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Job search, search intensity and labour market transitions:
An empirical analysis

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JOB SEARCH, SEARCH INTENSITY AND LABOUR MARKET TRANSITIONS: AN EMPIRICAL ANALYSIS

by

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Abstract

In this paper we present an empirical structural job search model with endogenously determined search intensity. The model describes both the behaviour of unemployed job searchers and on-the-job search. We use data on various indicators (or search channels) for the intensity of search, like the monthly number of applications, to study the influence of the intensity of search on labour market transitions. The estimation results give us insight in the effectiveness of search. The impact of the benefit level on the search intensity of unemployed job searchers is quantified. Moreover, the estimation results are used to gain insight in the "discouraged worker" effect. The generalized residuals are studied to discuss the fit of the model.

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email: hbloemen@feweb.vu.nl, this research was carried out at CentER, Tilburg University
1 Introduction

In empirical implementations of search models, the emphasis is on modeling the searcher's acceptance decision. The hazard rate, describing the transition out of unemployment into a job, consists of the product of an exogenous job offer arrival rate and a job offer acceptance probability. In empirical work, the focus is often on the effect of the unemployment benefit system on the job acceptance decision and on the unemployment duration.\(^3\)

The ability of individuals to influence the job offer arrival rate by varying effort spent on search, is usually left out of consideration. The inclusion of this aspect in a model can be used to gain insight in the impact of the benefit level on the decision to search and on the search effort, the effectiveness of search and the "discouraged worker" effect. The results are important for predicting the possible effects of policy analysis. To the political debate it is often argued that lowering unemployment benefits raises the search effort of the unemployed, and therefore increases the probability of a transition into work. Lowering benefits, though, may be a less effective policy tool for the discouraged.

Burdett and Mortensen (1978) present a search model with endogenous search effort. In their model, an increase in the time spent on search increases the average number of job offers arriving in a given time interval, but also causes a utility loss due to a decrease in leisure time. Individuals determine the optimal amount of time spent on search by determining the optimal trade-off between the returns of search in the form of expected job offers and the cost of search due to the loss of leisure time. In Mortensen (1986) a simpler version of the same model is presented. An explicit cost of search function\(^4\) is formulated and again an increase in search effort raises the job offer arrival rate.

To our knowledge, there are only a few empirical studies in which the relation between search effort and unemployment duration is analyzed. Yoon (1981) and Lindeboom and Theeuwes (1993) provide empirical work on the effect of search. Fougère, Bladel and Roger (1997) estimate a structural model with endogenous search intensity. Koning.

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\(^3\) See Atkinson and Micklewright (1991) and Devine and Kiefer (1991) for an overview of empirical work on job search.

\(^4\) This cost of search function need not necessarily be interpreted in terms of financial cost, but may rather be interpreted in terms of utility.
Van den Berg and Ridder (1997) estimate a structural model, based on the Mortensen (1986) framework, which includes the choice and impact of two different search methods (formal, by means of applications, and informal by means of referral).

In this paper, a structural empirical implementation of the model by Mortensen (1986) is estimated. Both on the job searchers and searchers without a job are considered. To make the model suitable for empirical application, some of Mortensen's simplifying assumptions have to be relaxed. We allow for differences in cost of search for workers and non-workers. Nonzero cost of turnover are allowed for. Moreover, differences in the job offer arrival rate between different labour market states may occur and the labour market state enters the utility function.

The data used are from the Dutch Socio Economic Panel. The panel contains several indicators for search intensity, related to different search instruments.

In section 2 the economic model is presented. In Section 3 the data are described. In section 4 contains the empirical specification and a discussion of the results. The final section concludes.

2 The economic model

2.1 Definitions and assumptions

The economic model, which serves as a basis for the empirical specification, is based on the model by Mortensen (1986). To make that model more suitable for empirical implementation, some extensions have to be incorporated.

Individuals are assumed to maximize expected lifetime utility. They make the decision to search for a job or not. They decide how much effort to spend on search, and decide to accept or reject job offers. The model contains the following features:

- **Utility**

  Utility within a period is a function of income and depends on the state of employment:

  \[
  \begin{align*}
  \text{utility}(\text{income}=x, \text{state}=\text{employed}) &= u(x) \\
  \text{utility}(\text{income}=x, \text{state}=\text{unemployed}) &= \omega u(x)
  \end{align*}
  \]  

  (2.1)
with \( u'(x) > 0 \) and \( \omega \) a parameter allowing for a different valuation of income in different labour market states.\(^5\) Income \( x = w + \mu \) if the individual is employed, \( w \) being the wage income and \( \mu \) the non-labour income. For someone unemployed, income is \( b + \mu \), with \( b \) the unemployment income.

- **Job offer process**
  Job offers arrive according to a Poisson process with parameter \( (\alpha_{10} + \alpha_l's)\lambda_l, l = e, u \). The subscript \( l \) indicates that the arrival rate may be different for different labour market states (\( e= \) employment and \( u= \) unemployment); \( s \) is an \( S \)-dimensional vector of indicators of search intensity, possibly including different search instruments or channels; \( \lambda_l \) is the exogenously determined part of the arrival rate. In the empirical implementation, we assume that \( \lambda_l \) depends on individual characteristics: \( \lambda_l = \exp(\kappa_l'z) \), with \( \kappa_l \) a parameter vector and \( z \) is a vector of individual specific variables, related to demand side conditions. \( z \) does not contain an intercept. \( \alpha_l \) is an \( S \)-dimensional vector of parameters measuring the impact of the different search indicators on the arrival rate. Thus, the parameters \( \alpha_{10} \) and \( \alpha_l \) may be interpreted as ‘baseline’ parameters related to search, whereas \( \lambda_l \) is a factor describing individuals specific deviations from this baseline. The parameter \( \alpha_{10} \) is identified by the observations on nonsearchers, and by the fact that \( z \) does not contain an intercept. The parameter vector \( \alpha_l \) is identified by observations with different search behaviour, and \( \kappa_l \) (or \( \lambda_l \)) is identified by variation in individual characteristics. Note that \( \lambda_l \) affects marginal returns to search. A low value of \( \lambda_l \) generates low marginal returns to search, and therefore reduces the incentive to search. Thus, the parameter \( \lambda_l \) is related to the discouraged worker effect.

- **Cost of search**
  Individuals, searching for a job, are faced by cost of search, \( \alpha_l(s), l = e, u \). The cost

\(^5\) The same specification for within period utility was used by Narendranathan and Nickell (1985) and Van den Berg (1990).
function has the following properties:
\[
\begin{align*}
  c_i(s) &= \sum_{j=1}^S c_{ij}(s_j) \\
  c_{ij}(0) &= 0, j = 1, \ldots, S \\
  c_{ij}(s_j) &> 0, j = 1, \ldots, S \\
  c_{ij}'(s_j) &> 0, j = 1, \ldots, S
\end{align*}
\] (2.2)

The cost of search is assumed to be additive in the cost of the separate search indicators. The second and third conditions in (2.2) imply no search, no cost, and more search, higher cost, respectively. The condition on the second order derivatives ensures the existence of an optimal level of search intensity (convex search costs).

- **Wage offers, cost of turnover and layoff risk**

  The wage offer density function is \( f(w) \) with distribution function \( F(w) \). For job to job transitions there is a cost of turnover of \( k \). Moreover, the employed are faced by an exogenous layoff rate \( \sigma \).

- **Utility maximization**

  Individuals maximize the expected present value of utility minus cost of search. The rate of time preference is given by \( \rho \).

2.2 Implications of the model

**Reservation wage**

Let \( V \) denote the value function of an unemployed individual, and \( W(w) \) the value function of someone employed at wage \( w \). The reservation wage \( \xi \) is defined by \( W(\xi) = V \), the value of the wage for which the individual is indifferent between working and not working. For job to job transitions, the reservation wage \( \alpha(w) \) is defined by \( W(\alpha(w)) = W(w) + k \). At zero cost of turnover \( k \), \( \alpha(w) = w \), implying that any job with a wage that is higher than the current wage will be accepted. As this seems an unrealistic assumption, we allow for nonzero cost of turnover.

