DISCUSSION PAPER SERIES

IZA

IZA DP No. 223

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December 2000

Forschungsinstitut
zur Zukunft der Arbeit
Institute for the Study
of Labor

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Discussion Paper No. 223
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IZA Discussion Paper No. 223
December 2000

ABSTRACT

Wages, Training, and Job Turnover in a Search-Matching Model*

In this paper we extend a job search-matching model with firm-specific investments in training developed by Mortensen (2000) to allow for different offer arrival rates in employment and unemployment. The model by Mortensen changes the original wage posting model (Burdett and Mortensen, 1998) in two aspects. First, it provides a link between the wage posting framework and the search-matching framework (eg. Pissarides, 1990). Second, it improves the correspondence between the theoretical characterization of the endogeneously derived earnings density and the empirically observed earnings density. We subsequently estimate the model on Danish labour market data using a structural non-parametric estimation procedure. We find that the model provides a good characterization of some empirical features of the labor market.

JEL Classification: C51, D83, J31, J41, J6

Keywords: Search equilibrium, matching, wage dispersion, firm-specific human capital

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* Financial support from the Danish Research Foundation is gratefully acknowledged. We are grateful to Dale Mortensen for helpful comments, to Karin Lund Madsen for carefully reading the manuscript, and to seminar participants at the Dept. of Economics, University of Aarhus.

1. Introduction

The evolution of equilibrium wage dispersion models for the labor market has recently taken a new turn with the integration of the equilibrium search wage-posting model of Burdett and Mortensen (1989, 1998) into the matching model framework of Pissarides (1990). The integrated model, henceforth denoted the search-matching model, is presented in Mortensen (2000). He shows that with homogeneous firms and workers the equilibrium outcome in this model is identical to the equilibrium outcome in the wage-posting model. He then extends the search-matching model with the introduction of endogenous firm-specific investments in training. The presence of firm-specific training implies that ex-ante homogeneous workers will differ with respect to productivity once they are employed.

In the present paper, we first extend the model of Mortensen (2000) by allowing different offer arrival rates in employment and unemployment. This complicates the theoretical representation of the model slightly. Secondly, we estimate the model on a sample of Danish workers (stratified according to age, gender, and educational attainments) followed during the 1980s, using a modification of a structural non-parametric estimation procedure proposed by Bontemps, Robin and van den Berg (2000) which allows for constrained likelihood analysis. We compare the estimation results with a number of variations of wage-posting models that have been estimated on the same data set (Bunzel et al., 2000, and Christensen et al., 2000). The estimations and subsequent analyses indicate that some empirical features of the labor market are well explained by the model. The relevance of our model extension reveals itself here, since the offer arrival rates in employment and unemployment differ for all strata. The analyses also point at empirical features that are not very well explained by the model, such as the distribution of job durations, where improvements might be worth considering.

The search-matching model with firm-specific training offers a clear improvement in the characterization of the wage offer density when compared with the original wage posting model and the basic search-matching model (without investments in training). In the wage posting model and the basic search-matching model (which are observationally equivalent in the simplest versions) the density of wage offers is strictly increasing over the support. This feature is clearly at odds with empirical findings. A number of recent studies (see e.g. van den Berg and Ridder (1998), Bontemps, Robin and van den Berg (2000), Bowlus, Kiefer and Neumann (1995)) introduce heterogeneity in the Burdett-Mortensen (wage posting) model and obtain wage offer densities that, to a large extent, reflect the empirically observed cross-sectional wage densities. The approach taken in this line of research has been to incorporate exogenously given heterogeneity in the productivity of firms. In van den Berg and Ridder (1998) and in Christensen et al. (2000), the labor market is assumed to consist of a large number of segments. Each segment is a separate labor market of its own, and workers and firms in a particular segment are homogeneous. The different markets differ in the value product of workers. Bontemps, Robin and van den Berg (2000) argue that it is not very realistic to assume that all firms in a given segment have identical productivities. They, subsequently, derive and estimate an extension of the Burdett-Mortensen model with continuous within-market heterogeneity[1]. In their model there is one common labor market in which firms with different productivity endowments compete.

In the wage-posting and the search-matching frameworks, the productivity of firms may be endogenized by the introduction of firm-specific investments in training (Quercioli, 1998, and Mortensen, 2000). It is thus also within-market heterogeneity, but in contrast to the model of Bontemps, Robin and van den Berg (2000), heterogeneity is endogenous. This extension also accommodates unimodal earnings densities (see calibration studies by Mortensen, 2000, and Quercioli, 1998)[2].

The intuition of the model is the following. Investment in firm-specific training should according to traditional economic theory be paid for partly by the employee and partly by the employer. Due to uncertainty about the future no firm is willing to cover the total investment in firm-specific training, as the revenue generated from training is lost if the employee quits. On the other hand, the employee is not willing to pay fully for training which only increases her skills in the job she is presently occupying. In the present model search frictions imply that there is a trade-off between wages and labor turnover from the perspective of the firm. A higher wage will reduce the probability that an employee accepts job offers from other firms. The negative association between wage and labor turnover creates incentives for training employees - thus increasing firm-specific productivity - and paying a higher wage, since the expected duration of the match is longer and the period in which the firm can recoup its investment thus increases. Consequently, the model predicts a positive relation between the amount of training supplied and the wage paid. Firms offer wage packages consisting of both a wage and a training contract. In equilibrium, firms choose different levels of training and wage offers, which results in endogenous within-market productivity differences and consequently a dispersed equilibrium wage offer distribution.

Into this model we introduce the possibility of different arrival rates of job offers in employment and unemployment. Obviously this is necessary if the model is to be confronted with real data, since most existing studies suggest that these arrival rates are indeed different. This addition to the model leads to a slight complication that works through the matching function. The steady state properties of the model may still be characterized, though.

The structure of the remainder of the paper is as follows. Section 2 presents the extended search-matching model with firm-specific training and different offer arrival rates in employment and unemployment. In Section 3, we present and discuss the data set used. In Section 4, we derive the likelihood function and present the structural non-parametric estimation method. Section 5 contains the estimation results, other

[1] Mortensen (1990) theoretically derives a version of the pure Burdett-Mortensen model with discrete within-market heterogeneity. This model is estimated by Bowlus, Kiefer and Neumann (1995) and Bunzel et al. (2000). The model is highly non-linear and consequently the estimation becomes very cumbersome.

[2] Acemoglu and Shimer (2000) offer an alternative model of endogenous productivity dispersion. A version of this model is estimated by Robin & Roux (1998).

useful statistics, and additionally presents some specification tests, and in Section 6, we conclude.

2. A Search-Matching Model with Firm-Specific Training

In this Section, we specify the economic model along the lines of Mortensen (2000). In the matching model framework, firms create identical jobs - in fact each firm only creates one job site which is either filled or vacant. Free entry drives the value of issuing a vacancy to zero which consequently determines the equilibrium condition for the model. The labor force, the measure of which is normalized to 1, consists of u unemployed and $1-u$ employed workers, who are assumed to be homogeneous ex ante. Firms post wages and the workers search, both as unemployed and employed. We assume that job offers arrive with Poisson rate λ_0 when unemployed and with Poisson rate λ_1 when employed. Job destruction occurs exogenously at Poisson rate δ. The matching function, $m(v,u,1-u)$, measuring the number of encounters between workers and firms, is a function of the number of vacancies, v, and the number of unemployed and employed workers. It is equal in value to the total flow of offers received by workers, and it is assumed increasing and concave in all three arguments.[3]

$$m(v,u,1-u) = \lambda_0 u + \lambda_1(1-u). \tag{2.1}$$

In the model by Mortensen (2000), it was assumed that $\lambda_0 = \lambda_1 = \lambda$. Consequently, his matching functions only required two arguments, the number of vacancies and the number of workers which is normalized to 1. Allowing for different λ_0 and λ_1 is obviously of interest in an empirical investigation, as is also noted by Mortensen (2000).

As in Burdett and Mortensen (1998) unemployed workers accept any wage exceeding the reservation wage, whereas employed workers accept any wage above their current wage. As no employer can profit from offering a wage below the reservation wage, this wage is also the lower bound on the wage offer distribution.

In steady state the flow into unemployment equals the flow out of unemployment; the inflow equals $\delta(1-u)$, whereas the outflow is $\lambda_0 u$, since all unemployed workers accept any wage from the wage offer distribution. The steady state unemployment rate is consequently

$$u = \frac{\delta}{\delta + \lambda_0}. \tag{2.2}$$

In addition, the flow into jobs paying a wage w or less must also equal the outflow out of jobs paying w or less. Letting $G(w)$ represent the cross-sectional distribution of earned wages and $F(w)$ the distribution of wage offers, the inflow into jobs paying w

[3] $\lambda_1$and λ_0 are increasing concave functions of v. We will demonstrate shortly that there is a unique positive equilibrium value, v^*, where $\lambda_0(v^*)$ and $\lambda_1(v^*)$ are positive and finite. We consider this equilibrium in the following and suppress the arguments of $\lambda_1$and λ_0.

or less is $\lambda_0 u F(w)$, and the outflow is $(1-u)G(w)(\delta+\lambda_1(1-F(w)))$. In steady state

$$G(w) = \frac{\delta F(w)}{\delta + \lambda_1(1-F(w))}. \tag{2.3}$$

In the present model, firms are assumed to issue vacancies that when filled pay a wage w and involves training the employee by an amount t. The relevant profit term for the firm in the matching setup is the expected return attributable to the creation of a vacancy. Using the discount rate r, the asset value of a vacant job solves the continuous time Bellman equation

$$rV = \max_{w,t}\left\{\left(\frac{\lambda_0}{v}u + \frac{\lambda_1}{v}(1-u)G(w)\right)(J(w,t)-t-V) - c\right\}, \tag{2.4}$$

where $\frac{\lambda_0}{v}u$ and $\frac{\lambda_1}{v}(1-u)G(w)$ is the average rate at which the vacancy is filled with an unemployed or employed worker, respectively, c is the flow cost of recruiting per vacancy, and $J(w,t)$ is the value of a filled job.

Once a worker is hired, there is a positive probability that he will leave the job for a better paying job or that the job is destroyed. Consequently the rents generated from a filled job solve

$$rJ(w,t) = pQ(t) - w - \lambda_1(1-F(w))(J(w,t)-V) - \delta J(w,t), \tag{2.5}$$

where $pQ(t)$ is the flow value of match product and $\lambda_1(1-F(w))$ is the expected rate at which an unemployed worker finds a job paying more than w. The specification allows an employer to seek another worker in the event of a quit but presumes that the job is of no value in the case of a job destruction.

In the model, each employer precommits to both the wage offered and the extent of firm-specific training. After substituting expressions (2.2), (2.3), and (2.5) into expression (2.4) we obtain, in equilibrium, where $V=0$ as a result of free entry, and every wage offer and training combination yields the same profit, that

$$\begin{aligned}\frac{cv}{\lambda_0} &= \max_{w,t}\left[\frac{\delta\left[pQ(t)-w-t(r+\delta+\lambda_1(1-F(w)))\right]}{(r+\delta+\lambda_1(1-F(w)))}\right] \\ &\quad\times\left[\frac{(\delta+\lambda_1)}{(\delta+\lambda_0)(\delta+\lambda_1(1-F(w)))}\right]\end{aligned} \tag{2.6}$$

holds for every wage offer choice in the support of w. This optimization problem directly implies that the optimal training investment is described by

$$t(w) = \arg\max\left\{pQ(t) - w - t(r+\delta+\lambda_1(1-F(w)))\right\} \tag{2.7}$$

A *search equilibrium* is a vacancy level v, a wage offer distribution $F(w)$, and an investment policy function $t(w)$ that satisfy (2.6) and (2.7) for all w in the support of $F(w)$. In the special case, where $\lambda_0(v) = \lambda_1(v)$, Mortensen (2000) shows the existence of two solutions for market tightness; one stable solution where v is strictly positive and one unstable solution where v is zero. In the general case where we may have $\lambda_0(v) \neq \lambda_1(v)$, it is not necessarily the case that there is only one positive equilibrium value of v. However, it is possible to define very mild conditions such that there exists one and only one positive equilibrium value for v. Make the following assumption:

A1: $\lambda_1(v) = \beta \cdot \lambda_0(v)$, where $\beta < 1$. Furthermore, $\lambda_0(v)$ satisfies the Inada conditions.

Then we have the following proposition:

Proposition 2.1. *There exists one and only one positive equilibrium value of* v.

The proof of Proposition 1 is in the appendix. We shall assume in the following that A1 is satisfied. The corresponding equilibrium wage offer distribution solves

$$\frac{cv}{\delta\lambda_0}\gamma = \frac{\max_{t\geq 0}\{pQ(t) - w - t(r+\delta+\lambda_1(1-F(w)))\}}{(r+\delta+\lambda_1(1-F(w)))(\delta+\lambda_1(1-F(w)))}, \tag{2.8}$$

where $\gamma = (\delta + \lambda_0)/(\delta + \lambda_1)$. Since the right hand side of expression (2.8) is strictly decreasing in w and strictly increasing in $F(w)$, a unique continuous wage offer distribution exists.

Notice, that for any choice of w, the optimal training investment policy is fully characterized by the first order condition,

$$pQ'(t(w)) = r + \delta + \lambda_1(1 - F(w)) \tag{2.9}$$

given the standard production function assumptions: $Q(0) = 1$ (a normalization implying that a worker's productivity in the case of no training is the inherited productivity p), $Q'(0) = \infty$, $Q'(t) > 0$, and $Q''(t) < 0$. Expression (2.9) states that the marginal return to training is equal to the interest rate plus the match separation rate. The relationship between training and the wage is[4]

$$t'(w) = \frac{-\lambda_1 F'(w)}{pQ''(t)} > 0. \tag{2.10}$$

That is, employers who offer higher wages invest more in firm-specific training because workers quit high-wage paying employers at a lower rate. Hence, workers employed at higher wages are more productive even though all workers and employers are identical ex ante[5].

[4]This feature is confirmed in a number of empirical studies (see eg. Lynch & Black (1998)).

[5]A similar result is found by Quercioli (1998) based on the wage posting job-search model by Burdett and Mortensen (1998).

The general shape of the equilibrium wage offer density is characterized using equation (2.8). By differentiating all terms w.r.t. w and invoking the envelope theorem, the following expression is obtained

$$\lambda_1 F'(w) = \frac{1}{t(w) + \gamma \frac{cv}{\delta \lambda_0}(r + 2(\delta + \lambda_1(1 - F(w))))}. \tag{2.11}$$

Since $t(w)$ is increasing in w and the other term in the denominator is decreasing in w, it is possible to obtain an unimodal wage offer density with an interior mode. A unimodal wage offer density is what is typically observed in wage data. In Mortensen (2000) this is obtained for $Q(t)$ specified as a Cobb-Douglas production function. The Cobb-Douglas production function specification implies that it is not possible to obtain a closed form solution for the wage offer distribution.[6] This means that the theoretical model cannot be estimated by the standard maximum likelihood procedure as in e.g. van den Berg and Ridder (1998). As an alternative to searching for specifications that imply a closed form solution we leave the production function unspecified. Instead, we apply a structural non-parametric estimation procedure, conditional on the restriction $t'(w) > 0$ implied by the model, to obtain the structural parameters of the model. Based on these estimates we can infer the implied specification of the match production function given the assumption of linear training investments (i.e. linear cost of training). We discuss and implement the procedure in Section 4.

