is 1 iff judges that bus drivers contribute a great deal to society
minister	:	is 1 iff judges that ministers of religion contribute a great deal to society
teacher	:	is 1 iff judges that teachers contribute a great deal to society
lwpaper	:	is 1 iff reads a left wing paper
broadsheet	:	is 1 iff reads broadsheets

'Individualistic' attitudes (SA2)

banker	:	is 1 iff judges that bankers contribute a great deal to society
director	:	is 1 iff judges that directors contribute a great deal to society

Table 1. Continued on next page

Table 1. Continued from previous page		
entrepreneur	:	is 1 iff judges that entrepreneurs contribute a great deal to society
lawyer	:	is 1 iff judges that lawyers contribute a great deal to society
plumber	:	is 1 iff judges that plumbers contribute a great deal to society
cpaper	:	is 1 iff reads a centre paper
rwpaper	:	is 1 iff reads a right wing paper
tabloid	:	is 1 iff reads tabloids
Other variables		
union	:	is 1 iff is a member of a union
parttime	:	is i iff individual i works parttime
large	:	is 1 iff works for a large firm
medium	:	is 1 iff works for a medium sized firm
small	:	is 1 iff works for a small firm

Table 2 : Some estimated probits

note : 1 corresponds to self employment and 0 to paid employment. t ratios are in parentheses. A * indicates significance at the 5% level.

variable			
constant	-2.802	-2.488	-2.590
	(-3.884*)	(-3.756*)	(-3.823*)
sex	-0.529	-0.514	-0.492
	(-2.97*)	(-3.05*)	(-2.90*)
age1	-3.422	-3.643	-3.553
	(-0.133)	(-0.140)	(-0.136)
age2	0.414	0.166	0.198
	(0.728)	(0.310)	(0.362)
age3	0.0024	-0.144	-0.163
	(0.0045)	(-0.282)	(-0.314)
age4	0.313	0.145	0.164
	(0.580)	(0.283)	(0.316)
age5	0.0347	-0.110	-0.147
	(0.065)	(-0.220)	(-0.290)
age6	0.295	0.249	0.200
	(0.559)	(0.500)	(0.394)
age7	0.205	0.045	0.022
	(0.394)	(0.092)	(0.044)
age8	0.567	0.379	0.390
	(1.07)	(0.756)	(0.768)
age9	0.713	0.468	0.493
	(1.274)	(0.889)	(0.922)
sclassab	0.244	0.190	0.169
	(0.901)	(0.750)	(0.661)
sclassc1	-0.188	-0.223	-0.226
	(-0.731)	(-0.906)	(-0.909)
sclassc2	-0.240	-0.251	-0.231
	(-0.946)	(-1.016)	(-0.933)
marital1	0.535	0.533	0.556
	(1.668)	(1.702)	(1.762)
marital2	0.682	0.653	0.642
	(1.776)	(1.763)	(1.717)

Table 2. Continued on next page

Table 2. Continued from previous page			
variable			
marital3	0.995	0.916	0.956
	(2.524*)	(2.372*)	(2.453*)
childage1	-0.298	-0.331	-0.365
	(-0.690)	(-0.802)	(-0.882)
childage2	0.238	0.174	0.148
	(0.650)	(0.495)	(0.419)
childage3	-0.194	-0.127	-0.149
	(-0.543)	(-0.367)	(-0.429)
childage4	-0.541	-0.587	-0.571
	(-1.406)	(-1.579)	(-1.526)
childage5	-0.570	-0.610	-0.648
	(-1.200)	(-1.331)	(-1.407)
nochild1	0.179	0.248	0.303
	(0.410)	(0.601)	(0.726)
nochild2	0.547	0.536	0.587
	(0.925)	(0.935)	(1.024)
nochild3	1.143	1.21	1.238
	(1.348)	(1.50)	(1.530)
nochild4	1.400	1.438	1.540
	(1.178)	(1.27)	(1.358)
contact1	0.044	0.0204	0.0245
	(0.273)	(0.130)	(0.155)
contact2	0.270	0.256	0.258
	(1.687)	(1.657)	(1.659)
contact3	-0.035	0.0153	-0.0184
	(-0.149)	(0.0672)	(-0.0803)
regdb	0.806	0.780	0.749
	(2.541*)	(2.565*)	(2.447*)
regdc	1.040	0.983	1.015
	(3.150*)	(3.11*)	(3.184*)
regdd	0.939	0.851	0.860
	(3.037*)	(2.876*)	(2.885*)
pchar2	0.402	0.320	0.326
	(2.351*)	(2.028*)	(2.055*)
pchar7	-0.514	-0.523	-0.534