---

6 In the empirical specification we will assume cross restrictions between the parameters of the different terms \( c_{ij}(s_j) \) of the cost of search function.
Using the assumptions made in section 2.1, the reservation wage $\xi$ is implicitly defined by\textsuperscript{7}

\[
\omega u(\beta + \mu) - c_{\mu}(\mathbb{s}_n) + (\alpha_{s0} + \alpha_{s}s^*_n)\lambda_n \int_{\xi}^{\infty} [W(x) - W(\xi)]dF(x) =
\]
\[
u(\xi + \mu) - c_{\nu}(s^*_n(\xi)) + (\alpha_{e0} + \alpha_{es}s^*_n(\xi))\lambda_e \int_{\alpha(\xi)}^{\infty} [W(x) - W(\alpha(\xi))]dF(x) =
\]

(2.3)

In (2.3) $s^*_n$ denotes optimal search intensity for someone unemployed, and $s^*_e(w)$ denotes optimal search intensity for someone employed at wage $w$.

From the defining relation of $\alpha(w)$ it can be derived that

\[
\alpha'(w) = \frac{u'(w + \mu)}{u'(\alpha(w) + \mu)} \frac{\rho + \sigma + (\alpha_{s0} + \alpha_{es}s^*_e(\alpha(w)))\lambda_e \bar{F}(\alpha(\alpha(w)))}{\rho + \sigma + (\alpha_{e0} + \alpha_{es}s^*_e(\alpha(w)))\lambda_e \bar{F}(\alpha(\alpha(w)))}
\]

(2.4)

Van den Berg (1992) proposes to use a Taylor expansion around zero costs of turnover, making use of the relation $\alpha(w) = w \iff k = 0$.

Optimal search intensity

Optimal search intensity is the value of $s$ at which the marginal cost of search is equal to the marginal returns of search:

\[
\begin{align*}
\bar{c}_{\mu j}(\bar{s}_{2j}) &= \alpha_{\mu j} \lambda_n \int_{\xi}^{\infty} [W(x) - W(\xi)]dF(x) =: R_{\mu j} \\
s^*_{\mu j} &= \max \{0, \bar{s}_{\mu j}\}, j = 1, \ldots, S \\
\bar{c}_{\nu j}(\bar{s}_{\nu j}(w)) &= \alpha_{\nu j} \lambda_e \int_{\alpha(\nu j)}^{\infty} [W(x) - W(\alpha(w))]dF(x) =: R_{\nu j}(w) \\
s^*_{\nu j}(w) &= \max \{0, \bar{s}_{\nu j}(w)\}, j = 1, \ldots, S
\end{align*}
\]

(2.5)

Note that there is a negative relationship between the search intensity and the reservation wage. If the reservation wage is high enough, the individual decides not to search. As there is a positive relation between current income (earnings or benefit level, depending on someone's labour market state) and the reservation wage, there is a negative relation between current income and the decision to search.

In the empirical implementation, we approximate the integrand at the right hand side

\textsuperscript{7} The derivation is given in appendix B.
of (2.5) by

\[ \langle \rho + \sigma \rangle [W(x) - W(w)] \approx u(x + \mu) - u(w + \mu) \]  

(2.6)

3 The data

The data are from the Dutch Socio-Economic Panel (SEP), a household survey collected by Statistics Netherlands (CBS). In the SEP, detailed information on the search behaviour of individuals is available in the waves of October 1987, April 1988, and October 1988. Individuals, employed or unemployed in October 1987, are selected. The backward recurrence times of employment and unemployment spells can be determined from the survey information. The individuals selected are screened for changes in their labour market state up to April 1989, which is the end of the observation period. In addition, in April 1988 and October 1988, employment and unemployment spells are selected that have not yet been selected before. The sample thus obtained is a stock sample.

Various questions on search behaviour are asked to the survey respondents:

"Are you searching for a paid job at the moment, or if you already have a paid job, are you searching for a different one?"

Possible answers are: "Yes, I am searching seriously", "Yes, I am thinking about it", and "No".

If the respondent has answered positively to this first question, some additional questions have to be answered:

"Have you been looking for work in the past two months (yes/no)?"  

\footnote{Note that the integrand can be written as \( (\rho + \sigma) [W(x) - W(w)] = u(x + \mu) - u(w + \mu) - \left[ c_y(s_1^*(x)) - c_y(s_1^*(w)) \right] + \left[ (\alpha_0 + \alpha_0 s_1^*(x)) \lambda \int_{s_1^*(x)}^{s_1^*(w)} [W(x) - W(\alpha(x))] \frac{d\alpha(x)}{\alpha(x)} - (\alpha_0 + \alpha_0 s_1^*(w)) \lambda \int_{s_1^*(w)}^{s_1^*(x)} [W(x) - W(\alpha(x))] \frac{d\alpha(x)}{\alpha(x)} \right] \) If \( s_1^*(x) - s_1^*(w) \) is small, but not equal to zero, this expression can be approximated by: \( (\rho + \sigma) [W(x) - W(w)] \approx u(x + \mu) - u(w + \mu) + (s_1^*(x) - s_1^*(w)) \left[ -c_y(s_1^*(w)) + R_1(w) \right] \) The term between the brackets is the difference between the marginal cost of search and the marginal returns of search, which, in case of nonzero optimal search intensity, is zero. For the behaviour of the individual searcher it implies that the searcher still incorporates the search opportunities in the next job expected, but ignores the search opportunities of the job that may come after the next. Intuitively, it does not seem very restrictive to assume that the individual does not incorporate the search opportunities of a job that may arrive after a job that has not yet even arrived.

\footnote{"Looking for work" in this context means responding to an advertisement, placing an advertisement, gaining information from employers, relatives or the employment office, screening the advertisements etc.}
“How many times have you applied for a job in the past two months?”

“Are you registered at the employment office?”

For an individual with a positive intensity of search, four indicator variables \( \hat{s}_1, \hat{s}_2, \hat{s}_3 \) and \( \hat{s}_4 \) can be constructed:

\[
\hat{s}_1 = \begin{cases} 
1 & \text{if searching seriously} \\
0 & \text{if not}
\end{cases} \\
\hat{s}_2 = \begin{cases} 
1 & \text{if looking for work in the past two months} \\
0 & \text{if not}
\end{cases} \\
\hat{s}_3 = \begin{cases} 
1 & \text{if registered at the employment office} \\
0 & \text{if not}
\end{cases} \\
\hat{s}_4 = \text{number of applications in the past two months}^{11}
\] (3.1)

These four variables are indicators for the intensity of search. The information on labour market state and search can be used to distinguish four groups in the sample: Employed searchers, employed non-searchers, unemployed searchers, and unemployed non-searchers.

Table 1: Observed transitions

<table>
<thead>
<tr>
<th>.transitions rate in %</th>
<th>Employed</th>
<th>Unemployed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3266 observations</td>
<td>352 observations</td>
</tr>
<tr>
<td># observations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Searchers</td>
<td>500 (15%)</td>
<td>312 (89%)</td>
</tr>
<tr>
<td>Non-searchers</td>
<td>2766 (85%)</td>
<td>40 (11%)</td>
</tr>
<tr>
<td>Transitions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>into employment</td>
<td>127 (25%)</td>
<td>139 (45%)</td>
</tr>
<tr>
<td>into unemployment</td>
<td>20 (4%)</td>
<td>13 (33%)</td>
</tr>
</tbody>
</table>

Table 1 displays information about the numbers of observations and transitions in the sample. The percentage job-to-job transitions is higher among the employed searchers than among the employed non-searchers. A similar observation is made for the unemployed.

10 "Applying for a job" means writing a letter of application, making a phone call, etc.

11 Thus we obtain the number of applications per time unit. In measuring the number of applications per two months, it has to be accounted for the fact that individuals with a backward recurrence time of one month report applications per month, rather than per two months. We do this by rescaling the number of applications. Note that the procedure of rescaling can be justified if the number of applications in a given time interval are assumed to follow the Poisson distribution.

12 Job to job transitions for employed. The percentages in the table indicate the number of transitions as a percentage of the number of observations in the specific subgroup.
The figures 1 and 2 present Kaplan-Meier estimates of the survivor functions of the raw data, without correction for any source of heterogeneity. Neglected heterogeneity will bias downward any estimate of duration dependence.

Figure 1b is a graph of the Kaplan-Meier survivor function of unemployment duration, estimated with data on both searchers and non-searchers. Figure 1a show minus the logarithm of this survivor function, providing an estimate of the integrated hazard. The integrated hazard rises fast in the first ten months of unemployment duration. After 10 months, the slope of figure 1b gets smaller, indicating negative duration dependence, which may have been caused by neglected heterogeneity. Most transitions occur within three years. There are only eight transitions into employment of unemployed who have been unemployed for more than 48 months. These eight individuals are searchers. Figures 1c and 1d show the Kaplan-Meier survivor function and the integrated hazard for searchers only. As there are only 40 unemployed non-searchers, there is not much difference with the figures 1a and 1b. Finally, for completeness, figures 1e and 1f show the data for unemployed non-searchers. Due to the low number of observations, these graphs are hard to interpret.