3. Data

The sample used in this study is based on CLS' longitudinal database which is a representative 1% sample of the Danish population in the age group 16-75. It is a register based data set, and the available information is merged from a number of registers maintained by Statistics Denmark. The database contains weekly information on labor market status from January 1, 1981 - December 31, 1990. This information is also the basis for payments of unemployment insurance benefits, so it is considered highly reliable, when it comes to the duration variables. The information on the hourly wage is obtained by combining information on hours worked during the year with annual income from work, so it is an average hourly wage during the year. The hourly wage is measured in Danish kroner (DKK).[7]

We sample all individuals who are observed to be either employed or unemployed during the first week of 1986. In case of the individual being unemployed in this week, the following is recorded: the total duration of the sampled unemployment spell (i.e. the sum of the elapsed and residual duration), measured in weeks (this spell may be left- and right-censored - indicators for these events are also recorded), and in case

[6]Burdett and Svarer (2000) find that, in a model with a linear relation between the amount of training and productivity, and with quadratic training costs, there is an analytical solution for the offer density. However, when put to the test of estimation, it seems that the degree of convexity in quadratic training costs is not sufficient to generate a 'log-normally looking' earned wages density.

[7]8 DKK correspond approximately to 1 US$.

of a transition from unemployment to employment we record the subsequent hourly reemployment wage. If the individual is employed the first week of 1986, the total duration of the job spell (sum of the elapsed and residual duration), again measured in weeks, is recorded (including a left-censoring indicator), along with the wage earned, and the destination state, i.e. information on whether the job ended in a layoff (i.e. was followed by unemployment), a quit (namely, a new job), or was right-censored in the data set (either due to a drop out of the labor force, or because the job continued beyond the end of the survey period). The wages are inflated to 1990 levels, using the Danish consumer price index. The sample is then split according to age, gender, and educational attainments, in order to obtain fairly homogeneous sub samples on which to perform the estimations.

The resulting sample consists of 13,466 individuals divided into 1034 individuals being unemployed in the first week of 1986 and 12,432 being employed. This corresponds to an unemployment rate of 7.7%. 5.6% of the unemployment spells are right-censored, and 33.7% of the employment spells are right-censored. 73.7% of the completed employment spells end with a transition into a new job (i.e. they have no intermediate unemployment spell between two jobs). This is in an international context a very high fraction. However, the figures are robust when compared to other Danish data resources, e.g. Westergård-Nielsen (2000).

Additional summary statistics for each sub-sample are provided in Table 1 and Table 2.[8] Individuals with less than 12 years of education have the highest unemployment rates, and this is so in particular for the younger groups. Unemployment duration tends to increase with age and is longer for females than for males, and shorter for high school graduates (12 years of education) than groups with lower educational attainment. Employment duration also increases with age and is longer for males than for females, and it is shorter for individuals with less than 12 years of education. Wages increase with education and tend to peak in the interval 31-50 years of age. On average wages are highest for men and the earned wage for individuals being employed during the first week of 1986 is on average higher than the reemployment wage accepted by individuals being unemployed on the same date, which is an additional prediction (not derived in this paper) of the model.[9]

4. Econometric Specification

In this Section, we present the likelihood function which will be maximized. In the maximization procedure we modify a structural non-parametric estimation procedure proposed by Bontemps, Robin and van den Berg (2000). In what follows, we assume

[8]Note that each sub-sample is trimmed by 1 % in each end of the overall distribution of wages, in order to reduce measurement error sensitivity. Since the entire sample is obtained by trimming directly on that sample, rather than just adding the trimmed sub samples, the lowest wage in the entire sample exceeds that of the minimum of the lowest wages in the sub samples.

[9]Formally, it can be shown that the distribution of earned wages first-order stochastically dominates the distribution of accepted wages.

that the discount rate, r, is equal to zero.[10]

4.1. The Likelihood Function

The dependent variables in this paper are aspects of the individual labor market histories.

Labor market status at time of observation:	
x	$= 0$ if unemployed
	$= 1$ if employed
Total duration in labor market state:	
t_{0b}	$=$ elapsed unemployment duration
t_{0f}	$=$ residual unemployment duration
d_{0b}	$= 1$ if unemployment spell is left censored
d_{0f}	$= 1$ if unemployment spell is right censored
t_{1b}	$=$ elapsed employment duration
t_{1f}	$=$ residual employment duration
d_{1b}	$= 1$ if employment spell is left censored
d_{1f}	$= 1$ if employment spell is right censored
Paid and accepted wages:	
w_0	$=$ wage accepted by unemployed individuals
w_1	$=$ wage of employees at observation time
Destination state after employment spell:	
e	$= 0$ if job-to-job transition
	$= 1$ if job-to-unemployment transition.

Based on the above variables the individual's contribution to the likelihood function is derived. First consider an individual who is unemployed at the observation time; she contributes with the probability of being unemployed, $f_x(x = 0)$, the joint distribution of elapsed and residual unemployment durations, $f_{t_{0b},t_{0f}}(t_{0b}, t_{0f})$, appropriately modified by the censoring indicators, and the subsequent draw from the wage offer distribution if she finds a job, $f_{w_0}(w_0)$.

For an individual employed at the time of observation the likelihood contribution is the product of the probability of being employed, $f_x(x = 1)$, the joint distribution of elapsed and residual employment durations and the destination state after employment, $f_{t_{1b},t_{1f},e}(t_{1b}, t_{1f}, e)$, appropriately modified by destination indicators, and the wage she earns, $g(w)$. Based on the model described in Section 2 the contributions can be specified as a function of the structural parameters. The probability of sampling an unemployed person is $\delta/(\delta + \lambda_0)$. As both the elapsed and residual unemployment durations are exponentially distributed, the contribution for an unemployed person is

$$L(\Phi|x = x_0) = \frac{\delta}{\delta + \lambda_0} \cdot \left[\lambda_0^{2-d_{0f}-d_{0b}} \exp(-\lambda_0(t_{0b} + t_{0f}))\right] \cdot f(w)^{1-d_{0f}} \tag{4.1}$$

[10] Sensitivity checks with respect to this identifying assumption is performed at the end of Section 5.

with $\Phi = (\delta, \lambda_0, \lambda_1)$. The probability of sampling an employed person is $\lambda_0/(\delta + \lambda_0)$. The elapsed duration of employment is a mixture of exponential distributions; the residual employment duration is exponential distributed with parameter δ if a job-to-unemployment transition occurs and with parameter $\lambda_1(1 - F(w))$ if a job-to-job transition occurs. In sum, the contribution of an employed person is

$$\begin{aligned} L(\Phi|x &= x_1) = \frac{\lambda_0}{\delta + \lambda_0} \{\delta + \lambda_1(1 - F(w))\}^{1-d_{1b}} \\ &\cdot \exp\left[-(\delta + \lambda_1(1 - F(w)))(t_{1b} + t_{1f})\right] \\ &\cdot \left[\delta^e \cdot (\lambda_1(1 - F(w)))^{1-e}\right]^{1-d_{1f}} \cdot g(w) \end{aligned} \tag{4.2}$$

In order to apply standard maximum likelihood techniques, we need to know the closed-form solutions for $F(w)$ and $f(w)$. These are, however, not obtained in the model. As an alternative, we modify a structural non-parametric estimation procedure suggested by Bontemps, Robin and van den Berg (2000). This procedure enables us to obtain estimates of the structural parameters of the model without assuming a particular functional form for the match product function $Q(t)$.

4.2. A Structural Non-Parametric Estimation Procedure

The structural non-parametric estimation approach has been applied by Bontemps, Robin and van den Berg (2000) to estimate a Burdett-Mortensen model with productivity heterogeneity. The estimation procedure modified to be adequate for our particular estimation problem consists of three steps:

1. Estimate $G(w)$ and $g(w)$ from the empirical distribution of earned wages using nonparametric procedures[11]. Let $\widehat{G(w)}$ and $\widehat{g(w)}$ be such estimators. Conditional on δ and λ_1 consistent estimates of $F(w)$ and $f(w)$ are:

$$\widehat{F(w)} = \frac{\widehat{G(w)}(\delta + \lambda_1)}{\delta + \lambda_1 \widehat{G(w)}}$$

and

$$\widehat{f(w)} = \frac{(\delta + \lambda_1)}{(\delta + \lambda_1 \widehat{G(w)})^2} \delta \widehat{g(w)}$$

which are derived from (2.3).

2. Replace $F(w)$ and $f(w)$ in the likelihood function equations with the above expressions. Then, maximize the resulting function. Steps 1 and 2 are repeated until convergence is obtained[12]. This step is conditional on the model being well-specified,

[11] We use Gaussian kernels. The distribution function is found by numerical integraton of the kernel density.

[12] In the second step we use the CML (Constrained Maximum Likelihood) procedure in Gauss. The loglikelihood was maximized using the BHHH algorithm. The required first derivatives were obtained by numerical differentiation. The covariance matrix is estimated by the heteroscedasticity-consistent (sandwich) estimator.

that is conditional on the requirement (in expression (2.10)) that the function $t(w)$ is increasing in the wage

$$2\frac{\delta+\lambda_0}{\delta+\lambda_1}\frac{cv}{\delta\lambda_0}\lambda_1 F'(w) - \frac{F''(w)}{\lambda_1 (F'(w))^2} \geq 0. \tag{4.3}$$

Expression (4.3) is derived by differentiation of expression (2.11). For all strata we find that (4.3) is non-binding.

3. Use expressions (2.11) and (2.8) (imposing the equal profits constraint), which, given the wage, represent two equations in two unknowns, to calculate the values of the function $t(w)$ and $pQ(t(w))$. This yields a non-parametric relationship between the wage, training investments, and the match product. Of course, the parameter cv is not identified, since we condition on the kernel density estimate of the wage distributions, but given an identifying assumption, e.g. $t(R) = 0$ (i.e. that the training amount at the reservation wage is zero) it can be calculated. Finally, the reservation wage is, as suggested by Kiefer and Neumann (1993), estimated by the super-efficient estimator $w_{\min}$. We have thus used all the available information in the wage distribuition to obtain our non-parametric estimates of $t(w)$ and $pQ(t)$, i.e. the third step of the estimation procedure is just identified given the identifying assumption mentioned above.

5. Results and Analysis

In Table 3, the results of the estimations are presented and some interesting results appear. In general, we find that $\lambda_0 > \lambda_1 > \delta$. The parameters λ_0 and δ are both decreasing in age, whereas the pattern is not uniform for λ_1. The size of λ_0 indicates expected durations of unemployment which are in accordance with the actual observed unemployment spells. The offer arrival rate in both unemployment and employment is (mostly) increasing with educational level. The job separation rate, δ, decreases in education.

Compared to other Danish studies (e.g. Bunzel et al. (2000)), this model is an obvious improvement of the characterization concerning transitions out of jobs. Bunzel et al. find that in general $\lambda_1 < \delta$. This result is not coherent with the descriptive statistics which clearly show that the majority of jobs end in a new job. The differences may stem from the fact that Bunzel et. al use flow-sampling of workers entering unemployment during a given period. This has the implication that individuals with a weak labor market attachment may be over-represented. In an international perspective our results are in line with the results in van den Berg and Ridder (1998) obtained from data from the Dutch labor market. They also find that $\lambda_1, \lambda_0 > \delta$, and that these arrival rates are decreasing in age. Likewise, they find that the job offer arrival rates increase with education. Estimations performed on the French labor market (Bontemps, Robin and van den Berg (2000)) find that $\lambda_0 > \lambda_1 > \delta$. Bowlus, Kiefer and Neumann (2000) estimate a discrete heterogeneity version of the Burdett-Mortensen model on US data, and also find that $\lambda_0 > \lambda_1 > \delta$.

Regarding the magnitude of the structural parameters, our results suggest that search is more profound on the Danish labor market compared to the Dutch, French, and US labor markets. The estimate of λ_0 is almost twice as large on the Danish labor market, whereas λ_1 is more or less of the same magnitude as in the other studies.[13,14]

The reservation wage is increasing in age, and the match product at the reservation wage is in general 20-50 % higher than the reservation wage itself, conditional on the normalization $t(R) = 0$. In the appendix, we produce plots of the kernel density estimates of the earnings density. In addition, we plot the implied relation between the wage and training investment, and the relation between training investment and match product. The relation between wages and training is by assumption increasing, and in addition it turns out to be convex. The figures relating wages and training reveal that training investments are rather substantial for high wage individuals. For instance, for the entire sample training investments for a person earning 140 Dkk (per hour) are approximately 80.000 Dkk, which corresponds to approximately 3-4 months of earnings. In Table 4 we present the mean and median training investment in the different segments of the labor market. The distribution of training costs is clearly skewed to the left as a result of the wage distribution. The magnitudes of training investment are in accordance with an earlier Danish study by Rosdahl (1986)[15]. Rosdahl's study, which is based on a survey consisting of 1,543 Danish establishments, shows that it is common to experience training investments equivalent to several months of earnings. Training investment is increasing in age and education, and is higher for women than for men.

The relation between training investment and the match product is increasing and concave, as it also should be. However, when we get to the very thin right tail of the earning density, the relation becomes almost linear. Note that this linear section of the graph is based on very few wage observations, as the bulk of wages, and hence training investment and match products, lie in the 'concave interval' of the plot.

In addition to the results already reported, a number of additional informative statistics may be calculated, such as the estimated steady-state unemployment rate, calculated as

$$u = \frac{\delta}{\delta + \lambda_0}.$$

In Table 4, the estimated and actual steady-state unemployment rate is presented. The figures show that u_E is consistently lower than u_S. This is not necessarily a problem, since u_S refers to the unemployment rate in the sampling week, whereas u_E is estimated

[13] The variety in results obtained from the estimation of almost similar models on data from different labour market suggests the need for a cross-country comparison study. The difference in the theoretical models implies that the cross-country comparison performed here only indicates possible differences.

[14] None of the above results correspond to the results obtained by Blau (1992). The models above all estimate the arrival parameters from (unemployment and job) duration data without any data on search behaviour. Blau uses a US data set consisting of search information, and shows that on average unemployed persons receive .25 offers per week, corresponding to an average duration between offer arrivals of 4 weeks.

[15] The size of the training investment is only indicative, since we have imposed an arbitrary normalization, namely, that $t(R) = 0$.

on the basis of employment and unemployment spells. However, another possible cause for the difference may be failure to account for negative duration dependence in unemployment. The estimated unemployment rate is decreasing in educational level and in age.

The average expected job duration may be calculated as

$$\overline{E\left[T_1\right]} = \frac{1}{n}\sum_{i=1}^{n} E\left[T_1|w_i\right]$$

where

$$E\left[T_1|w\right] = \frac{1}{\delta + \lambda_1(1 - F(w))}.$$

It appears that the mean expected job duration exceeds the actual mean job duration for all (except one) strata. This is due to the presence of right censored job durations. The mean expected job duration is increasing in age and education.

A measure of average monopsony power (MP) of firms in setting the wages may be calculated as

$$MP = \frac{1}{n}\sum_{i=1}^{n} \frac{pQ(t(w_i)) - w_i - t(w_i)(\delta + \lambda_1(1 - F(w_i)))}{pQ(t(w_i))}.$$

The MP index indicates how much power the firms can generate from the presence of search frictions on the labor market. The figures in Table 4 indicate that MP is decreasing in educational attainment. In addition, it is higher for women than for men. This finding could reflect the fact that unions representing female workers are less effective in achieving high wages than the unions representing male workers. The monopsony power index is strictly decreasing as a function of wage (see figures in appendix). This result contradicts Bontemps, Robin and van den Berg (2000). They find that especially for firms placed in the higher quartiles of the wage distribution, that the monopsony power index is increasing with the wage. This implies that more productive firms collect higher rents of the matches. If we ignore the cost of training workers (the last term in the numerator of the monopsony power index) we obtain the same pattern. In Bontemps, Robin and van den Berg it is costless for high productivity firms to become high productivity firms, since the firms productivity level is determined by a random draw from the distribution of productivities. In this model, however, the firms obtain high productivity status through training which is costly. This feature implies the reverse outcome of the monopsony power index as a function of wage.

A graphical specification test concerning job and unemployment durations is performed. The marginal distribution of job durations (not conditional on the wage) is a mixture of exponentials, while unemployment is exponentially distributed with parameter λ_0. The validity of this specification may be tested using Cox-Snell residual plots. Here we plot the estimated integrated hazards for job and unemployment spells, $[\delta + \lambda_1(1 - F(w))] \cdot t_1$, and $\lambda_0 t_0$, respectively, against minus the empirical log survivor function of these transformed job and unemployment durations for all uncensored observations. Since the integrated hazard is unit exponential, these points should lie approximately on the 45° line. The graphs in the appendix clearly show that the assumption of unit exponential (transformed) job durations is violated. For unemployment durations, the residual plots look much better, although the assumption of unit exponential integrated hazards is violated for some groups.