Table 2. Continued on next page

Table 2. Continued from previous page			
variable			
	(-3.195*)	(-3.476*)	(-3.524*)
pchar1	0.170		
	(0.788)		
pchar3	-0.227		
	(-1.336)		
pchar4	0.324		
	(1.385)		
pchar5	-0.137		
	(-0.498)		
pchar6	-0.068		
	(-0.388)		
pchar8	-0.072		
	(-0.379)		
pchar9	0.228	0.284	0.270
	(1.072)	(1.422)	(1.339)
pchar10	0.474	0.488	0.478
	(2.463*)	(2.666*)	(2.594*)
busdriver	-0.453	-0.358	-0.375
	(-2.147*)	(-1.891)	(-1.959)
minister	-0.164	-0.179	-0.176
	(-0.706)	(-0.792)	(-0.774)
teacher	0.209	0.249	0.198
	(1.146)	(1.506)	(1.176)
lwpaper	-0.381	-0.418	-0.426
	(-1.117)	(-2.158*)	(-2.179*)
broadsheet	-0.537	-0.386	-0.389
	(-1.404)	(-1.877)	(-1.879)
banker	-0.172		
	(-0.895)		
director	-0.174		
	(-0.837)		
entrepreneur	0.334		0.323
	(2.072*)		(2.134*)
Table 2. Continued on next page			

Table 2. Continued from previous page			
variable			
lawyer	0.221		
	(1.204)		
plumber	0.199		
	(1.026)		
cpaper	0.122		
	(0.274)		
rwpaper	0.050		
	(0.139)		
tabloid	-0.162		
	(-0.434)		

Specification Tests :

$\chi^2(slopes = 0)$	141.1*	126.6*	131.2*
χ^2(OHC)	55.6*	55.9*	55.9*
χ^2(L)	13.1*	12.3*	12.3*
χ^2(RA)	18.6*	19.0*	19.0*
χ^2(PHC)	4.8		
χ^2(PFE)	7.4*	9.5*	9.5*
χ^2(SA1)	18.0*	15.8*	15.8*
χ^2(SA2)	9.2		

Table 3 : Earnings Equations
for individuals in Paid Employment

variable		
constant	8.834	8.961
	(53.762*)	(58.408*)
sex	-0.0374	-0.0498
	(-0.751)	(-1.044)
age1	0.565	0.536
	(3.319*)	(3.183*)
age2	0.433	0.489
	(2.931*)	(3.227*)
age3	0.412	0.427
	(2.898*)	(2.924*)
age4	0.455	0.476
	(3.16*)	(3.225*)
age5	0.576	0.597
	(3.987*)	(4.009*)
age6	0.671	0.717
	(4.531*)	(4.694*)
age7	0.414	0.449
	(2.888*)	(3.042*)
age8	0.447	0.489
	(2.983*)	(3.178*)
age9	0.467	0.552
	(2.985*)	(3.436*)
sclassab	0.620	0.679
	(8.435*)	(9.229*)
sclassc1	0.360	0.388
	(5.930*)	(6.425*)
sclassc2	0.255	0.248
	(4.355*)	(4.284*)
regdb	-0.0376	
	(-0.605)	
regdc	-0.0147	
	(-0.199)	
regdd	0.068	