Figures 2a and 2b show the Kaplan-Meier survivor function and its integrated hazard for job duration of both searchers and non-searchers. It can be seen that there is a strong negative duration dependency. In terms of the model this could be explained by the fact that once individuals have found a job with a satisfactory wage level, they stop searching for another job and stay employed. Another reason may be seniority: that may be approximated by age, due to which older workers have a lower probability to be laid off.

Figures 2c and 2d show employment duration of searchers only. The kink after 43 months is caused by the small number of transitions after 43 months, which is 5. The number of searchers with a duration longer than 43 months is only 24.

Finally, figures 2e and 2f show the employment data for non-searchers only. The pattern is similar to that of figures 2a and 2b.

Table 2 provides sample statistics of duration, weekly income, and background characteristics of employed and unemployed searchers and non-searchers. The mean of duration
is based on both completed and right hand censored spells. The mean of duration of unemployed nonsearchers is 8 months higher than the mean of unemployed searchers. The mean weekly benefit income of unemployed nonsearchers is higher than for unemployed searchers.

There is a considerable difference between the mean wage of employed searchers and the mean wage of employed nonsearchers. The mean wage of searchers is lower than the mean wage of nonsearchers, which is in accordance with the theoretical model in the previous section, which predicts a negative relation between the current wage and the decision to search.

Available background characteristics are age, four education dummies for the level of education, educ1, educ2, educ3 and educ4, with educ1 the lowest level of education (the highest level, educ5, serves as reference group), three sectoral dummies, sec1, sec2 and sec3, the regional dummies region1, region2 and region3, and a dummy for marital status which is one if married and zero if not. Sec1 is a dummy for education in the technical sector which includes chemistry, physics, mathematics and biology, sec2 refers to economic and administrative education, sec3 is general education and the fourth sector, which serves as reference sector and is not included as a dummy, is the service sector. Region1 is a dummy for the strongly industrialized western part of the Netherlands, Region2 is the east in which there is a mixture of industry and agriculture, Region3 is the south of the Netherlands with some larger companies and agricultural industry and the fourth region, which is the region of reference for which no dummy variable is included, is the remaining part with a sizeable agricultural sector. Note that the mean age for searchers is lower than for non-searchers in both labour market states. Non-labour income includes child care benefits, interest income, income received out of renting rooms, and a rest category.
### Table 2 Sample statistics

<table>
<thead>
<tr>
<th>Employed (n=3266)</th>
<th>Searchers (n=500)</th>
<th>Nonsearchers (n=2766)</th>
</tr>
</thead>
<tbody>
<tr>
<td>variable</td>
<td>mean</td>
<td>std. dev.</td>
</tr>
<tr>
<td>age</td>
<td>32</td>
<td>7.8</td>
</tr>
<tr>
<td>family size (persons)</td>
<td>3.2</td>
<td>1.3</td>
</tr>
<tr>
<td>wage (guilders/week)</td>
<td>517.6</td>
<td>233.2</td>
</tr>
<tr>
<td>non-labour income (guilders/week)</td>
<td>15.3</td>
<td>53.5</td>
</tr>
<tr>
<td>positive non-labour income (guilders/week)</td>
<td>45.3</td>
<td>84.4</td>
</tr>
<tr>
<td>duration (months)</td>
<td>19.0</td>
<td>13.1</td>
</tr>
<tr>
<td>education level</td>
<td>mode 3</td>
<td></td>
</tr>
<tr>
<td>Dutch nationality</td>
<td>96.6%</td>
<td></td>
</tr>
<tr>
<td>region 1 (industrialized west)</td>
<td>44.4%</td>
<td></td>
</tr>
<tr>
<td>region 2 (east)</td>
<td>24.8%</td>
<td></td>
</tr>
<tr>
<td>region 3 (south)</td>
<td>20.8%</td>
<td></td>
</tr>
<tr>
<td>region 4 (agricultural)</td>
<td>10.0%</td>
<td></td>
</tr>
<tr>
<td>married</td>
<td>65.6%</td>
<td></td>
</tr>
<tr>
<td>sector of education 1 (technical)</td>
<td>28.6%</td>
<td></td>
</tr>
<tr>
<td>sector of education 2 (economic/administrative)</td>
<td>17.4%</td>
<td></td>
</tr>
<tr>
<td>sector of education 3 (no specialization)</td>
<td>27.6%</td>
<td></td>
</tr>
<tr>
<td>sector of education 4 (services)</td>
<td>23.4%</td>
<td></td>
</tr>
<tr>
<td>Unemployed (n=352)</td>
<td>Searchers (n=312)</td>
<td>Nonsearchers (n=40)</td>
</tr>
<tr>
<td>variable</td>
<td>mean</td>
<td>std. dev.</td>
</tr>
<tr>
<td>age</td>
<td>31</td>
<td>11.7</td>
</tr>
<tr>
<td>family size (persons)</td>
<td>3.0</td>
<td>1.6</td>
</tr>
<tr>
<td>benefit income (guilders/week)</td>
<td>150.5</td>
<td>164.2</td>
</tr>
<tr>
<td>positive benefit income (guilders/week)</td>
<td>284.7</td>
<td>112.8</td>
</tr>
<tr>
<td>non-labour income (guilders/week)</td>
<td>37.1</td>
<td>107.5</td>
</tr>
<tr>
<td>positive non-labour income (guilders/week)</td>
<td>146.4</td>
<td>172.9</td>
</tr>
<tr>
<td>duration (months)</td>
<td>27.1</td>
<td>27.2</td>
</tr>
<tr>
<td>education level</td>
<td>mode 1</td>
<td></td>
</tr>
<tr>
<td>Dutch nationality</td>
<td>92.3%</td>
<td></td>
</tr>
<tr>
<td>region 1 (industrialized west)</td>
<td>37.2%</td>
<td></td>
</tr>
<tr>
<td>region 2 (east)</td>
<td>27.9%</td>
<td></td>
</tr>
<tr>
<td>region 3 (south)</td>
<td>23.4%</td>
<td></td>
</tr>
<tr>
<td>region 4 (agricultural)</td>
<td>11.5%</td>
<td></td>
</tr>
<tr>
<td>married</td>
<td>35.5%</td>
<td></td>
</tr>
<tr>
<td>sector of education 1 (technical)</td>
<td>24.4%</td>
<td></td>
</tr>
<tr>
<td>sector of education 2 (economic/administrative)</td>
<td>10.6%</td>
<td></td>
</tr>
<tr>
<td>sector of education 3 (no specialization)</td>
<td>52.5%</td>
<td></td>
</tr>
<tr>
<td>sector of education 4 (services)</td>
<td>11.2%</td>
<td></td>
</tr>
</tbody>
</table>
Table 3 Sample statistics search indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Employed</th>
<th>Unemployed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>500 obs</td>
<td>312 obs</td>
</tr>
<tr>
<td></td>
<td>sample freq</td>
<td>sample freq</td>
</tr>
<tr>
<td>Searching seriously</td>
<td>47.8%</td>
<td>81.8%</td>
</tr>
<tr>
<td>Looking for work</td>
<td>74.6%</td>
<td>78.2%</td>
</tr>
<tr>
<td>Registered at employment office</td>
<td>0%</td>
<td>77.6%</td>
</tr>
<tr>
<td># applications past 2 months &gt; 0</td>
<td>56.5%</td>
<td>64.1%</td>
</tr>
<tr>
<td># applications past 2 months = 1</td>
<td>25.6%</td>
<td>16.3%</td>
</tr>
<tr>
<td># applications past 2 months = 2</td>
<td>13.4%</td>
<td>11.5%</td>
</tr>
<tr>
<td># applications past 2 months = 3</td>
<td>5.4%</td>
<td>9.3%</td>
</tr>
<tr>
<td># applications past 2 months = 4</td>
<td>3.8%</td>
<td>7.1%</td>
</tr>
<tr>
<td># applications past 2 months &gt;= 5</td>
<td>7.5%</td>
<td>19.9%</td>
</tr>
</tbody>
</table>

Table 3 contains information about the indicators of search. As the indicators of search are only applicable to the searchers, the information in Table 4 refers to the subsample of searchers. From the 500 employed searchers, 47.8% reports to be “searching seriously”. The percentage of them who is “looking for work”, in the way defined before, is 74.6%. None of the employed searchers is registered at the employment office. Among the group of employed searchers 56.5% has actually been applying for a job in the past two months. A large part of them (25.6%) has been applying for a job only once, whereas 13.4% applied twice. Among the subsample of 312 unemployed searchers, 81.8% reports to be “searching seriously”. This is obviously a higher percentage than we found for the employed searchers. The remaining search indicators also show that the unemployed search more intensely than the employed: 78.2% is “looking for work”, whereas 64.1% has been applying for a job in the past two months.