Finally, we offer some evidence on the sensitivity of the estimated model with respect to the identifying assumptions. First, the assumption $r = 0$ has no effect on the maximum likelihood estimates of λ_0, λ_1, and δ; r does not enter directly into the likelihood, but it enter the condition that $t'(w) > 0$ specified in the econometric section indirectly, through the calculation of the parameter product cv. Non zero values of r will thus only affect the shape and size of training investments and consequently match products. To see the effects of reasonable positive values of r on training and match product, we calculated the training investment and the match product with the annual discount rate 0.05, that is, $r = 1.05^{1/52} - 1$. As an example, the mean training investment changed from 37,600 to 37,598 and the median changed from 10,390 to 10,385 for the group of men with less than 12 years of school, aged between 31 and 50. The changes were negligible across all groups, hence we conclude that the model is not sensitive with respect to changes in the discount rate. With respect to the identifying assumption $t(R) = 0$, it turns out that in order to ensure that the condition $cv > 0$ holds, admissible values of $t(R)$ are close to 0. Typically, the value at which cv becomes negative is around values of $t(R) = 500$, which is a small value compared to the values for the mean and median in Table 4. We thus conclude that small values of training investments at the reservation wage is an implication of the model, given the data used for estimation, as much as it is an identifying assumption.

6. Conclusion

In this paper, we have extended and estimated a search-matching model of the labor market with firm-specific training. The model implies that *ex ante* homogeneous firms and workers differ *ex post* in productivity due to differences in the amount of training. The productivity differences are thus endogenized into the model. The model explains several of the stylized facts which we observe on the labor market. First of all, the model implies that firms paying higher wages also invest more in firm-specific training. Secondly, it explains how senior persons are better paid and less mobile. Thirdly, it improves upon more parsimonious job-search models in the characterization of the wage offer density by allowing for unimodal wage offer densities with long right tails.

The model is estimated on a sample of Danish workers, who are stratified according to age, gender, and education. The estimation technique applied is structural, non-parametric, and constrained (the constraint turns out never to be binding, though). Our main findings are that offer arrival rates in employment and unemployment differ for all groups - and that they are higher than the job destruction rate. We recover the distributions of training investments and match products non-parametrically, and find that (on average) training investments correspond to a few months' earnings. The match product is an increasing and concave function of training investment, although strict concavity is apparently only present for low and medium sized investments in training. The estimation of the match product and training investment distributions is just identified, hence a useful extension of the estimation procedure would obtain and exploit more information, such as information on either training investments, firm productivities, or vacancies and costs of issuing vacancies. This information is not present in the data set used for the analysis in this paper, though.

Graphical specification tests show that the assumption that job durations are a mixture of exponential distributions does not hold. We may therefore consider ways to extend the model to allow for duration dependence. There are several ways to do this. First, we could make an ad hoc assumption that either the parameter λ_1 or δ or both is a function of duration. This, however, seriously complicates the theoretical characterization of the model. Another possibility is to allow for more general specifications of the training investment. For instance, an assumption that training takes time, and that, while in training, workers are less productive and hence receive lower wages, will produce a gradually increasing reservation wage until the time when training is completed and the wage increases, thus leading to a period with negative duration dependence.

References

[1] Acemoglu, D. and R. Shimer (2000). "Wage and Technology Dispersion", *Review of Economic Studies*, forthcoming.

[2] Blau, D. M. (1992). "An Empirical Analysis of Employed and Unemployed Job Search Behaviour", *Industrial and Labor Relations Review*, Vol. 45, No. 4, p738-752.

[3] Bontemps, C., J.-M. Robin, and G. J. van den Berg (2000). "Equilibrium Search with Continuous Productivity Dispersion: Theory and Non-Parametric Estimation", *International Economic Review, 41(2), 305-358.*

[4] Bowlus, A. J., N. M. Kiefer, and G. R. Neumann (1995). "Estimation of Equilibrium Wage Distribution with Heterogeneity", *Journal of Applied Econometrics.* Vol. 10, S119-S131.

[5] Bowlus, A. J., N. M. Kiefer, and G. R. Neumann (2000). "Equilibrium Search Models and the Transition from School to Work," *International Economic Review*, (Forthcoming).

[6] Bunzel, H., B. J. Christensen, P. Jensen, N. Kiefer, L. Korsholm, L. Muus, G. Neumann and M. Rosholm (2000). "Specification and Estimation of Equilibrium Search Models", *Review of Economics Dynamics*, (Forthcoming).

[7] Burdett, K. and D. T. Mortensen (1989). "Equilibrium Wage Differentials and Employer Size", Discussion Paper No. 860, Northwestern University.

[8] Burdett, K. and D. T. Mortensen (1998). “Wage Differentials, Employer Size, and Unemployment”, *International Economic Review,* Vol. 39, No.2, p257-273.

[9] Burdett, K. and M. Svarer (2000), ”Training and Wage Dispersion”, Chapter 4 of this thesis.

[10] Christensen, B. J. , P. Jensen, K. Poulsen, M. Rosholm and M. Svarer (2000). “The Equilibrium Search Model with Productivity Dispersion and Structural Unemployment: An Application to Danish Data ”, in: Bunzel et al., eds. *Panel Data and Structural Labour Market Models.*

[11] Kiefer, N.M. and G. Neumann (1993), ”Wage Dispersion with Homogeneity: The Empirical Equilibrium Search Model” in Bunzel et al. eds., Panel Data and Labour Market Dynamics, New York: North-Holland, 57-74.

[12] Lynch, L. and S. E.. Black (1998). ”Beyond the Incidence of Employer-Provided Training”, *Industrial and Labor Relations Review*, Vol. 52, No. 1, p64-81.

[13] Mortensen, D. T. (1990), ”Equilibrium Wage Distributions: A Synthesis” in: J. Hartog et al., eds. Panel Data and Labour Market Studies, New York: North-Holland, 279-96.

[14] Mortensen, D. T. (2000). “Equilibrium Unemployment with Wage Posting: Burdett-Mortensen Meet Pissarides” in: Bunzel et al., eds. **Panel Data and Structural Labour Market Models**.

[15] Pissarides, C. A. (1990). *Equilibrium Unemployment Theory.* Oxford: Basil Blackwell.

[16] Quercioli, E. (1998). *Firm Specific Training in a Search Equilibrium: Theory and Evidence*, Ph.D. thesis, University of Essex.

[17] Robin, J. M. and S. Roux (1998). ”Random Matching or Balanced Matching: An Equilibrium Search Model with Endogenous Capital and Matching”, Working Paper, CREST-INSEE.

[18] Rosdahl, A. (1986). (In Danish) ”Arbejdsgiveres arbejdskraftsefterspørgsel”. Socialforskningsinstituttet, Publikation 156.

[19] van den Berg, G. and G. Ridder (1998). ”An Empirical Equilibrium Search Model of the Labor Market”. *Econometrica*, vol. 66, No. 5, p1183-1221.

[20] Westergård-Nielsen, N. C. (2000). ”Decomposition of Labour Market flows”. Mimeo, CLS.

Appendix

In the following, we prove that - given A1 - there exists one and only one positive equilibrium value of vacancies, v. Equation 2.8 must hold for all wages in the support of $F(.)$, so, in particular, it must hold for the lowest wage, $\underline{w}$. Imposing the normalisation that $t(\underline{w}) = 0$ (this normalisation is also imposed on the estimation problem in section 4), and realizing that $F(\underline{w}) = 0$, this equation simplifies to

$$cv = (p - \underline{w}) \frac{\delta \lambda_0(v)}{(\delta + \lambda_0(v))(\delta + \lambda_1(v))} \tag{6.1}$$

noting, explicitly, the dependence of arrival rates on v, and setting the interest rate, r, equal to zero, without loss of generality.

The left hand side is obviously increasing in v. We will show that the right hand side is initially increasing in v, that it reaches a maximum and then declines towards zero as v approaches infinity. In order to rule out multiple equilibria, we also show that while the right hand side is increasing, its second derivative is negative, that is, it is strictly concave on the interval from 0 to its maximum.

Define the $\phi(v)$ as the right hand side of 6.1, and impose A1. We then have

$$\phi(v) = (p - \underline{w}) \frac{\delta \lambda_0(v)}{(\delta + \lambda_0(v))(\delta + \beta \lambda_0(v))}$$

Differentiating with respect to v, we find

$$\phi'(v) = (p - \underline{w}) \frac{\delta \lambda_0^{'}(v) \left(\delta^2 - \beta \lambda_0(v)^2\right)}{(\delta + \lambda_0(v))^2 (\delta + \beta \lambda_0(v))^2} \tag{6.2}$$

Assuming that $\lambda_0(v)$ satisfy the Inada conditions, we have that both sides in equation 6.1 are zero for $v = 0$, and that

$$\phi'(v)|_{v=0} = \infty$$

As v increases and as long as $\delta^2 - \beta\lambda_0(v)^2 > 0$, $\phi(v)$ increases at a declining rate since the denominator in equation 6.2 is increasing in v and the numerator is decreasing in v. For a certain value of v, $\delta^2 = \beta\lambda_0(v)^2$ and consequently $\phi^{'}(v) = 0$. After this point $\phi^{'}(v) < 0 \; \forall v$.

We have now shown that the first derivative of the function $\phi(v)$ is positive for small values of v, then negative for larger values. Moreover, while $\phi^{'}(v) > 0$, it holds that $\phi^{''}(v) < 0$. It follows that there is one and only one positive value for v for which 6.1 holds.

Table 1. Descriptive statistics, durations (sum of elapsed and residual durations) are measured in weeks.

	Observations	# U	# U uncens.	U spell mean	U spell std. dev.
Education < 12 years.					
Men and women, 16-21	336	58	46	30.8	27.2
Men, 22-30	715	101	68	32.5	28.6
Men, 31-50	1436	121	82	37.5	39.7
Women, 22-30	625	94	58	45.2	34.1
Women, 31-50	1284	123	68	53.2	39.4
Men and women, >50	1078	95	51	44.9	38.1
Education, 12 years					
Men and women, 16-21	347	24	24	22.1	14.2
Men, 22-30	1177	78	65	23.4	20.1
Men, 31-50	2008	97	68	29.4	30.6
Women, 22-30	806	56	38	38.6	29.8
Women, 31-50	850	44	244	44.3	32.8
Men and women, >50	823	49	23	58.8	41
Education, 13-17 years					
Men and women, 22-50	1999	94	71	31.3	33.2
Entire sample	13466	1034	686	38.5	34.9

Table 2. Descriptive statistics, durations (sum of elapsed and residual durations) are measured in weeks

	#E	E-E	E-U	E spell	Accepted wages	Earned. wages
Education < 12 years.						
Men and women, 16-21	278	153	109	104.9	91.9	88.5
				80.0	*20.1*	*20.0*
Men, 22-30	614	346	153	178.1	106.4	108.8
				145.3	*28.6*	*24.4*
Men, 31-50	1315	649	234	250	113.6	120.8
				161	*46.6*	*31.4*
Women, 22-30	531	263	182	180.8	89.4	90.4
				139.8	*18*	*17.9*
Women, 31-50	1161	502	260	258.6	91.9	95.1
				158.1	*17.8*	*21.2*
Men and women, >50	983	379	142	281.4	105	102.6
				157.3	*30.2*	*23.9*
Education, 12 years						
Men and women, 16-21	323	194	91	142.3	86	83.7
				99.1	*19.8*	*18.5*
Men, 22-30	1099	666	198	186	112.5	112.2
				134.7	*28.6*	*23.9*
Men, 31-50	1911	989	215	280.6	119.5	126
				164.4	*51.9*	*30.6*
Women, 22-30	750	430	144	211	91.6	92.2
				140.6	*34.6*	*18.7*
Women, 31-50	806	331	109	311.3	92.6	101
				158.7	*17.2*	*23*
Men and women, >50	774	262	95	322.6	104	118.1
				163.3	*29.7*	*34.6*
Education, 13-17 years						
Men and women, 22-50	1905	918	242	267.9	121.2	131.5
				157.9	*59.1*	*44*
Entire sample						
	12432	6073	2167	248.8	103.9	112
				160.8	*37.1*	*33.1*

Note: standard deviations in italics.

Table 3. Structural, non-parametric estimation results, durations measured in weeks.

	λ_0	λ_1	δ	R	$pQ(t(R))$
Education < 12 years					
Men and women, 16-21	0.0466	0.0099	0.0055	59.64	89.54
	0.0044	*0.0008*	*0.0004*		
Men, 22-30	0.0395	0.0084	0.0030	64.82	97.17
	0.0033	*0.0006*	*0.0001*		
Men, 31-50	0.0350	0.0066	0.0019	73.90	100.28
	0.0030	*0.0004*	*0.0001*		
Women, 22-30	0.0322	0.0069	0.0032	60.50	87.21
	0.0021	*0.0005*	*0.0002*		
Women, 31-50	0.0289	0.0045	0.0020	60.29	89.99
	0.0017	*0.0002*	*0.0001*		
Men and women, > 50	0.0288	0.0046	0.0017	60.52	92.98
	0.0023	*0.0003*	*0.0001*		
Education, 12 years					
Men and women, 16-21	0.0662	0.0072	0.0030	58.34	78.47
	0.0087	*0.0006*	*0.0002*		
Men, 22-30	0.0611	0.0098	0.0023	64.18	90.28
	0.0052	*0.0006*	*0.0001*		
Men, 31-50	0.0468	0.0069	0.0017	71.31	101.07
	0.0040	*0.0003*	*0.0000*		
Women, 22-30	0.0398	0.0082	0.0021	60.5	77.93
	0.0035	*0.0006*	*0.0001*		
Women, 31-50	0.0352	0.0050	0.0015	60.11	88.42
	0.0033	*0.0004*	*0.0001*		
Men and women, > 50	0.0272	0.0044	0.0015	64.82	100.50
	0.0025	*0.0003*	*0.0001*		
Education, 13-17 years					
Men and Women, 22-50	0.0454	0.0073	0.0016	63.38	90.40
	0.0042	*0.0004*	*0.0000*		
Entire sample					
	0.0367	0.0065	0.0019	60.29	91.36
	0.0009	*0.0001*	*0.0000*		

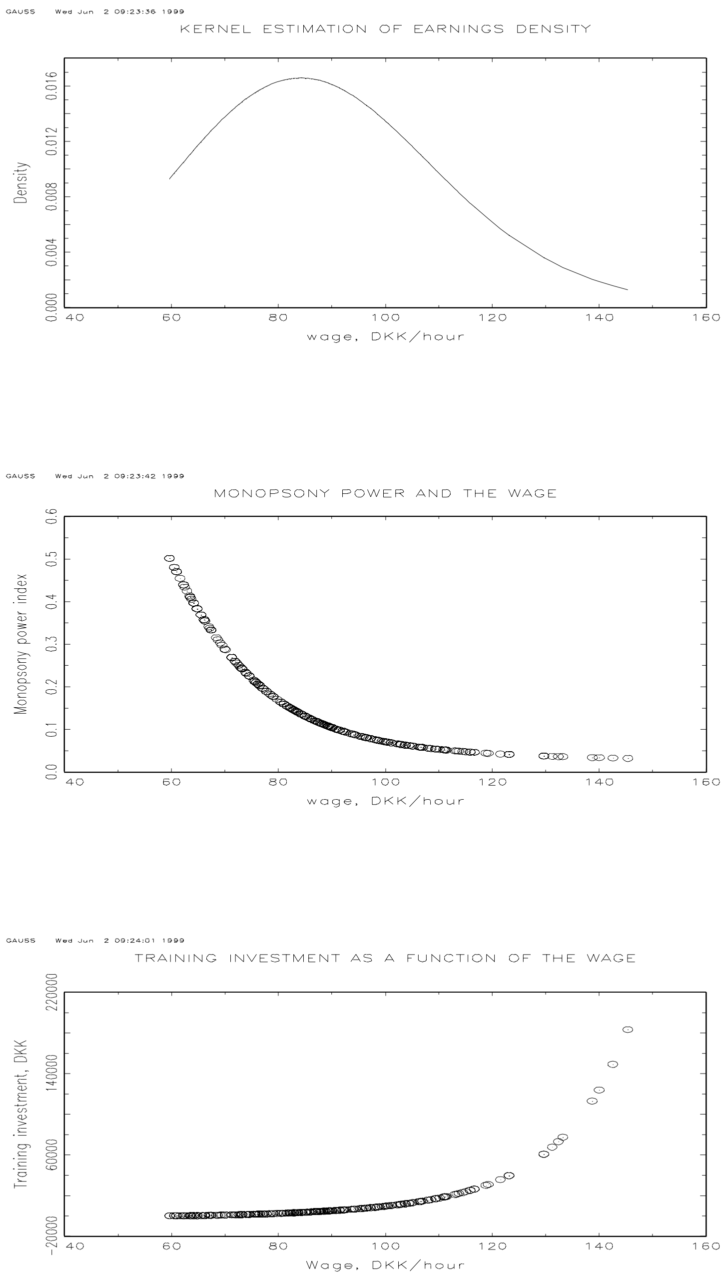
Note: standard deviations in italics

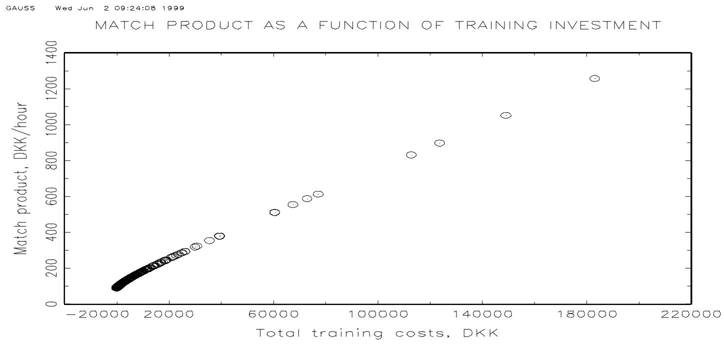
Table 4. Derived results from the estimation, durations measured in weeks.