Table 3. Continued on next page

Table 3. Continued from previous page		
variable		
	(1.099)	
pchard2	-0.0577	
	(-1.211)	
pchard7	0.0762	
	(1.74)	
pchard1	0.042	
	(0.773)	
pchard3	0.045	
	(1.059)	
pchard4	0.103	
	(1.323)	
pchard5	0.0992	
	(1.197)	
pchard6	-0.0093	
	(-0.204)	
pchard8	0.0626	
	(1.262)	
pchard9	0.0356	
	(0.58)	
pchard10	0.007	
	(0.160)	
union	-0.0527	-0.055
	(-1.095)	(-1.16)
parttime	-0.0778	-0.108
	(-1.30)	(-1.788)
large	0.0028	-0.006
	(0.0566)	(-0.111)
medium	-0.0169	-0.028
	(-0.263)	(-0.433)
small	-0.150	-0.173
	(-2.772*)	(-3.146*)
σ_{pe}	0.348	0.356
	(14.659)	(15.093)
Table 3. Continued on next page		

Table 3. Continued from previous page		
variable		
ρ_{pe}	0.188	0.015
	(0.541)	(0.0534)

Specification Tests :

χ^2(OHC)	98.31*	113.26*
χ^2(L)	5.29	
χ^2(RA)	4.56	
χ^2(PHC)	9.36	
χ^2(PFE)	0.34	
χ^2(Other)	11.57*	15.42*

Table 4 : Earnings Equations
for individuals in Self Employment

variable			
constant	7.576	8.112	8.768
	(10.503*)	(13.16*)	(14.841*)
sex	-0.0961	-0.085	0.021
	(-0.641)	(-0.617)	(0.142)
age2	0.752	0.697	0.364
	(1.700)	(1.604)	(0.803)
age3	0.234	0.224	0.025
	(0.584)	(0.571)	(0.058)
age4	0.438	0.307	0.193
	(1.084)	(0.785)	(0.454)
age5	0.378	0.346	0.229
	(0.942)	(0.879)	(0.532)
age6	0.438	0.337	0.161
	(1.079)	(0.851)	(0.376)
age7	0.31	0.218	0.261
	(0.762)	(0.549)	(0.60)
age8	0.037	-0.015	0.037
	(0.092)	(-0.038)	(0.085)
age9	0.806	0.741	0.476
	(1.695)	(1.571)	(0.983)
sclassab	0.632	0.596	0.578
	(2.871*)	(2.765*)	(2.657*)
sclassc1	0.407	0.378	0.437
	(1.996*)	(1.878)	(2.073*)
sclassc2	0.033	0.046	0.090
	(0.173)	(0.243)	(0.461)
regdb	0.781	0.760	0.601
	(2.313*)	(2.275*)	(1.916)
regdc	0.55	0.508	0.326
	(1.6)	(1.532)	(1.045)
regdd	0.968	0.918	0.783
	(2.780*)	(2.679*)	(2.454*)

Table 4. Continued on next page

Table 4. Continued from previous page			
variable			
pchard2	0.257		
	(1.789)		
pchard7	0.136		
	(0.965)		
pchard1	0.198	0.219	
	(1.299)	(1.423)	
pchard3	0.139	0.126	
	(1.056)	(0.981)	
pchard4	0.553	0.539	
	(2.554*)	(2.487*)	
pchard5	0.357	0.453	
	(1.539)	(1.854)	
pchard6	0.029	0.109	
	(0.23)	(0.889)	
pchard8	-0.268	-0.250	
	(-1.925)	(-1.816)	
pchard9	-0.029		
	(-0.179)		
pchard10	0.163		
	(0.978)		
σ_{se}	0.425	0.408	0.452
	(4.298)	(5.241)	(5.358)
ρ_{se}	0.457	0.181	-0.028
	(1.278)	(0.555)	(-0.088)

	Specification Tests :		
χ^2(OHC)	16.75	16.01	13.42
χ^2(L)	11.46*	11.26*	10.79*
χ^2(RA)	4.12		
χ^2(PHC)	10.18	10.64	
χ^2(PFE)	1.05		

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