4 Empirical analysis

In this section we describe the empirical implementation of the search model. In section 4.1 we specify the cost of search function, and we describe how we make the connection between the observed search indicators and the (latent) optimal search intensity. In section 4.2 we specify the likelihood contributions. In section 4.3 the results of estimation will be presented. In section 4.4 we present the outcomes in terms of elasticities and section 4.5 discusses the fit of the model.

The parameters of the wage offer distribution are estimated separately. A log-normal
wage distribution is specified. To correct for selectivity, the wage parameters are estimated jointly with an equation for participation, and an equation for search.

In the literature on structural job search models, several examples can be found of separate estimation of the wage offer parameters. (Van den Berg (1990), Narendranathan and Nickell (1985)). Joint estimation requires the specification of additional stochastic structure on the model and complicates the estimation and computational burden considerably. An example of the joint estimation of wage offer parameters and other structural parameters can be found in Bloemen (1997). Narendranathan and Nickell (1985) actually defend the method of separate estimation as it does not impose too much structure on the data. Details of the estimation of the wage offer distribution can be found in appendix A.

In the second step, estimates of arrival rates and cost of search parameters are obtained, using the information on duration and search intensity. This step is described below.

4.1 Specification

The following cost of search function is specified:13

\[
\begin{align*}
    c_l(s) &= \sum_{j=1}^{4} c_{lj}(s_j), l = e, u \\
    c_{lj}(s_j) &= \gamma_{0l,j} C_{lj} \left[ \exp \left( \frac{s_j}{\gamma_{u,l,j}} \right) - 1 \right] 
\end{align*}
\]  

(4.1)

in which \( \gamma_{0l,j}, l = e, u \) are parameters. Note that (4.1) satisfies (2.2) if \( \gamma_{u,l,j} > 0 \) and \( C_{lj} > 0 \). The cost function (4.1) is made dependent on a vector \( q \) with individual characteristics by specifying

\[
    C_{lj} = \exp \left( -\frac{\gamma_{ij} q}{\gamma_{0l,j}} \right) 
\]  

(4.2)

The solution to the first order conditions for optimal search intensity is

\[
\begin{align*}
    \bar{s}_{uj} &= \gamma_{uj} q + \gamma_{0u,j} \ln R_{uj} \\
    \bar{s}_{ej}(w) &= \gamma_{ej} q + \gamma_{0e,j} \ln R_{ej}(w)
\end{align*}
\]  

(4.3)

in which \( R_{uj} \) and \( R_{ej}(w) \) represent the marginal returns of search defined in (2.5).

---

13 Note that for the employed there are only three search indicators, since none of the employed is registered at the employment office. We stick to the notation introduced in (3.1) where the fourth indicator denotes the number of applications.
The theoretical concept of search intensity, i.e. the outcome of the first order conditions (4.3), needs to be linked to the information on search intensity in the dataset (3.1). In the data there are two types of indicators: (i) dichotomous indicators, and (ii) a count variable (# of applications). Let \( \epsilon_{lj}, l = e, u \) denote random errors, and let \( \tilde{s}_{lj}, j = e, u \) one of the dichotomous search indicators, then we define the following relation:

\[
\begin{align*}
\tilde{s}_{lj} & = 1 \quad \text{if} \quad \tilde{s}_{lj} := \tilde{s}_{lj} + \epsilon_{lj} > 0 \\
& = 0 \quad \text{if} \quad \tilde{s}_{lj} := \tilde{s}_{lj} + \epsilon_{lj} \leq 0 \\
\tilde{s}_{ej} & = 1 \quad \text{if} \quad \tilde{s}_{ej}(w) + \epsilon_{ej} > 0 \\
& = 0 \quad \text{if} \quad \tilde{s}_{ej}(w) + \epsilon_{ej} \leq 0 
\end{align*}
\] (4.4)

For future reference, we define:

\[
\tilde{s}^*_{lj} = \max\{0, \tilde{s}_{lj}\} \\
\tilde{s}^*_{ej} = \max\{0, \tilde{s}_{ej}\}
\] (4.5)

For the observed number of applications, \( \tilde{s}_{lj}, l = e, u \), we make some additional assumptions. We assume that the number of applications enters the arrical rate in a logarithmic transformation: as one plus the number of applications.\(^{14}\) Now let \( \tilde{s}^*_l \) be defined as in (4.5) and let \( \tilde{s}^*_M \) be defined by \( \tilde{s}^*_M = \ln(1 + \tilde{s}^*_M) \), so \( \tilde{s}^*_M \) represents the optimal (latent) number of job offers in terms of the level, whereas \( \tilde{s}^*_l \) represents the logarithmic transformation. Expressing \( \tilde{s}^*_M \) in terms of \( \tilde{s}^*_l \) we get the optimal number of job offers \( \tilde{s}^*_l = \exp(\tilde{s}^*_l) - 1, l = e, u \). At this point we introduce a distinction in the stochastic specification of the number of applications for individuals who do search and individuals who do not. For individuals who do not search the observed number of applications is always zero. The likelihood contribution for these individuals will be the probability that \( \tilde{s}^*_M = 0 \) (or, equivalently, \( \tilde{s}^*_l \leq 0 \)). For individuals who search, we assume that \( \tilde{s}^*_l > 0 \). In addition, we assume that for searchers the observed number of job offers \( \tilde{s}_{lj} \) (conditional on \( \tilde{s}^*_l > 0 \)) follows a Poisson process with parameter \( \tilde{s}^*_l > 0 \):

\[
P(\tilde{s}_{lj}|\tilde{s}^*_l > 0) = \frac{[\tilde{s}^*_l]^{\tilde{s}_{lj}} \exp(-\tilde{s}^*_l)}{\tilde{s}_{lj}!}, l = e, u
\] (4.6)

Note that the condition \( \tilde{s}^*_l > 0 \) (or, equivalently, \( \tilde{s}^*_l > 0 \)) ensures that the parameter of the Poisson distribution is positive. Note that the difference in the specification

\(^{14}\) Note that this assumption implies that marginal returns of search are decreasing in the number of applications, so 100 applications in two months does not lead to ten times as many job offers as 10 applications in the same period.
for searchers and nonsearchers provides a natural distinction between observing zero applications because someone is not searching (the optimal search intensity is zero), and observing zero applications for someone searching (optimal search intensity is positive, but zero applications occurred according to the Poisson distribution).

For the utility function \( u(x) \) a linear specification is chosen. Combining a linear specification with (2.1) gives:

\[
\text{utility}(\text{income}=x, \text{state}=\text{employed}) = x \\
\text{utility}(\text{income}=x, \text{state}=\text{unemployed}) = \omega x
\]  

(4.7)

The cost of turnover may be parametrized as:

\[ k = \delta^'c \]  

(4.8)

in which \( \delta \) is a parameter vector and \( c \) is a vector of individual characteristics. \( \lambda_u \) and \( \lambda_e \) will be parametrized by

\[
\lambda_u = \exp(\kappa_u^'z) \\
\lambda_e = \exp(\kappa_e^'z)
\]  

(4.9)

in which \( z \) is a vector of individual characteristics and \( \kappa_u \) and \( \kappa_e \) are parameter vectors.

In a similar way, the layoff rate \( \sigma \) can be made dependent on individual characteristics by the parameterization

\[ \sigma = \exp(\zeta^'m) \]  

(4.10)

To restrict the number of parameters we assume that

\[
\gamma_{uj} = \vartheta_{uj} \gamma_u, \vartheta_{u1} = 1, j = 1, 2, 3, 4 \\
\gamma_{ej} = \vartheta_{ej} \gamma_e, \vartheta_{e1} = 1, j = 1, 2, 3, 4
\]  

(4.11)

where \( \vartheta_{uj} \) and \( \vartheta_{ej} \) are scalars.