	U_S	U_E	T_{E_S}	T_{E_E}	Training Mean	Training Median	MP
Education < 12 years							
Men and women, 16-21	0.17	0.11	104	108	9013	3704	0.17
Men, 22-30	0.14	0.07	178	191	15213	7477	0.09
Men, 31-50	0.09	0.05	248	288	24707	10887	0.06
Women, 22-30	0.15	0.09	180	180	18100	6077	0.12
Women, 31-50	0.09	0.06	258	295	27825	10365	0.12
Men and women, > 50	0.09	0.06	282	332	29068	13122	0.11
Education, 12 years							
Men and women, 16-21	0.07	0.04	142	174	16080	5918	0.11
Men, 22-30	0.07	0.04	187	234	18401	10031	0.05
Men, 31-50	0.05	0.03	279	328	25680	13495	0.05
Women, 22-30	0.07	0.05	211	257	26349	7606	0.05
Women, 31-50	0.05	0.04	311	369	34737	13960	0.08
Men and women, > 50	0.06	0.05	319	370	35649	16049	0.10
Education, 13-17 years							
Men and Women, 22-50	0.05	0.03	263	340	31538	13525	0.05
Entire sample							
	0.08	0.05	246	287	27204	12454	0.08

Note: U_S and U_E is the observed sample and estimated unemployment rate, respectively. T_{E_S} and T_{E_E} is the observed sample and estimated duration of employment (including censored observations). Training mean and median indicates the mean and median of the training costs, respectively. MP is the average monopsony power index.

Figure 1: Plots for men and women, aged 16-21 with less than 12 years of formal education.

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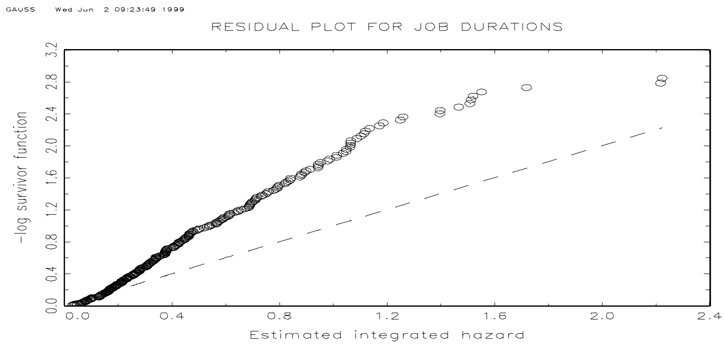
MATCH PRODUCT AS A FUNCTION OF TRAINING INVESTMENT
Match product, DKK/hour
Total training costs, DKK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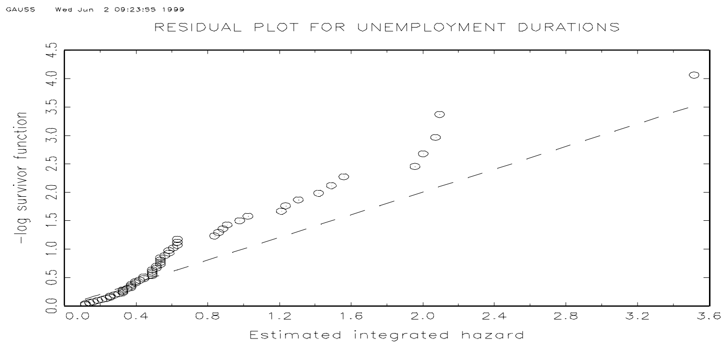
-log survivor function
Estimated integrated hazard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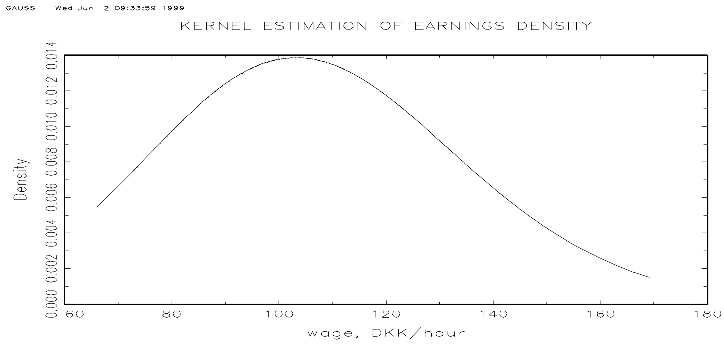
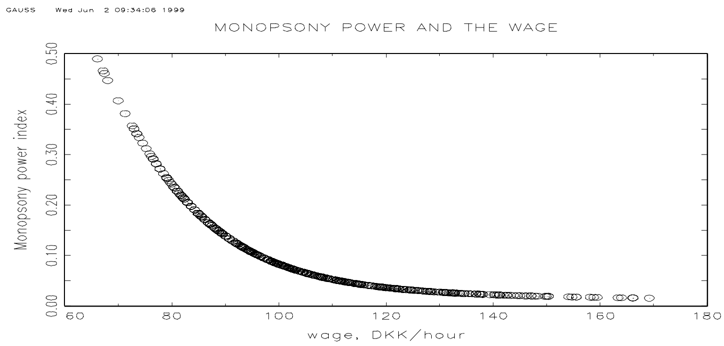
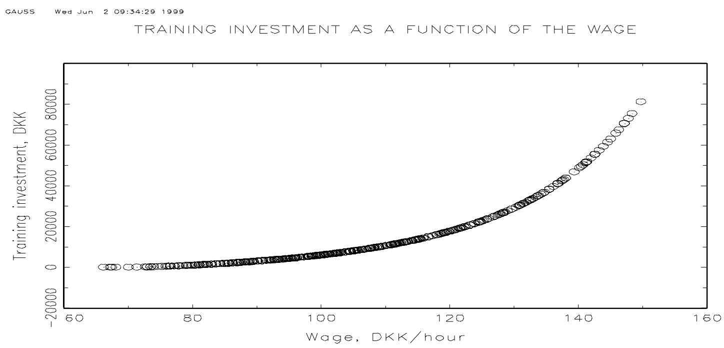
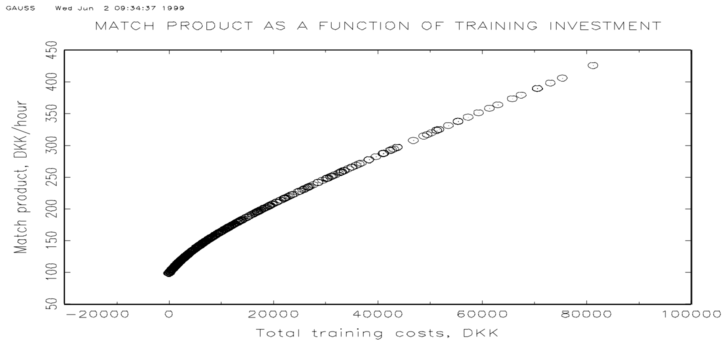
RESIDUAL PLOT FOR UNEMPLOYMENT DURATIONS
-log survivor function
Estimated integrated hazard

Figure 2: Plots for men, aged 22-30 with less than 12 years of formal education.





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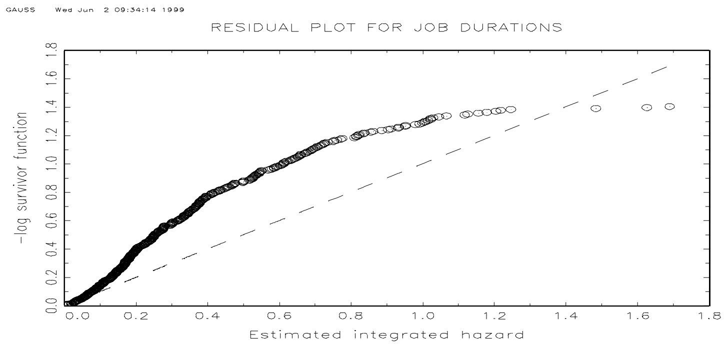
Match product, DKK/hour
Total training costs, DKK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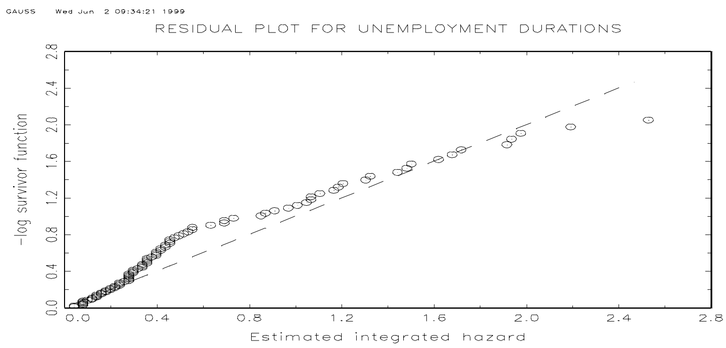
-log survivor function
Estimated integrated hazard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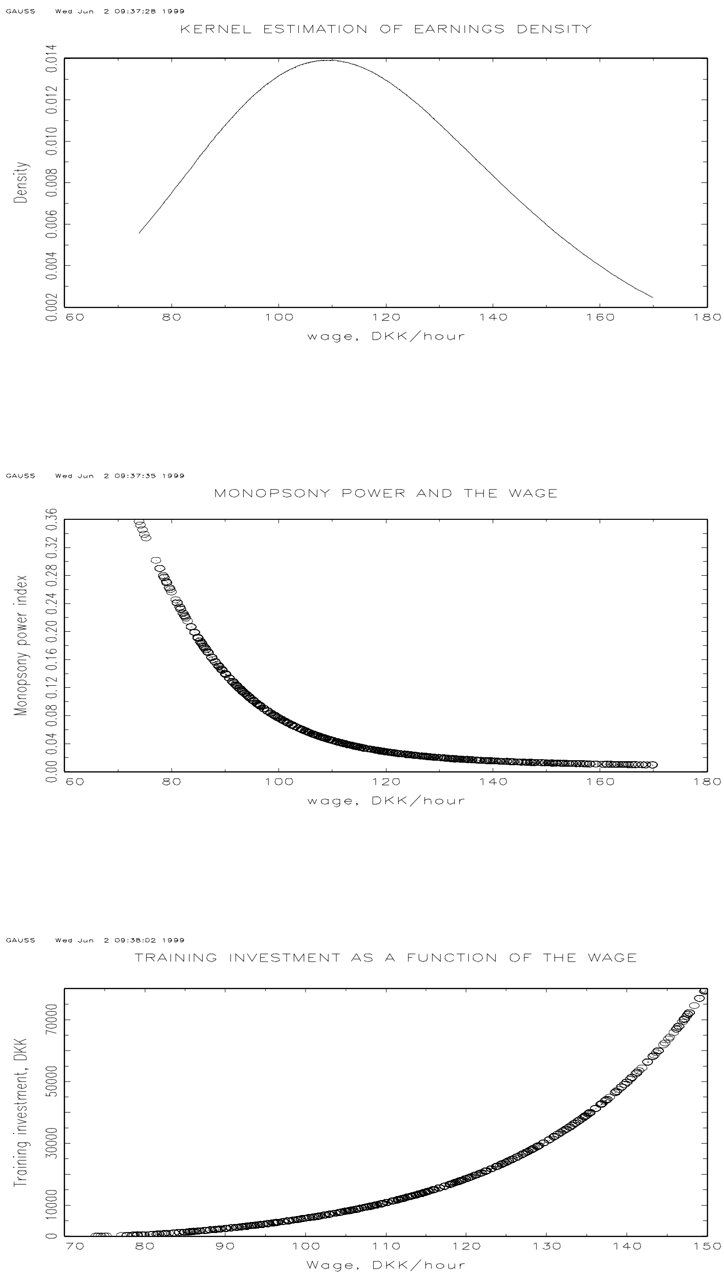
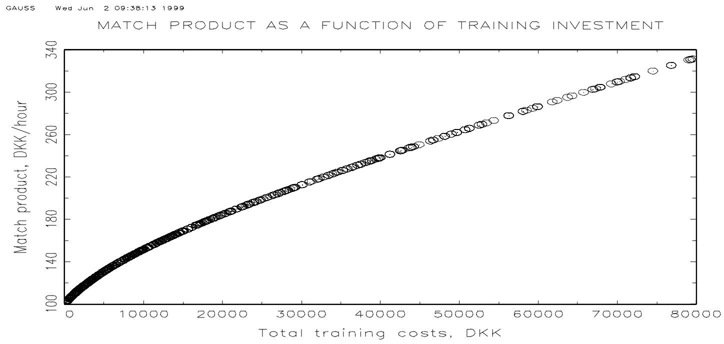
-log survivor function
Estimated integrated hazard

Figure 3: Plots for men, aged 31-50 with less than 12 years of formal education.

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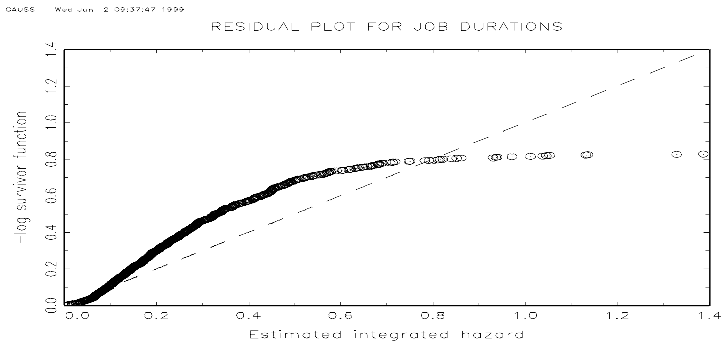
MATCH PRODUCT AS A FUNCTION OF TRAINING INVESTMENT
Match product, DKK/hour
Total training costs, DKK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RESIDUAL PLOT FOR JOB DURATIONS
-log survivor function
Estimated integrated hazard

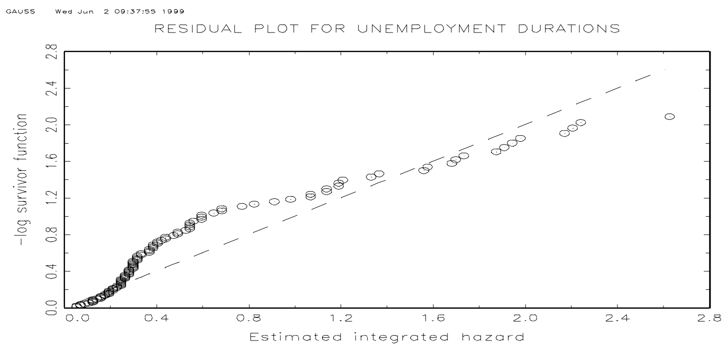
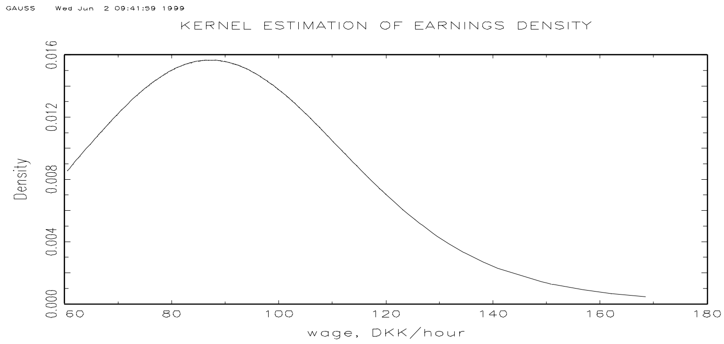
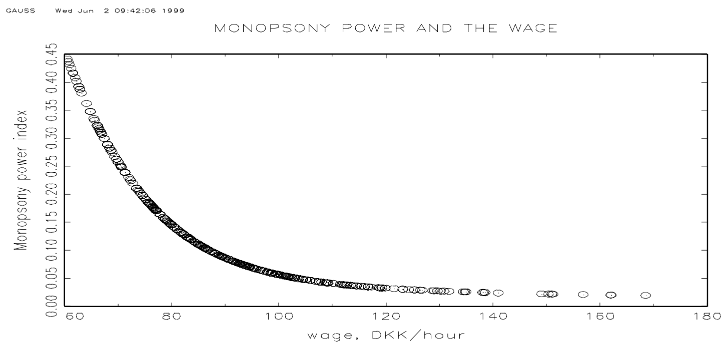
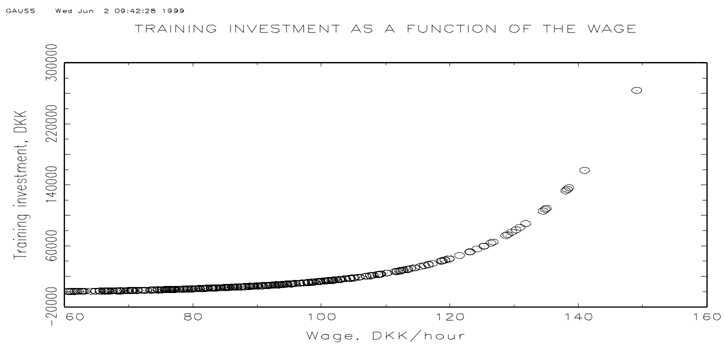
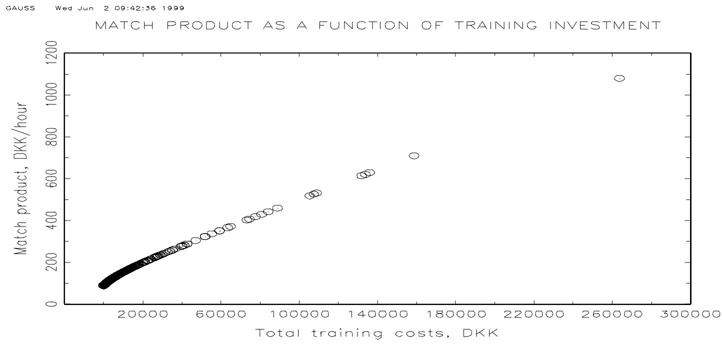

GAUSS Wed Jun 2 09:37:55 1999
RESIDUAL PLOT FOR UNEMPLOYMENT DURATIONS
-log survivor function
Estimated integrated hazard

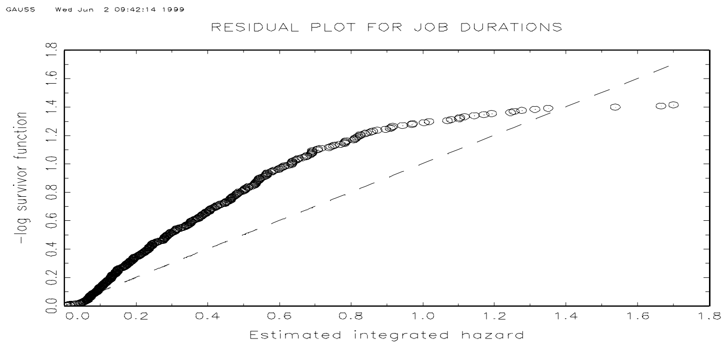
Figure 4: Plots for women, aged 22-30 with less than 12 years of formal education.








GAUSS Wed Jun 2 09:42:36 1999
MATCH PRODUCT AS A FUNCTION OF TRAINING INVESTMENT
Match product, DKK/hour
Total training costs, DKK


GAUSS Wed Jun 2 09:42:14 1999
RESIDUAL PLOT FOR JOB DURATIONS
-log survivor function
Estimated integrated hazard

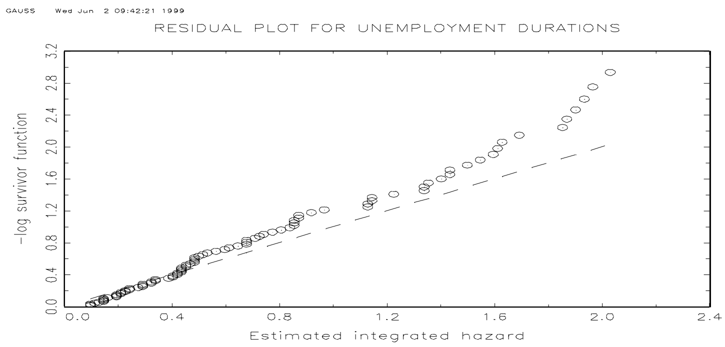
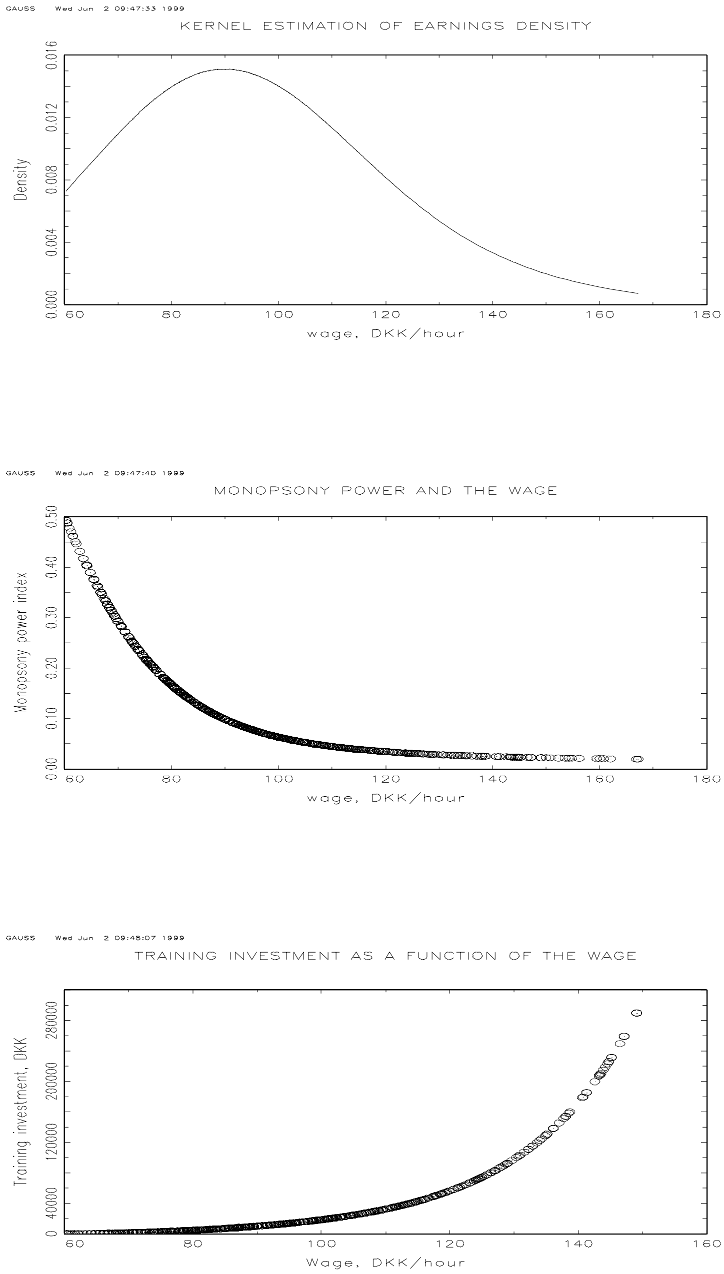
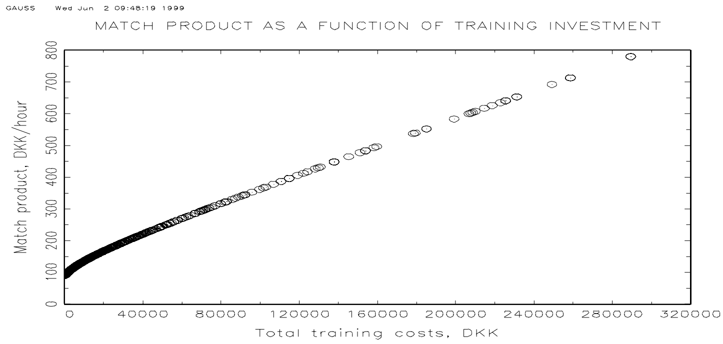
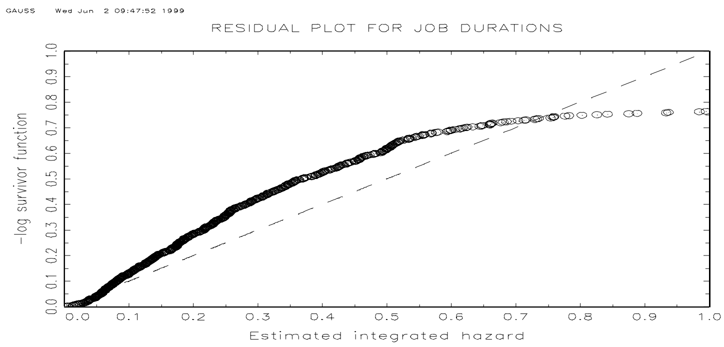

GAUSS Wed Jun 2 09:42:21 1999
RESIDUAL PLOT FOR UNEMPLOYMENT DURATIONS
-log survivor function
Estimated integrated hazard

Figure 5: Plots for women, aged 31-50 with less than 12 years of formal education.




GAUSS Wed Jun 2 09:48:19 1999
MATCH PRODUCT AS A FUNCTION OF TRAINING INVESTMENT
Match product, DKK/hour
Total training costs, DKK


GAUSS Wed Jun 2 09:47:52 1999
RESIDUAL PLOT FOR JOB DURATIONS
-log survivor function
Estimated integrated hazard

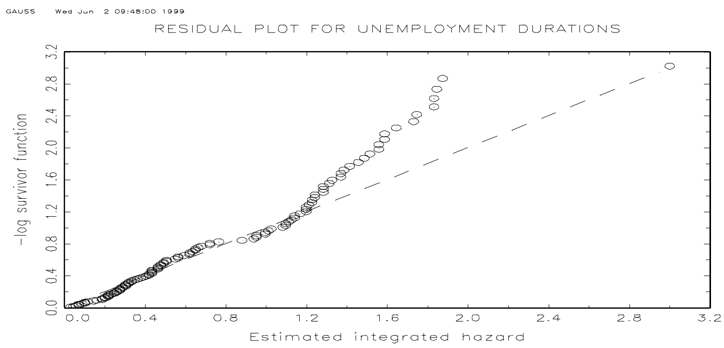
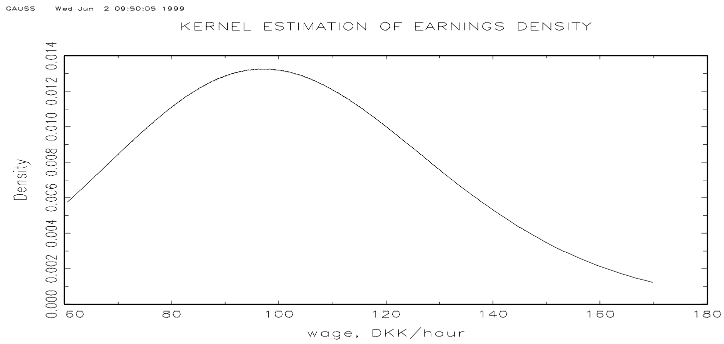
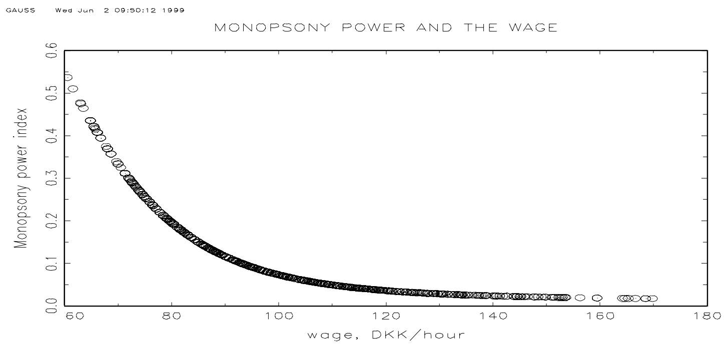
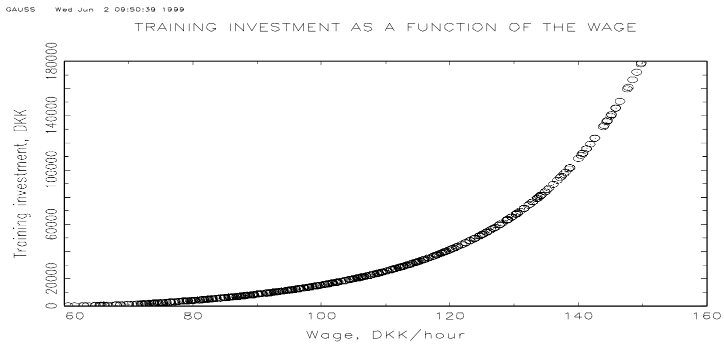
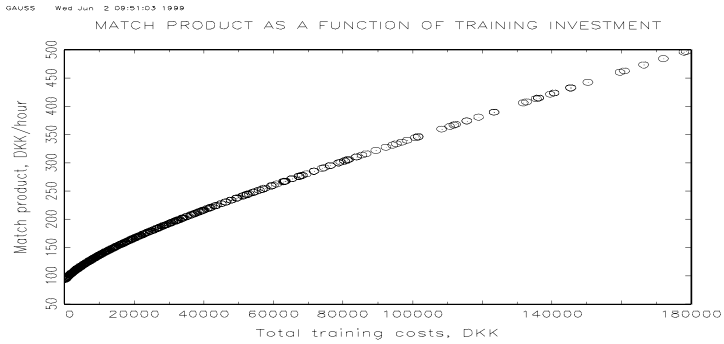

GAUSS Wed Jun 2 09:48:00 1999
RESIDUAL PLOT FOR UNEMPLOYMENT DURATIONS
-log survivor function
Estimated integrated hazard

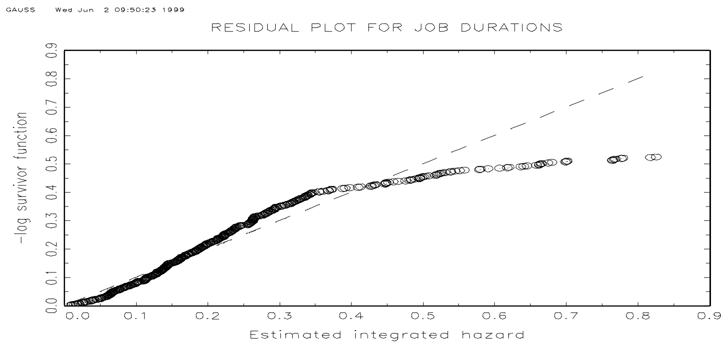
Figure 6: Plots for men and women, aged 51 and above with less than 12 years of formal education.