### 4.2 Estimation

The model parameters are estimated by the method of simulated maximum likelihood. The individual likelihood contributions consist of three parts: (i) the density functions of unemployment duration \( (t_u) \) and job duration \( (t_e) \), conditional on the value of the (latent) search intensity \( \tilde{s}_u^l, l = e, u \) (defined in (4.4)); (ii) the density function of the latent search intensity \( \tilde{s}_u^l, l = e, u \); (iii) the Poisson distribution for the observed number of applications (defined in (4.5)).
(i) Denoting transition intensities for transitions from unemployment into employment by $\theta_{ue}(s_u^*)$ and job to job transitions by $\theta_{ee}(s_e^*)$ we have:

$$
\theta_{ue}(s_u^*) = (\alpha_{u0} + \alpha_{u} s_u^*) \lambda_u \bar{F}(\xi) \\
\theta_{ee}(s_e^*) = (\alpha_{e0} + \alpha_{e} s_e^*) \lambda_e \bar{F}(\alpha(w))
$$

(4.12) (4.13)

The density functions of unemployment duration and job duration, conditional on search intensity and wages, are

$$
f_u(\tilde{s}_u|s_u^*) = \frac{\theta_{ue}(s_u^*) \exp\{-\theta_{ue}(s_u^*) t_u\}}{0 < t_u < \infty} \\
f_e(\tilde{s}_e|s_e^*) = \frac{\theta_{ee}(s_e^*) \exp\{-((\theta_{ee}(s_e^*) + \sigma) t_e\}}{0 < t_e < \infty} \\
f_e(\tilde{s}_e|s_e^*) = \frac{\exp\{-((\theta_{ee}(s_e^*) + \sigma) t_e\}}{0 < t_e < \infty}
$$

(4.14)

(ii) To define the density of $\tilde{s}_i^*, l = e, u$, we first specify the density function of $\tilde{s}_i, l = e, u$, defined in (4.4). It is assumed that $\epsilon_l, l = e, u$ in (4.4) follows a normal distribution:

$$
\epsilon_l \sim N(0, \Sigma_i), l = e, u
$$

(4.15)

The definition of $\tilde{s}_i, l = e, u$ and the assumption (4.15) implicitly define the density function of $\tilde{s}_i, l = e, u$ which we denote by $g(\tilde{s}_i; \Sigma_i), l = e, u$. The function $g(\tilde{s}_i; \Sigma_i), l = e, u$ defines the distribution of $\tilde{s}_i^*, l = e, u$ in (4.5).

(iii) The Poisson distribution of the observed number of job offers for searchers is given in (4.6):

$$
P(\tilde{s}_{il}|s_{il}^* > 0)
$$

(4.16)

The final step in the construction of the likelihood contributions is the multiplication of the parts defined in steps (i) to (iii), and integrating over the vector $\tilde{s}_i, l = e, u$ of latent search intensity. The region of integration, $A(\tilde{s}_i)$, is defined by the observed vector of search indicators $\tilde{s}_i, l = e, u$, combined with the definitions in (4.3) and (4.4). The following likelihood contributions are obtained: For searchers we have

$$
\int_{A(\tilde{s}_i)} f_i(\tilde{s}_i|s_i) g(\tilde{s}_i; \Sigma_i) P(\tilde{s}_{il}|s_{il}^* > 0) d\tilde{s}_i, l = e, u
$$

(4.17)
Note that in (4.17) the integration for the fourth search indicator (the number of applications) is over all positive values of $\tilde{s}_{it}$. For nonsearchers, the likelihood contribution is

$$
\int_{A_{it}} f(t|\tilde{s}_i^* \Sigma_i) d\tilde{s}_i, l = e, u
$$

(4.18)

In (4.18) integration for the fourth search indicator (the number of applications) is over all negative values of $\tilde{s}_{it}$, whereas $\tilde{s}_{it}^* = 0$ for all nonsearchers.

To evaluate the likelihood contribution, we need to calculate three and four dimensional integrals of normally distributed random variables. This problem can be handled by using the smooth recursive conditioning algorithm (SRC) for simulating multidimensional integrals over normally distributed random variables and applying simulated maximum likelihood (SML) as described in Börsch-Supan and Hajivassiliou (1993).

To allow for the fact that the available data on duration is a stock sample, we condition on backward recurrence times (cf. e.g. Lancaster (1979), Ridder (1984)). The derivation of the joint density of duration and search intensity, conditional on backward recurrence times is given in appendix B.

The reservation wage for unemployed individuals can be calculated by solving $\xi$ from the implicit equation (2.3). For employed individuals, the reservation wage $\alpha(u)$ is calculated by means of a Taylor approximation, as proposed by Van den Berg (1992).

The parameters $\alpha, \kappa, \lambda, \gamma, \gamma, \gamma_0, \gamma_0, \omega, \sigma$ and $k$ will be obtained by the (simulated) maximum likelihood principle.

### 4.3 Estimation results

In this section we present the estimation results. From the tables it follows which variables we included in the various parts of the model.

The estimation results of the structural model are reported in the tables 4.1 through 4.4. The rate of time preference $\rho$ has been fixed, such that on a yearly basis the discount rate is 5%. In the simulated maximum likelihood procedure we use 60 replications from the joint error distribution of the search indicators to simulate the integrals in (4.17) and (4.18). In the tables a double (single) asterisk indicates significance at the 5% (10%) level.
Table 4.1 contains the parameter estimates of the job offer arrival rates and the layoff rate. For the unemployed, the exogenous part of the job offer arrival rate, \( \lambda_u \), is decreasing in age. Recall (see table 2) that the mean age of unemployed nonsearchers is higher than the mean age of unemployed searchers. A lower value of \( \lambda_u \) for unemployed individuals with a higher age implies lower returns to search (everything else being equal) for older unemployed, and therefore a disincentive to search. Individuals that only followed a general type of education (sec 3) have the lowest arrival rate. Also for the employed individuals \( \lambda_e \) is decreasing in age. Individuals with the highest level of education (sec 3) have the highest value of the arrival rate \( \lambda_e \). Moreover, in the Western, more industrialized region of the Netherlands, individuals have higher arrival rates. The layoff rate decreases with age until the age of 42, after which it increases. Individuals in the economic and administrative sector have the highest layoff rate. The layoff rate is highest in the more agricultural regions of the Netherlands, whereas individuals with the lower levels of education tend to have the higher layoff rates.

The lower part of table 4.1 contains the coefficient estimates of the various search indicators in the job offer arrival rate. For both the unemployed and the employed the number of applications has the largest impact on the arrival rate, compared to the other search indicators. Moreover, the effect of the number of applications is significant for both labour market states. For the unemployed, the search attitude ("searching seriously") also is significant. The remaining indicators do not have a significant coefficient estimate. This indicates that e.g., screening alone, without taking any further action, does not significantly affect the job offer probability. Note, however, that there are significant correlations between the errors of the different search indicators (table 4.4).

Table 4.2 shows the parameters of the cost of search function. Recall that a parameter \( \gamma_j \) has a negative impact on the marginal cost of search and consequently a positive impact on the optimal search intensity. For the unemployed we do not find significant variation in the cost of search for different values of the observed characteristics included. This may be a reflection of the fact that cost for search is low for someone unemployed anyhow, irrespective of the individual's background. The parameter estimate of \( \gamma_{u,\cdot,j} \), \( j = 1, \ldots, 4 \) is significant for all of the four search indicators. This parameter measures the
impact of returns to search on the optimal search intensity. Apparently the returns to search are important in determining optimal search intensity. For the employed family size influences the cost of search negatively. Having a larger family may be a motivation to search for a better job. Marital status has a significant positive impact on the cost of search. The cost of search decreases with age until the age of 32 after which the cost of search increase. For the employed, we see that returns to search significantly affect the optimal number of applications (parameter $\gamma_{0eA}$). If we compare the cost of search functions between the unemployed and employed we may conclude that for the unemployed the emphasis is more on the returns to search, whereas for the employed the cost of search play a more dominant role in the determination of optimal search intensity and in taking the search decision.

Table 4.3 shows that the cost of turnover is significantly increasing in age. The estimate of the utility parameter $\omega$ (see table 4.3) is lower than one, but it is not significantly different from one, which means that we cannot say that utility levels are different for two different labour market states. The size of the estimate (0.75) is quite close to that found in Van den Berg (1990) for a similar specification of utility.

Finally, table 4.4 shows the parameter estimates of the variance-covariance matrix. The covariance of the errors of the various search indicators are positive and significant. It shows that it is important not to ignore (for the sake of a simpler estimation method) the covariance between the errors associated with the different search indicators.