GAUSS Wed Jun 2 09:51:03 1999
MATCH PRODUCT AS A FUNCTION OF TRAINING INVESTMENT
Match product, DKK/hour
Total training costs, DKK


GAUSS Wed Jun 2 09:50:23 1999
RESIDUAL PLOT FOR JOB DURATIONS
-log survivor function
Estimated integrated hazard

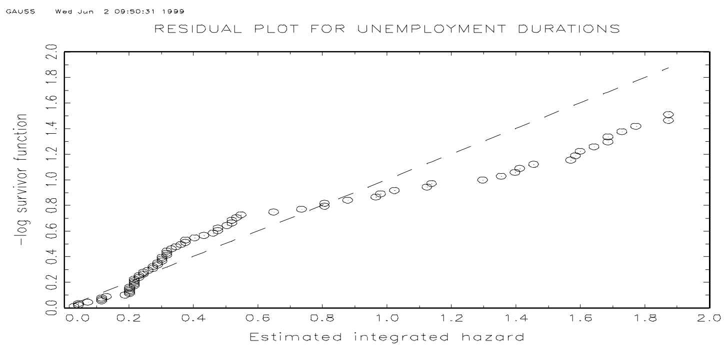
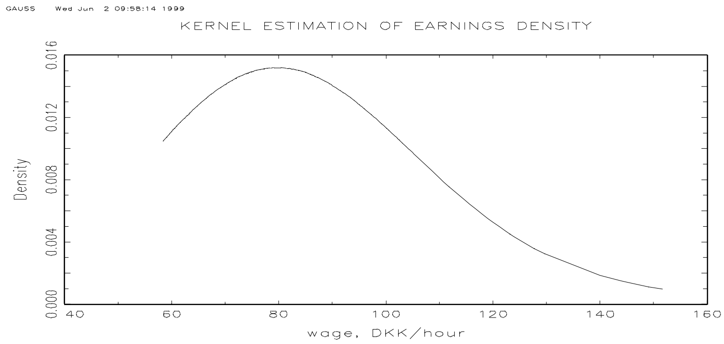
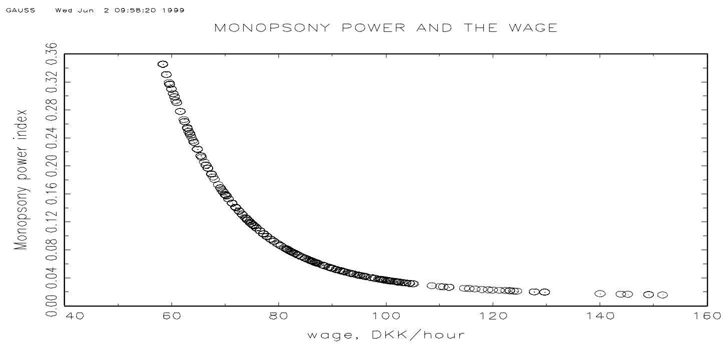
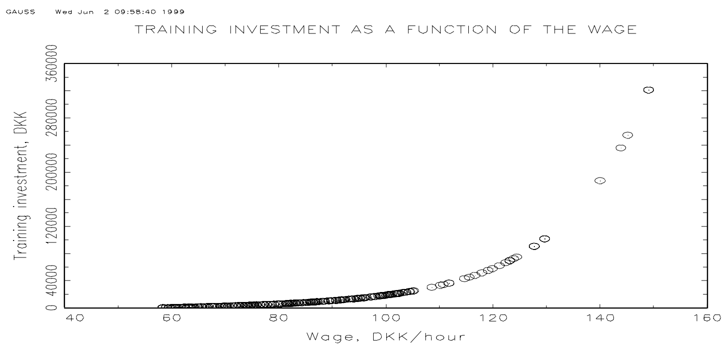
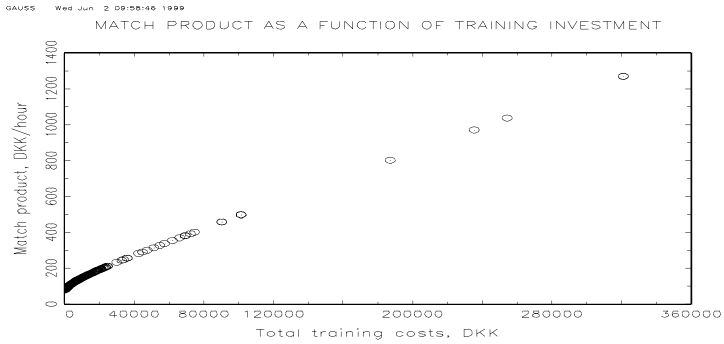

GAUSS Wed Jun 2 09:50:31 1999
RESIDUAL PLOT FOR UNEMPLOYMENT DURATIONS
-log survivor function
Estimated integrated hazard

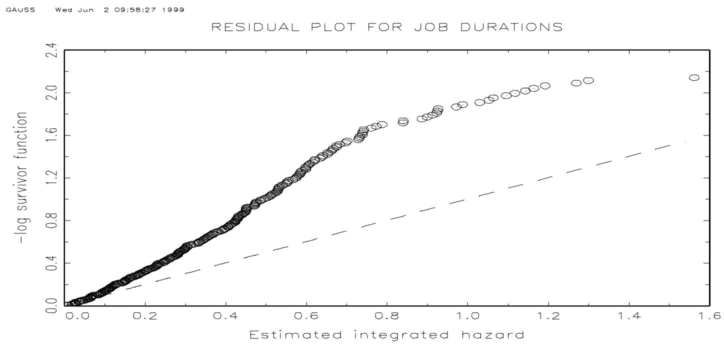
Figure 7: Plots for men and women, aged 16-21 with 12 years of formal education.








GAUSS Wed Jun 2 09:58:46 1999
MATCH PRODUCT AS A FUNCTION OF TRAINING INVESTMENT
Match product, DKK/hour
Total training costs, DKK


GAUSS Wed Jun 2 09:58:27 1999
RESIDUAL PLOT FOR JOB DURATIONS
-log survivor function
Estimated integrated hazard

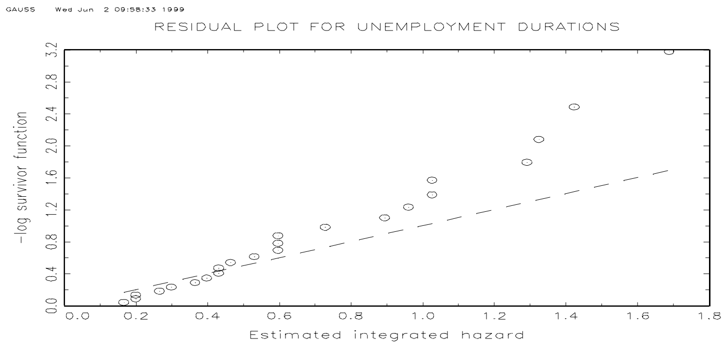
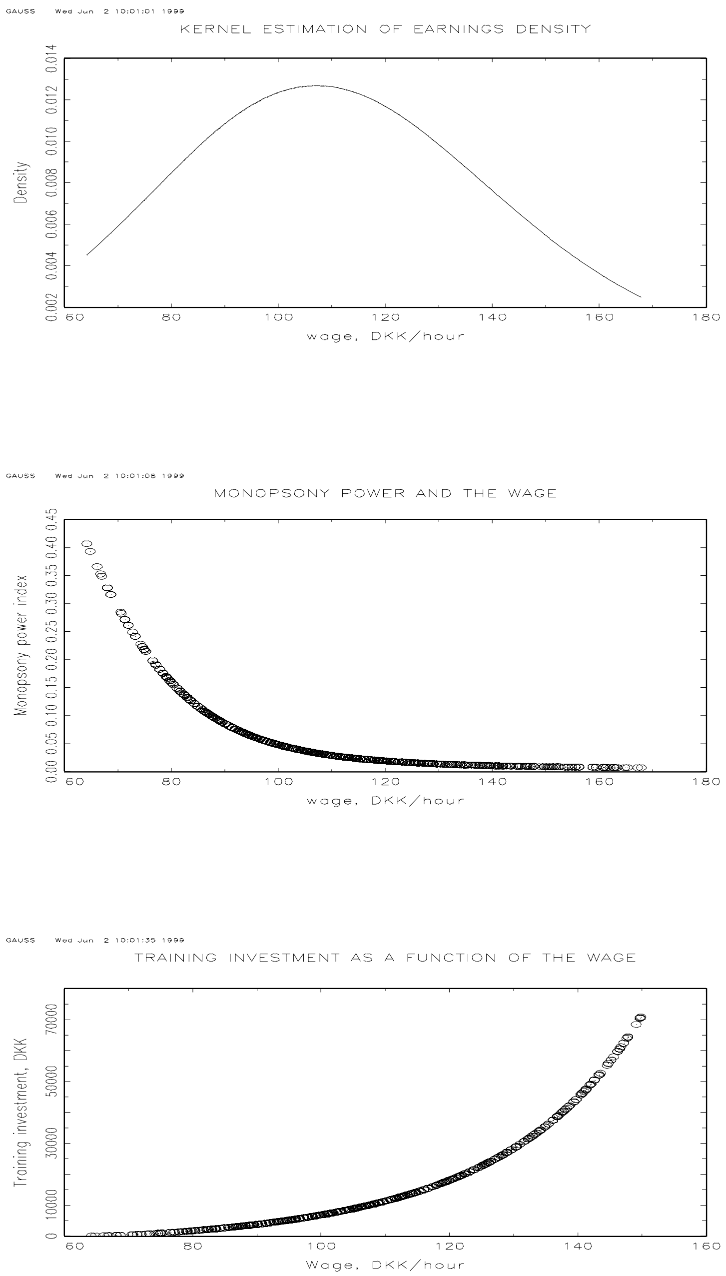
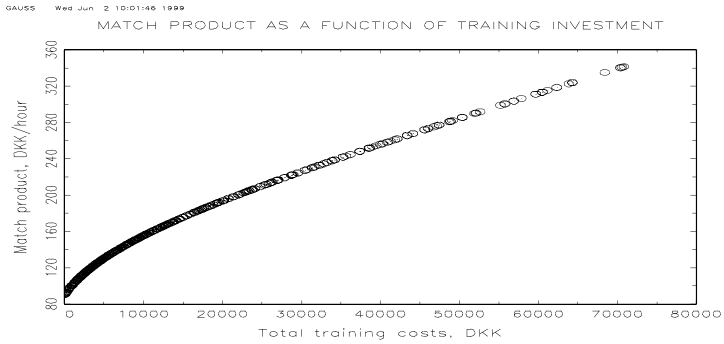
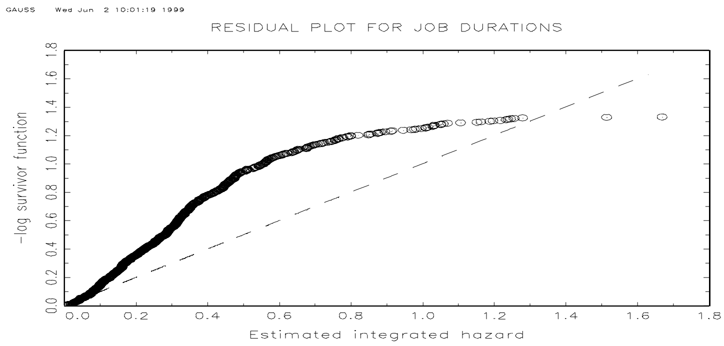

GAUSS Wed Jun 2 09:58:33 1999
RESIDUAL PLOT FOR UNEMPLOYMENT DURATIONS
-log survivor function
Estimated integrated hazard

Figure 8: Plots for men, aged 22-30 with 12 years of formal education.

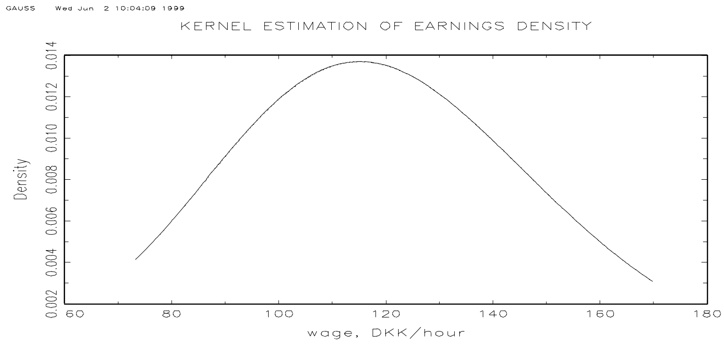


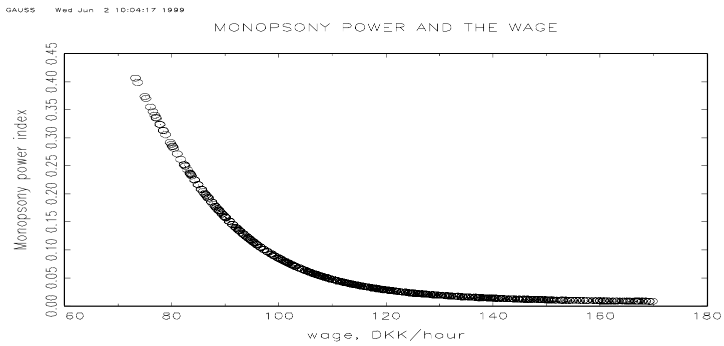

GAUSS Wed Jun 2 10:01:46 1999
MATCH PRODUCT AS A FUNCTION OF TRAINING INVESTMENT
Match product, DKK/hour
Total training costs, DKK

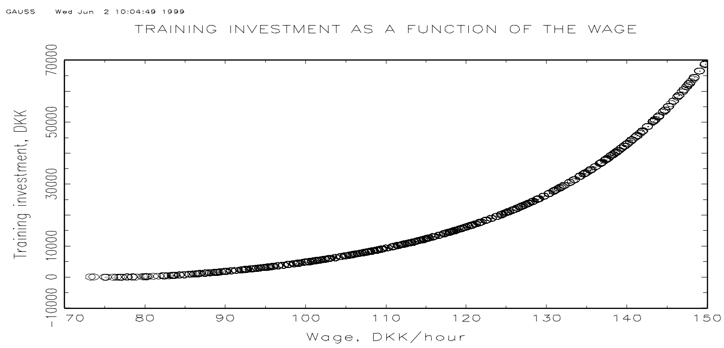

GAUSS Wed Jun 2 10:01:19 1999
RESIDUAL PLOT FOR JOB DURATIONS
-log survivor function
Estimated integrated hazard

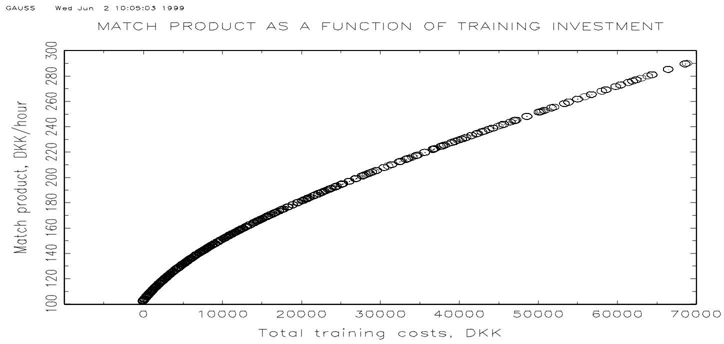

GAUSS Wed Jun 2 10:01:28 1999
RESIDUAL PLOT FOR UNEMPLOYMENT DURATIONS
-log survivor function
Estimated integrated hazard

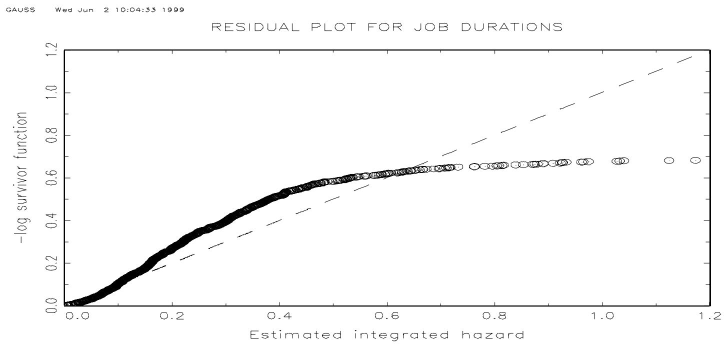
Figure 9: Plots for men, aged 31-50 with 12 years of formal education.