4.4 Elasticities

Up till now we have only looked at the separate coefficient estimates. In order to gain more insight in the implications of the model we computed several elasticities. Analytic expressions for the elasticities are presented in appendix D. The elasticities have been evaluated in the mean values of the observed characteristics of searchers and nonsearchers.
The computed values of various elasticities are shown in table 5. The computed values of various elasticities are shown in table 5.16

For the unemployed we computed the impact of the benefit level on the reservation wage. This quantifies the impact on of the benefit level on the decision to accept or reject a job. The elasticity of the reservation wage with respect to the benefit level is higher if it is evaluated in the mean characteristics of the nonsearchers than if it is evaluated in the mean characteristics of searchers. This suggests that the job acceptance decision of nonsearchers is more sensitive to a change in the benefit level than that of searchers. This can be explained once we note that the mean age of nonsearchers (see table 2) is considerably higher than the mean age of searchers. Arrival rates (through $\lambda_r$ and $\lambda_i$) at this higher age are lower, whereas the layoff rate is higher. Consequently, in the computation of the reservation wage, the future (through the value of the expected job offers) obtains less weight at higher ages, whereas the present (i.e., the benefit level) becomes more dominant. Apparently, unwillingness to accept a job is not the reason for being a non-searcher. More insight in this distinction between nonsearchers and searchers is obtained once we look at the next elasticity.

For the unemployed it is interesting to consider the effect of an increase in the benefit level on search. We present the elasticity for the number of applications, since this is the search indicator that can be directly observed and therefore is the easiest to interpret. The computation of the elasticity is based on (D.3) in appendix D. We evaluate the elasticity in the (simulated) mean level of the Poisson distribution. The elasticity of the (mean) number of applications with respect to the benefit level is -0.0045 in the characteristics of nonsearchers and -0.0096 in the characteristics of searchers. Thus, the

\[ \frac{\partial P}{\partial \beta} \]

(see table 2).15

15 For the dummy variables we chose the service sector, education level 3, and region 1. To compute the elasticities we simulated the (latent) levels of a search indicator by generating 60 replications from the joint distribution of the (latent) search indicators. If a generated search indicator is negative, it represents a corner solution of the marginal cost equals marginal returns of search condition. In this case, the simulated optimal level of search is zero. For each replication the elasticity is computed. The elasticities reported here are the average over replications.

16 Standard errors have been computed to account for variation in the elasticities that is due to variation around the estimated parameter values. The variance has been computed by simulation: 1000 parameter vectors have been drawn from the asymptotic distribution of the estimator, generating 1000 values for the elasticities of which the standard deviation has been computed. Note that most of the elasticities are not estimated precisely. The elasticity of the hazard with respect to the number of applications has been estimated significantly. The large number of parameters (82) adds to the imprecision of the estimated elasticities if the variance is computed in the way we did. In the sequel, we will not comment any further on the precision of the elasticity estimates.
number of applications is more sensitive with respect to the benefit level for someone with the mean characteristics of searchers.

We can also compute the elasticity of the probability that it is optimal to apply for a job (i.e. the \( P(\tilde{s}_4 > 0) \)) with respect to the benefit level. This elasticity takes the value of -0.0010 for someone with the mean characteristics of nonsearchers and -0.0098 for someone with the mean characteristics of searchers.

The decision to search and the optimal search intensity are apparently more sensitive to the benefit level for the mean searcher than for the mean nonsearcher. This can be explained again by the decrease in the arrival \( \lambda_u \) with age. For this reason expected returns to search are low for the mean nonsearcher. Consequently, a discouraged worker effect shows up. This discouraged worker effect reduces the impact of the benefit level on the search decision and on search intensity. This may indicate that the main problem of the nonsearchers is discouragement, and not unwillingness to accept a job.

To quantify the effectiveness of the number of applications on the intensity of search, we compute the elasticity of the hazard with respect to the (mean) number of applications, leaving the job acceptance probability constant. Note that this shows a partial effect only. The intensity of search and the reservation wage are simultaneously determined, and therefore a change in the mean number of applications and the acceptance probability will always go together. The value of the elasticity, however, provides insight in the effectiveness of search. We find that a 10\% increase in the number of applications leads to an increase of 6\% in the hazard for someone with the mean characteristics of a nonsearcher and an increase of 4.8\% for someone with the mean characteristics of a searcher. Note that this is a ceteris paribus effect, for a given value of \( \lambda_u \): ceteris paribus, it even seems that search is somewhat more effective for someone with the characteristics of the mean nonsearcher. But returns to search are low to the nonsearcher, due to unfavourable demand side conditions, characterized by \( \lambda_u \).

The total elasticity of the hazard with respect to the benefit level is -0.09 for the mean nonsearcher and -0.045 for the mean searcher. So even though optimal search and the search decision are less sensitive to a change in the benefit level for someone with the mean characteristics of a nonsearcher, the hazard rate is more sensitive, due to the
higher sensitivity of the acceptance decision.

To further quantify the discouraged worker effect we also computed the elasticity of the optimal number of applications with respect to the exogenous part of the arrival rate \( \lambda_u \). The elasticity takes the value 0.15 in the mean characteristics of nonsearchers and the value 0.070 in the mean characteristics of the searchers. This suggests that nonsearchers are stimulated relatively more by an increase in \( \lambda_u \) than searchers. This is just another way of showing that the more effective way to stimulate nonsearchers to search is to improve their labour marker opportunities,\(^{17}\) rather than to decrease the benefit level.

For employed individuals we computed the elasticity of the number of applications with respect to the wage. We find a value of -0.017 if we evaluate the elasticity in the mean characteristics of nonsearchers and a value of -0.38 if the elasticity is evaluated in the mean characteristics of searchers. Apparently searchers are still sensitive to higher wages and consequently show a larger response in the number of applications. The nonsearchers may already have reached wage levels they are satisfied with. For them, the cost of search is more dominant.

To quantify the effectiveness of the number of applications, we computed the elasticity of the job-to-job transition intensity, leaving reservation wage constant. The elasticity takes the value 0.36 and 0.39 for someone with the mean characteristics of nonsearchers and searchers, respectively. Ceteris paribus there is not much difference in the effectiveness of search of the mean nonsearcher and the mean searcher. This show again that differences in marginal cost of search and expected returns to search between searchers and nonsearchers determine the decision to search.

4.5 Residual analysis

In the structural modeling of duration data, usually a lot of structure is imposed on the data, both by the imposition of economic theory and by the choice of functional forms. The strength of a structural model is that it enables us to distangle things like

\(^{17}\) This may e.g. be achieved by schooling: table 4.1 showed that individuals with only general (nonspecialized) type of education have a significantly lower arrival rate, given everything else.
cost of search, returns to search, arrival rates, the discouraged worker effect and the acceptance decision. All this makes a structural model a good point of departure for evaluating policy measures. However, because of the structure imposed, the fit of the duration data in structural models usually leaves much to be desired. For this reason studies in which structural search models are used usually do not provide any analysis for the goodness-of-fit of the duration data.\footnote{A notable exception is Bloemen (1997).} We will present the Kaplan-Meier estimates of the generalized residuals of the model. One of the stronger assumptions that is imposed is the stationarity\footnote{Introducing nonstationarity in the model is technically complicated and numerically burdensome, see e.g. Van den Berg (1990). Moreover, the question is whether it is desirable in the context of a structural model to make, say the arrival rate, a function of time, whereas we may prefer to explain duration dependence in a structural model.} of the search model, which implies the absence of duration dependence of the various transition intensities. Plotting the Kaplan-Meier estimates of the distribution of the generalized residuals can provide us insight in the direction and the degree of the possible duration dependence. This may give us further insight in the search process, may enable us to predict the direction of possible biases in the estimates and may provide suggestions for future extensions of the model. Appendix E comments on the computation of the generalized residuals. The generalized residuals follow an exponential distribution with parameter 1, if the model is correctly specified; neglected sources of heterogeneity or neglected duration dependence will show deviations from this exponential distribution. It should be noted that neglected heterogeneity cannot be distinguished from neglected negative duration dependence.

The dotted line in figure 3a shows the Kaplan-Meier estimate of the distribution function of the residuals for the unemployed individuals. The straight line shows the exponential distribution function with parameter 1. The distribution of the residual is clearly above the exponential distribution, showing neglected negative duration dependence or neglected heterogeneity.

Figure 3b shows the Kaplan-Meier estimate of the distribution of the generalized residuals of the employed. The difference with the exponential distribution is very large. From table 2 it was clear that the job duration of employed nonsearchers can be very large: a stationary exponential distribution, like we use in the modeling, apparently cannot be
consistent with this, these low turnover rates and high survivor probabilities at higher levels of duration.

Note that the sample we use is largely a stock sample. In the estimation we allowed for that by conditioning on backward recurrence times. Another way to look at residuals is to split up duration in forward recurrence times and backward recurrence time. Since we conditioned on backward recurrence times, we actually have explained the forward recurrence times, given survival during a period with as length the backward recurrence time. Under the null hypothesis that model is specified correctly, the residuals based on forward recurrence times and on backward recurrence times each follow an exponential distribution with parameter 1.

The figures 4a and 4b show the Kaplan-Meier estimates based on the forward recurrence times for the unemployed and the employed respectively. The distribution of the residuals based on forward recurrence times of the unemployed follows the exponential distribution reasonably close, expect for a few outliers. For the employed, a comparison of the distribution of residuals based on forward recurrence times with the exponential distribution is much better than based on total duration, but the difference between the two distributions still is evident.

Figures 5a and 5b show the Kaplan-Meier estimates of the distribution of the residuals based on backward recurrence times for the unemployed and employed, respectively. The plots are very similar to figures 3a and 3b. This suggests that the model reasonably manages to fit transitions (i.e., fit the forward recurrence times), especially for the unemployed, given that one belongs to the stock of a given labour market state, but that the probability of being in that labour market state is not fitted well, due to negative duration dependence, which is in particular strong for the employed.

Finally, figures 6a and 6b show the Kaplan-Meier estimates of the residuals of the employed (based on total duration) for employed searchers and employed nonsearchers separately. For the searchers (figure 6a), we do better than the total plot in figure 3b: the distribution function of the residual is closer to the exponential distribution, but it is still too far away from it. For the nonsearchers (figure 6b), the estimate of the distribution function is evidently worse than in figure 3b. Given that the employed nonsearchers
form the waste majority of the sample of employed, the difference between figures 6b and 3b show that introducing the distinction between searchers and nonsearchers among the employed clearly adds to the explanation of the duration of employment. However, introducing search alone is not sufficient to explain the low turnover rates at higher durations.

5 Conclusions

We have specified an empirical version of the search model of Mortensen (1986), in which the intensity of search is a choice variable for the individual. A higher level of search intensity increases the job offer arrival rate, but at the same time cost of search rises. The individual chooses the intensity of search on the basis of a comparison of marginal returns of search with marginal cost of search. If the marginal returns to search are to high relative to the marginal cost of search, the individual will decide not to search. We extended the Mortensen (1986) framework to allow for differences in arrival rates and difference in the cost of search between the state of employment and the state of unemployment. Moreover, for the employed we allow for a nonzero cost of turnover. If cost of turnover is zero, the reservation wage in the employment state is equal to the present wage. A positive turnover cost raises the reservation wage in the employment state.

We use data on male individuals from the Dutch Socio Economic Panel (Statistics Netherlands). The dataset contains three dichotomous indicators for the intensity of search (search attitude, screening or not, registered at employment office) as well as information on the number of applications. In the empirical specification the observed indicators of search are linked to the optimal search intensity derived from the economic model. To deal with the integration over the latent variables and to allow for correlation in the stochastic structure of the different search indicators we employ the method of simulated maximum likelihood to estimate the model parameters.

Transition intensities for transitions from unemployment to employment and for job to job transitions are specified as the product of a job offer arrival rate and a job acceptance
probability. Moreover, we allow for an exogenous layoff rate. Information on wages is used to estimate the parameters of the wage offer distribution. With information on duration and search intensity we estimate the cost of search parameters and the parameters of the job offer arrival rate.

For the unemployed we find that the job offer arrival rate decreases with age. This turns out to be an important result for the interpretation of the difference between unemployed searchers and unemployed nonsearchers: the mean age of unemployed nonsearchers in considerably higher than the mean age of unemployed searchers. The unemployed that have had only general (no specialized) education also have lower job offer arrival rates.

The number of applications of the unemployed affects the arrival rate significantly, as does the search attitude. Screening and being registered at the employment office are not found to have a significant effect on the arrival rate.

For the unemployed we find no significant variation in the cost of search with the observed covariates that have been included. It seems that the returns of search are more important in the determination of optimal search intensity.

Also for the employed we find that arrival rates decrease with age (for a given level of search intensity). Employed individuals with the highest level of education have higher arrival rates. The layoff rate first decreases with age, but rises with age for individuals who are older than 42. Individuals with the lower levels of education have the highest layoff rates.

The number of applications is the most effective search indicator for the employed. Screening and attitude do not show a significant effect in the arrival rate, implying that the use of these search channels alone is not enough to find a job.

For the employed we observe variation in the cost of search for different levels of the observed covariates. For employed individuals with larger families the cost of search is lower. For married people, the cost of search is higher. The cost of search decreases with age until the age of 32, after which it increases.

We computed various elasticities to quantify the implications of the model. We evaluated elasticities in both the mean characteristics of searchers and the mean characteristics
of nonsearchers, for the employed and the unemployed separately. The estimates of the elasticities are not precise (apart from the effect of search intensity on the arrival rate), but the direction has a clear interpretation.

The decrease of the arrival rate of the unemployed with age implies that returns to search are lower for individuals with higher age (i.e. for the mean nonsearcher). Consequently, the search decision of the mean nonsearcher is less sensitive with respect to a change in the benefit level than for the mean searcher. The nonsearchers seem to be nonsearching due to a ‘discouraged worker effect’. The search decision of the mean nonsearcher is more sensitive to a change in the exogenous part of the arrival rate than the search decision of the mean searcher.

We quantified the impact of an increase in the number of applications on the job offer arrival rate: for someone with the mean characteristics of an unemployed nonsearcher the elasticity is 0.60 and for someone with the mean characteristics of an unemployed searcher the elasticity is 0.48. For the employed nonsearchers and searchers the numbers are 0.36 and 0.39 respectively.

For the employed searchers the optimal number of applications is more sensitive with respect to the wage than for the employed nonsearchers. This reflects the fact that employed nonsearchers already have higher wages and consequently their incentive to continue searching is lower.

We also studied the generalized residuals of the model in order to gain insight in the fit of the model, and in particular, to see whether it reveals something about neglected duration dependence.

For the unemployed the residual analysis shows that there is probably neglected duration dependence (maybe also neglected heterogeneity). A plot of residuals based on forward recurrence times looks reasonably well, which suggests that the model manages to track transitions.

For the employed, the misspecification of the model is clear. The exponential model without duration dependence cannot explain the low turnover rates at high durations observed in the data. A positive point that follows from the residual analysis is that the inclusion of search intensity in the model specification leads to an improvement in the
model specification: not distinguishing searchers from nonsearchers would have led to an even worse fit. However, the inclusion of search intensity alone is not enough to explain the high survivor rates of the nonsearchers.
Table 4.1 Estimates of the structural model  
Arrival rates and the lay-off rate

<table>
<thead>
<tr>
<th>Variable</th>
<th>Arrival rate $\lambda_u$ of the unemployed</th>
<th>Arrival rate $\lambda_e$ of the employed</th>
<th>Layoff-rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>const</td>
<td>estimate [0.4, 0.9]</td>
<td>estimate [0.4, 0.9]</td>
<td>estimate [0.4, 0.9]</td>
</tr>
<tr>
<td>log(age/17)</td>
<td>6.7**</td>
<td>0.28</td>
<td>0.49</td>
</tr>
<tr>
<td>square of log(age/17)</td>
<td>-10.5**</td>
<td>-1.0**</td>
<td>0.4</td>
</tr>
<tr>
<td>sec1 (technical)</td>
<td>1.4</td>
<td>-0.08</td>
<td>0.04</td>
</tr>
<tr>
<td>sec2 (econ/admin)</td>
<td>-0.15</td>
<td>0.12</td>
<td>-0.10</td>
</tr>
<tr>
<td>sec3 (not specialized)</td>
<td>-3.9**</td>
<td>-0.06</td>
<td>0.09</td>
</tr>
<tr>
<td>region1 (west)</td>
<td>0.41</td>
<td>0.21**</td>
<td>0.12</td>
</tr>
<tr>
<td>region2 (east)</td>
<td>-0.19</td>
<td>0.14</td>
<td>0.13</td>
</tr>
<tr>
<td>region3 (south)</td>
<td>1.2*</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>educ1 (lowest)</td>
<td>2.0</td>
<td>-0.31**</td>
<td>0.12</td>
</tr>
<tr>
<td>educ2</td>
<td>1.2</td>
<td>-0.43**</td>
<td>0.16</td>
</tr>
<tr>
<td>educ3</td>
<td>0.88</td>
<td>-0.34**</td>
<td>0.97</td>
</tr>
<tr>
<td>marital status</td>
<td>0.50</td>
<td>0.02</td>
<td>0.08</td>
</tr>
<tr>
<td>rationality</td>
<td>-1.9</td>
<td>0.07</td>
<td>0.19</td>
</tr>
</tbody>
</table>