GAUSS Wed Jun 2 10:05:03 1999
MATCH PRODUCT AS A FUNCTION OF TRAINING INVESTMENT
Match product, DKK/hour
100 120 140 160 180 200 220 240 260 280 300
0 10000 20000 30000 40000 50000 60000 70000
Total training costs, DKK


GAUSS Wed Jun 2 10:04:33 1999
RESIDUAL PLOT FOR JOB DURATIONS
-log survivor function
0.0 0.2 0.4 0.6 0.8 1.0 1.2
0.0 0.2 0.4 0.6 0.8 1.0 1.2
Estimated integrated hazard

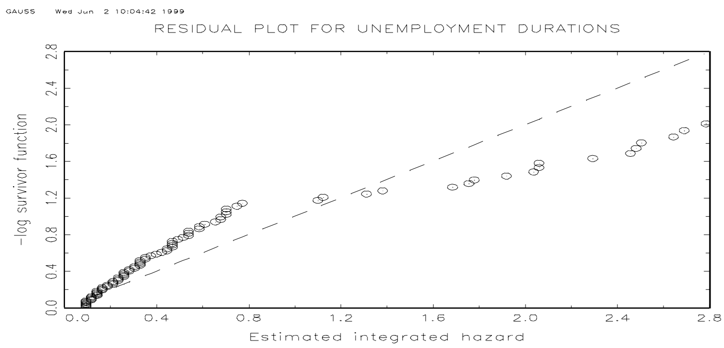
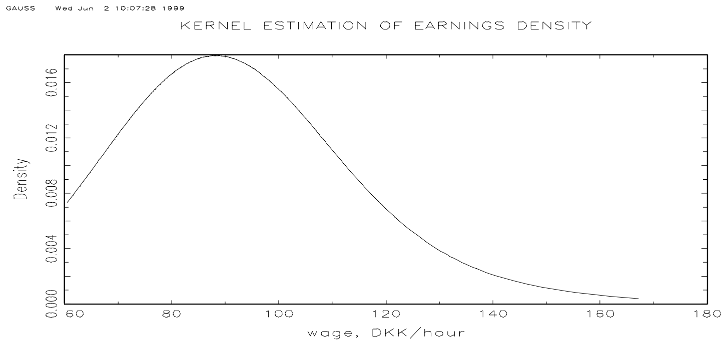
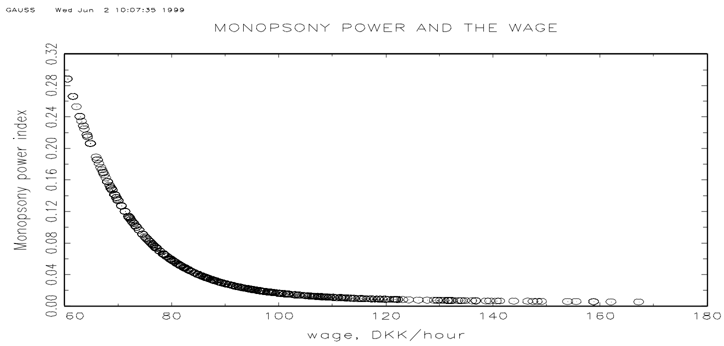
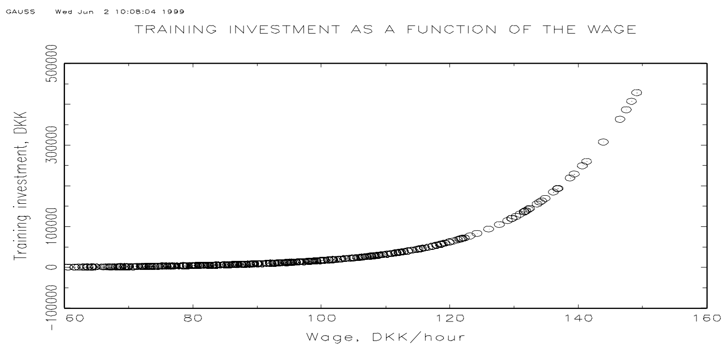
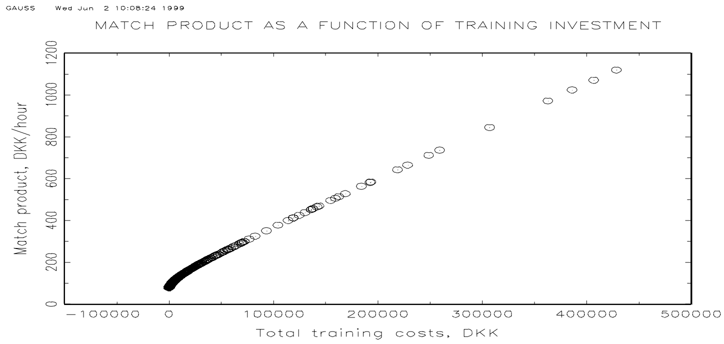

GAUSS Wed Jun 2 10:04:42 1999
RESIDUAL PLOT FOR UNEMPLOYMENT DURATIONS
-log survivor function
0.0 0.4 0.8 1.2 1.6 2.0 2.4 2.8
0.0 0.4 0.8 1.2 1.6 2.0 2.4 2.8
Estimated integrated hazard

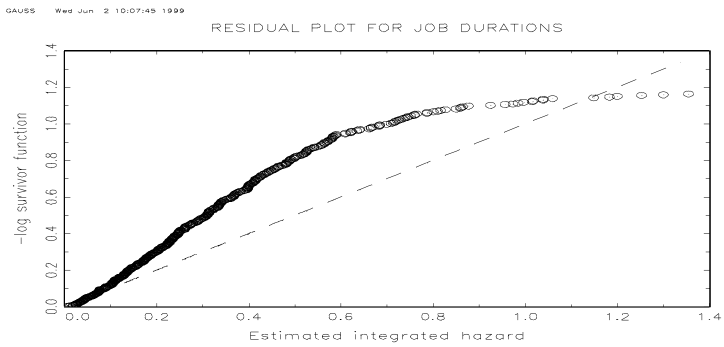
Figure 10: Plots for women, aged 22-30 with 12 years of formal education.








GAUSS Wed Jun 2 10:08:24 1999
MATCH PRODUCT AS A FUNCTION OF TRAINING INVESTMENT
Match product, DKK/hour
Total training costs, DKK
0
200
400
600
800
1000
1200
−100000
0
100000
200000
300000
400000
500000


GAUSS Wed Jun 2 10:07:45 1999
RESIDUAL PLOT FOR JOB DURATIONS
−log survivor function
Estimated integrated hazard
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

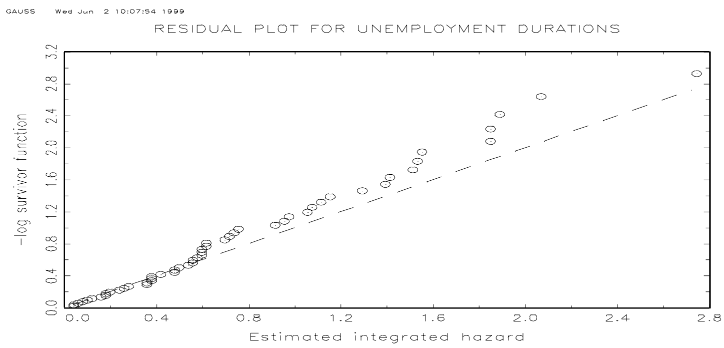
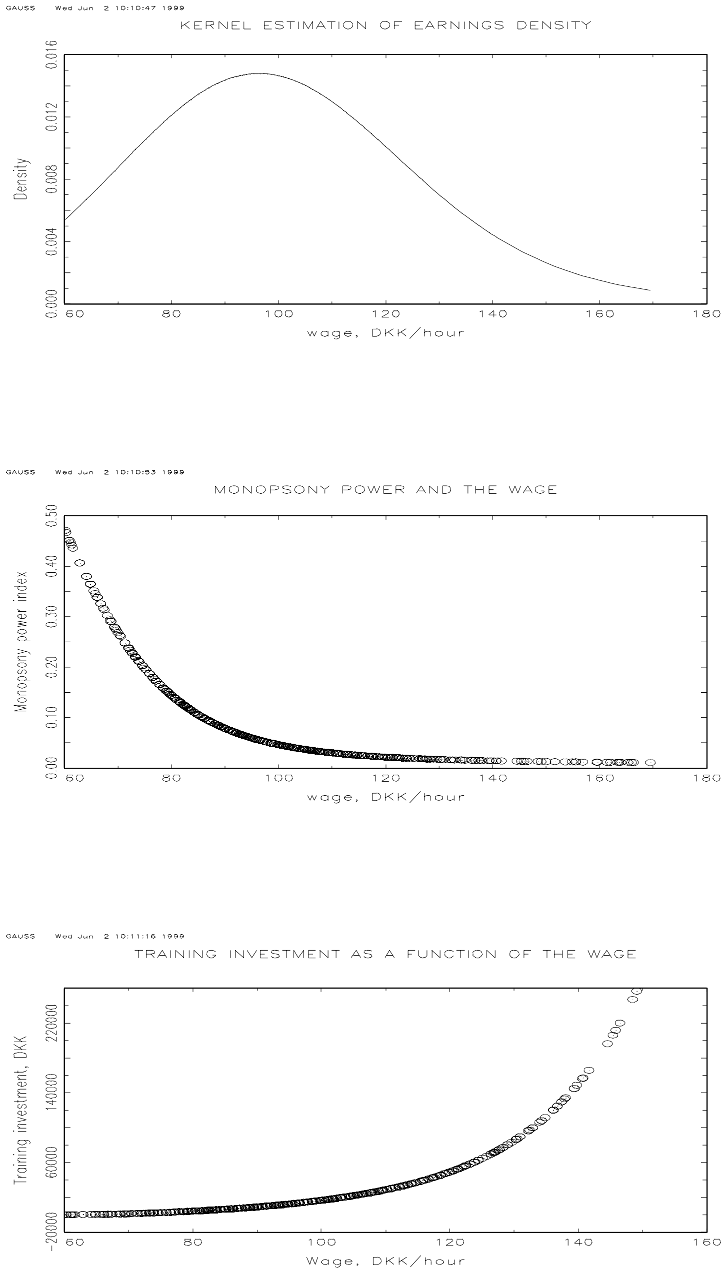
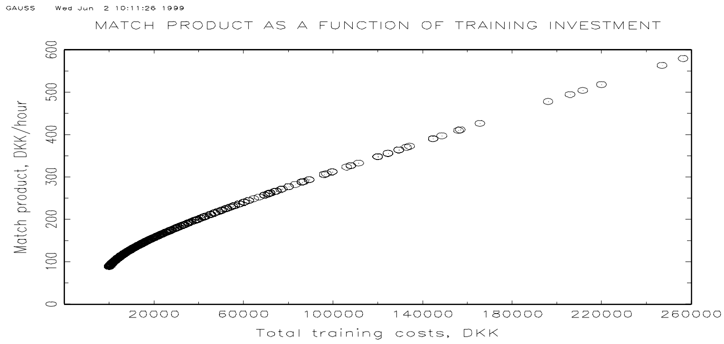
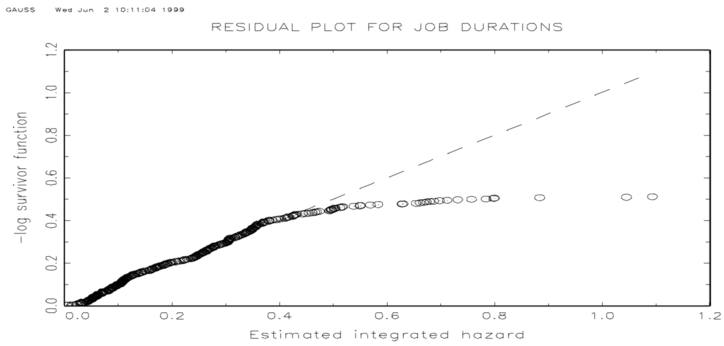

GAUSS Wed Jun 2 10:07:54 1999
RESIDUAL PLOT FOR UNEMPLOYMENT DURATIONS
−log survivor function
Estimated integrated hazard
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2

Figure 11: Plots for women, aged 31-50 with 12 years of formal education.




GAUSS Wed Jun 2 10:11:26 1999
MATCH PRODUCT AS A FUNCTION OF TRAINING INVESTMENT
Match product, DKK/hour
Total training costs, DKK


GAUSS Wed Jun 2 10:11:04 1999
RESIDUAL PLOT FOR JOB DURATIONS
-log survivor function
Estimated integrated hazard

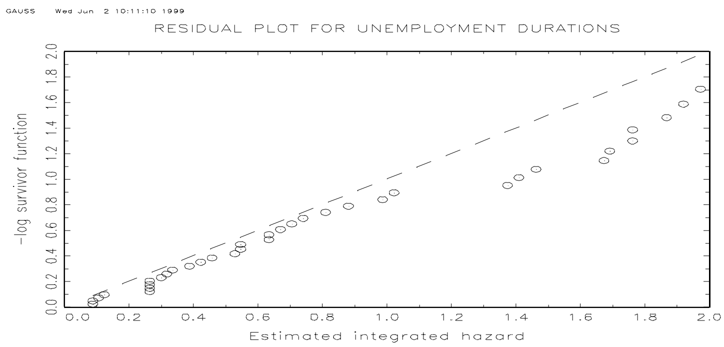
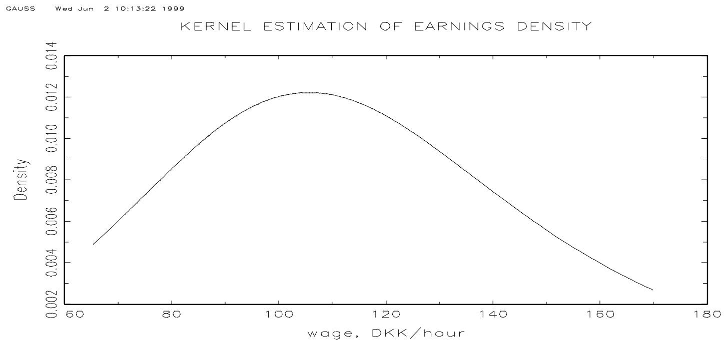
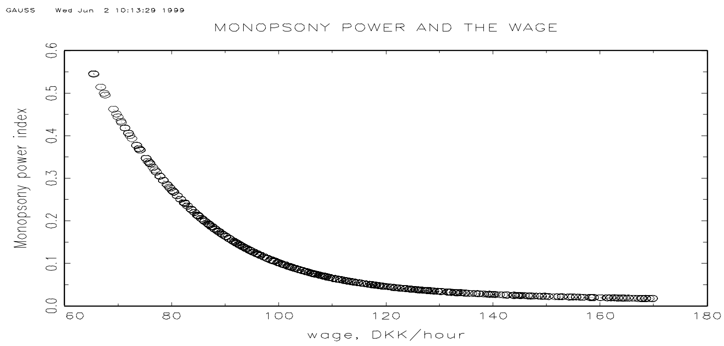
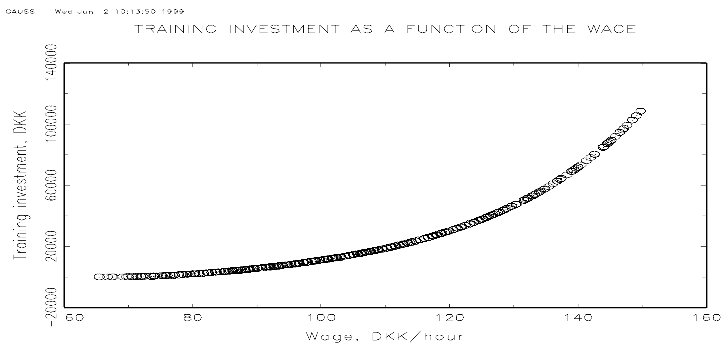
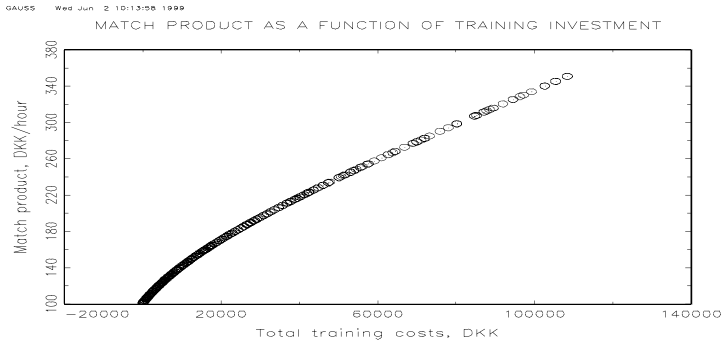

GAUSS Wed Jun 2 10:11:10 1999
RESIDUAL PLOT FOR UNEMPLOYMENT DURATIONS
-log survivor function
Estimated integrated hazard

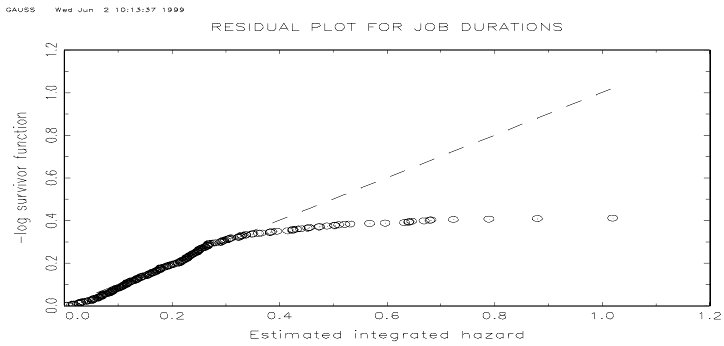
Figure 12: Plots for men and women, aged 51 and above with 12 years of formal education.








GAUSS Wed Jun 2 10:13:58 1999
MATCH PRODUCT AS A FUNCTION OF TRAINING INVESTMENT
Match product, DKK/hour
Total training costs, DKK


GAUSS Wed Jun 2 10:13:37 1999
RESIDUAL PLOT FOR JOB DURATIONS
-log survivor function
Estimated integrated hazard

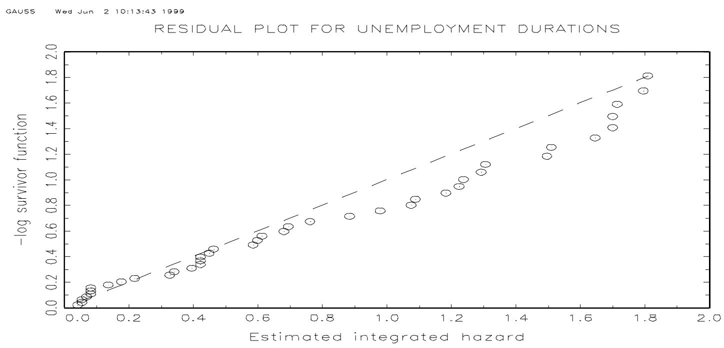
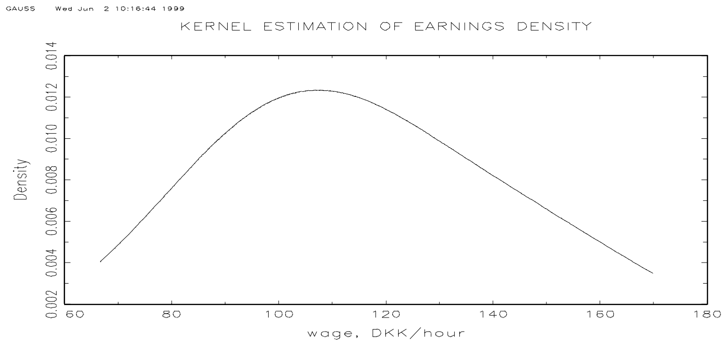
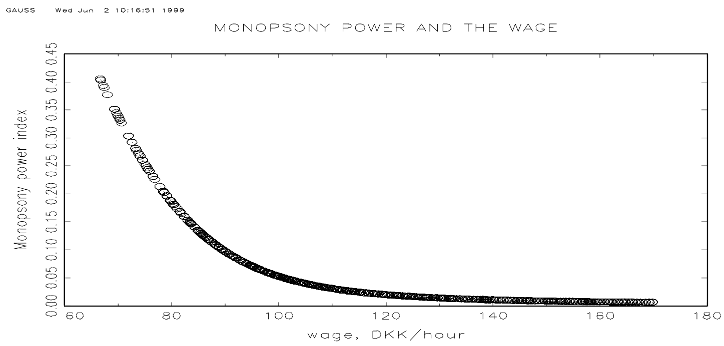
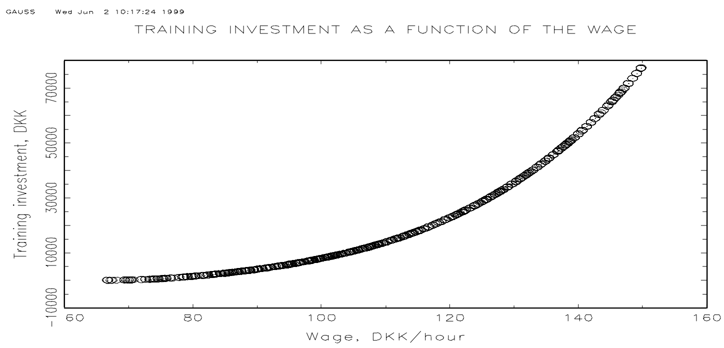
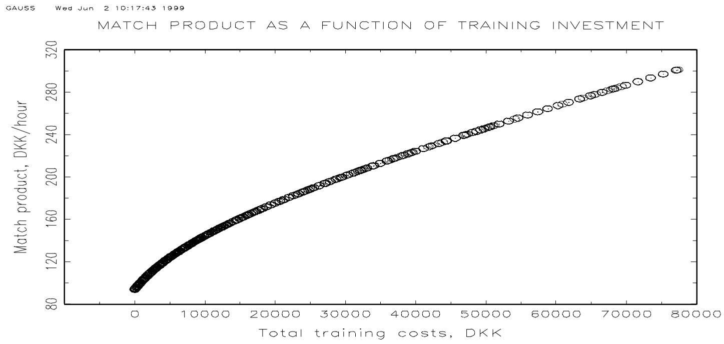

GAUSS Wed Jun 2 10:13:43 1999
RESIDUAL PLOT FOR UNEMPLOYMENT DURATIONS
-log survivor function
Estimated integrated hazard

Figure 13: Plots for men and women, aged 22-50 with 13 or more years of formal education.

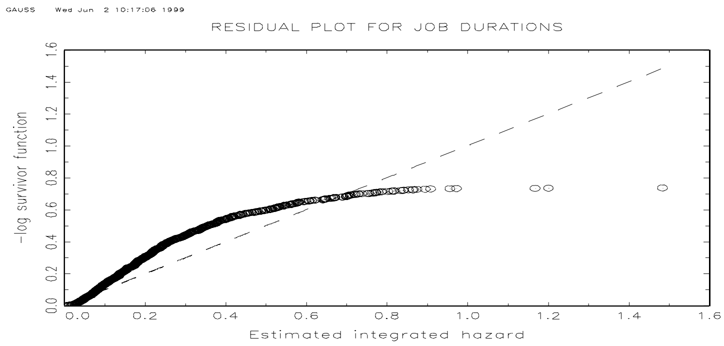




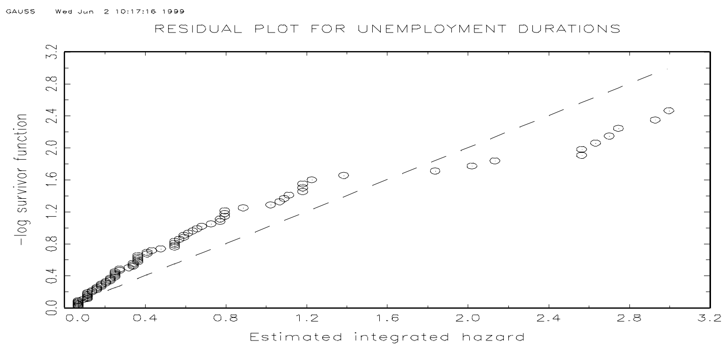




GAUSS Wed Jun 2 10:17:43 1999
MATCH PRODUCT AS A FUNCTION OF TRAINING INVESTMENT
Match product, DKK/hour
Total training costs, DKK

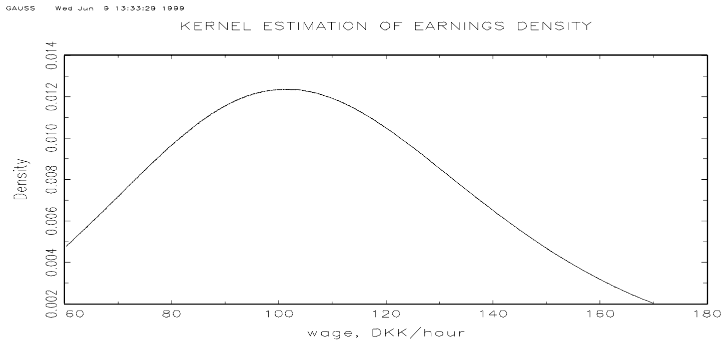


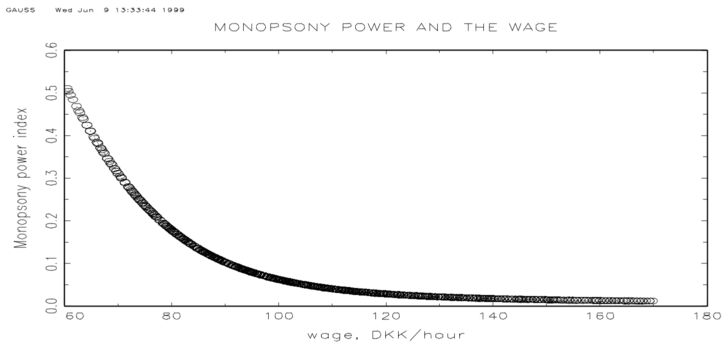
GAUSS Wed Jun 2 10:17:06 1999
RESIDUAL PLOT FOR JOB DURATIONS
-log survivor function
Estimated integrated hazard

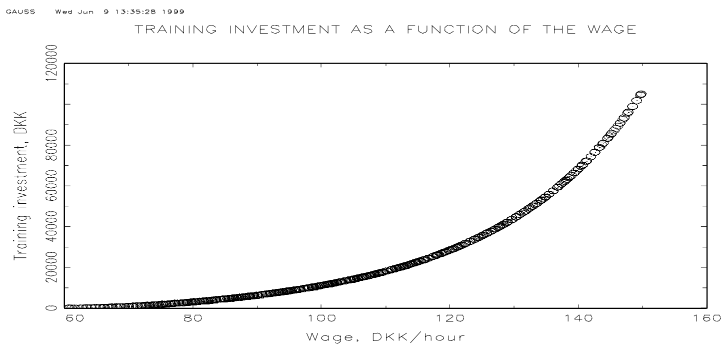


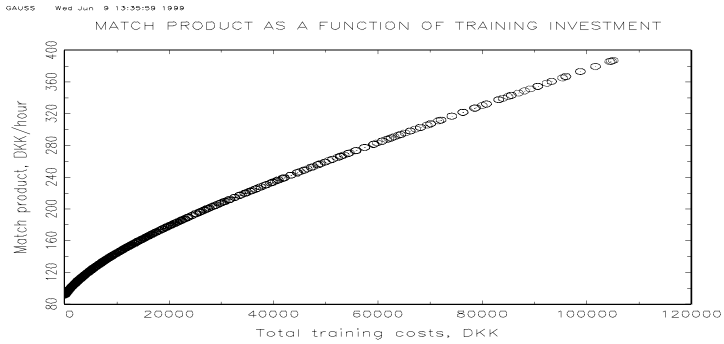
GAUSS Wed Jun 2 10:17:16 1999
RESIDUAL PLOT FOR UNEMPLOYMENT DURATIONS
-log survivor function
Estimated integrated hazard

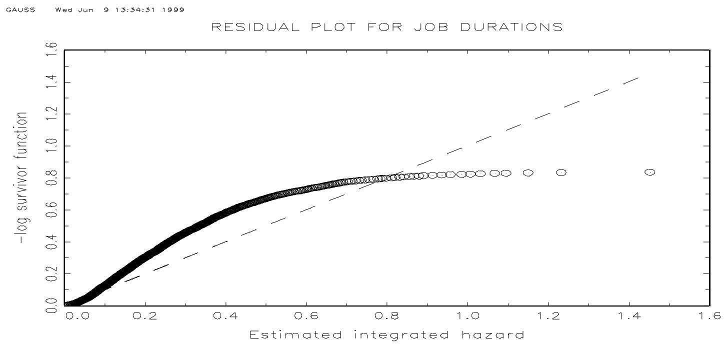
Figure 14: Plots for entire sample.

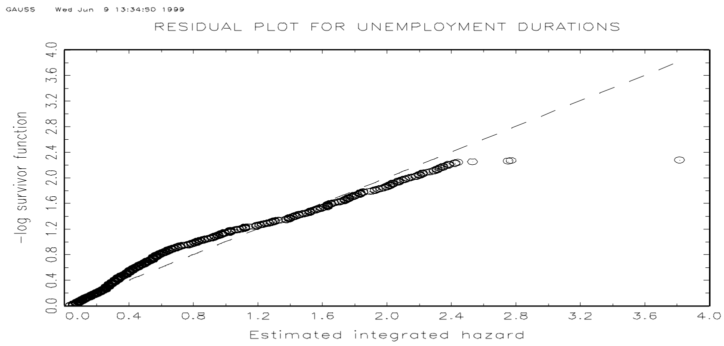







GAUSS Wed Jun 9 13:35:59 1999
MATCH PRODUCT AS A FUNCTION OF TRAINING INVESTMENT
Match product, DKK/hour
80 120 160 200 240 280 320 360 400
0 20000 40000 60000 80000 100000 120000
Total training costs, DKK


GAUSS Wed Jun 9 13:34:31 1999
RESIDUAL PLOT FOR JOB DURATIONS
-log survivor function
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6
Estimated integrated hazard


GAUSS Wed Jun 9 13:34:50 1999
RESIDUAL PLOT FOR UNEMPLOYMENT DURATIONS
-log survivor function
0.0 0.4 0.8 1.2 1.6 2.0 2.4 2.8 3.2 3.6 4.0
0.0 0.4 0.8 1.2 1.6 2.0 2.4 2.8 3.2 3.6 4.0
Estimated integrated hazard

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