EFFECTIVENESS OF SEARCH

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unemployed ($\alpha_u$)</th>
<th>Employed ($\alpha_e$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>estimate</td>
<td>std. error</td>
</tr>
<tr>
<td>intercept $\alpha_u$</td>
<td>0.61</td>
<td>0.41</td>
</tr>
<tr>
<td>attitude</td>
<td>0.31*</td>
<td>0.18</td>
</tr>
<tr>
<td>screening</td>
<td>0.25</td>
<td>0.24</td>
</tr>
<tr>
<td>employment office</td>
<td>0.09</td>
<td>0.07</td>
</tr>
<tr>
<td>applications</td>
<td>30.0**</td>
<td>14.2</td>
</tr>
</tbody>
</table>

Table 4.2 Estimates of the parameters of the cost of search function

<table>
<thead>
<tr>
<th>SEARCH INDICATOR $\gamma$</th>
<th>Unemployed</th>
<th>Employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma_0$</td>
<td>estimate</td>
<td>std. error</td>
</tr>
<tr>
<td>constant</td>
<td>-1.16**</td>
<td>0.46</td>
</tr>
<tr>
<td>log(family size)</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>marital status</td>
<td>-0.11</td>
<td>0.07</td>
</tr>
<tr>
<td>log(age/17)</td>
<td>-0.16</td>
<td>0.27</td>
</tr>
<tr>
<td>square of log(age/17)</td>
<td>0.044</td>
<td>0.21</td>
</tr>
</tbody>
</table>

EFFECT OF RETURNS OF SEARCH ON SEARCH INTENSITY

<table>
<thead>
<tr>
<th>$\gamma_{0}$</th>
<th>Unemployed</th>
<th>Employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>attitude</td>
<td>0.85**</td>
<td>0.19</td>
</tr>
<tr>
<td>screening</td>
<td>0.89**</td>
<td>0.19</td>
</tr>
<tr>
<td>employment office</td>
<td>0.85**</td>
<td>0.20</td>
</tr>
<tr>
<td>applications</td>
<td>0.52**</td>
<td>0.11</td>
</tr>
</tbody>
</table>

PARAMETER $\beta$

<table>
<thead>
<tr>
<th>$\beta$</th>
<th>Unemployed</th>
<th>Employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>screening</td>
<td>0.61</td>
<td>0.54</td>
</tr>
<tr>
<td>employment office</td>
<td>0.25</td>
<td>0.42</td>
</tr>
<tr>
<td>applications</td>
<td>2.0**</td>
<td>0.6</td>
</tr>
</tbody>
</table>
### Table 4.3 Estimates of cost of turnover and the utility parameter

<table>
<thead>
<tr>
<th>COST OF TURNOVER</th>
<th>estimate</th>
<th>standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k$ (constant)</td>
<td>93**</td>
<td>20</td>
</tr>
<tr>
<td>$k$ (age/17)</td>
<td>901**</td>
<td>85</td>
</tr>
<tr>
<td>$k$ (square of age/17)</td>
<td>40**</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>UTILITY PARAMETER</th>
<th>estimate</th>
<th>standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\omega$</td>
<td>0.75**</td>
<td>0.37</td>
</tr>
</tbody>
</table>

### Table 4.4 Estimates of the structural model

Parameters of error distribution, $\Sigma _{t, l = t, u}$

<table>
<thead>
<tr>
<th></th>
<th>Unemployed</th>
<th></th>
<th>Employed</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>estimate</td>
<td>standard error</td>
<td>estimate</td>
<td>standard error</td>
</tr>
<tr>
<td>$\sigma_{1,2}$ (cov: attitude-screening)</td>
<td>0.62**</td>
<td>0.08</td>
<td>0.87**</td>
<td>0.02</td>
</tr>
<tr>
<td>$\sigma_{1,3}$ (cov: attitude-employment office)</td>
<td>0.58**</td>
<td>0.08</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\sigma_{1,4}$ (cov: attitude-applications)</td>
<td>0.48**</td>
<td>0.05</td>
<td>0.50**</td>
<td>0.02</td>
</tr>
<tr>
<td>$\sigma_{2,3}$ (cov: screening-employment office)</td>
<td>0.62**</td>
<td>0.08</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\sigma_{2,4}$ (cov: employment-office-applications)</td>
<td>0.43**</td>
<td>0.05</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\sigma_{2,4}$ (cov: screening-applications)</td>
<td>0.51**</td>
<td>0.05</td>
<td>0.57**</td>
<td>0.02</td>
</tr>
<tr>
<td>$\sigma_{4,4}$ (std dev. applications)</td>
<td>0.67**</td>
<td>0.05</td>
<td>0.67**</td>
<td>0.02</td>
</tr>
</tbody>
</table>

### Table 5 Elasticities

$\frac{\partial \ln y}{\partial \ln x}$

<table>
<thead>
<tr>
<th>$y$</th>
<th>$x$</th>
<th>in mean characteristics nonsearchers</th>
<th>in mean characteristics searchers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The unemployed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reservation wage</td>
<td>benefit level</td>
<td>0.019</td>
<td>0.0050</td>
</tr>
<tr>
<td>number of applications</td>
<td>benefit level</td>
<td>-0.0045</td>
<td>-0.0095</td>
</tr>
<tr>
<td>Probability of search</td>
<td>benefit level</td>
<td>-0.0010</td>
<td>-0.0098</td>
</tr>
<tr>
<td>Hazard (arrival rate)</td>
<td>number of applications</td>
<td>0.60</td>
<td>0.48</td>
</tr>
<tr>
<td>Hazard</td>
<td>benefit level</td>
<td>-0.090</td>
<td>-0.045</td>
</tr>
<tr>
<td>Number of applications</td>
<td>arrival rate</td>
<td>0.15</td>
<td>0.070</td>
</tr>
</tbody>
</table>

| The employed | |                                     |                                  |

| Number of applications | wage | -0.017 | -0.38 |
| Hazard (arrival rate) | number of applications | 0.46 | 0.39 |
A The wage model

To obtain estimates for the parameters of the wage distribution, a reduced form wage-search-employment model is estimated. The parameters of the wage equation will be interpreted as the parameters of the wage offer distribution and the estimates are used in the structural estimation in section 4.

The wave of October 1987 from the SEP is used to estimate the model. It is observed whether or not the individual is searching for a job, and whether or not he is employed. The sample consists of 3016 individuals. The tables A1 and A2 present sample statistics.

The wage-search-employment model consists of a wage equation, an employment equation and, for each state of employment, a search equation. The model is:

\[
\ln w = \eta' x + v \\
y_i^* = \alpha' z_i + u_i \tag{A.2} \\
y_e^* = \beta' z_e + u_e \tag{A.3} \\
y_u^* = \beta' u + u_u \tag{A.4}
\]

The errors are assumed to be normally distributed with covariance matrix \( \Sigma \).

The covariance matrix of the disturbances is

\[
\Sigma = \begin{pmatrix}
\sigma_y^2 & \sigma_{yu} & \sigma_{ye} & * \\
\sigma_{yu} & 1 & \sigma_{ye} & \sigma_{yu} \\
\sigma_{ue} & \sigma_{ue} & 1 & * \\
* & \sigma_{yu} & * & 1
\end{pmatrix} \tag{A.5}
\]

Equation (A.2) is the employment equation: \( y_i^* > 0 \) for employed individuals and \( y_i^* \leq 0 \) for unemployed individuals. Equations (searcemp) and (searcunp) are the search equations for the employed and unemployed respectively, with \( y_i^* > 0, l = e, u \) for searchers and \( y_i^* \leq 0, l = e, u \) for nonsearchers. The variances of the error terms of the employment and the search equation have been normalized to one. The vectors \( x, z_i \) and \( z_i, l = e, u \) contain exogenous individual characteristics. From the tables A3 to A5 with estimation results it becomes clear which characteristics have been included in the model equations.

The estimates of the wage distribution in table A3 will be used in the estimation of the structural model. Since this model only serves as an auxiliary model, we do not
Figure 1: Kaplan-Meier plot of data on unemployment duration
Figure 2: Kaplan-Meier plot of data on unemployment duration
Figure 3: Distribution of residuals
Figure 4: Distribution of forward residuals
Figure 5: Distribution of backward residuals
Figure 6: Distribution of residuals by search status
spend time to discussing the outcomes.

<table>
<thead>
<tr>
<th>Table A.1 Sample statistics october 1987, n=3016</th>
</tr>
</thead>
<tbody>
<tr>
<td>variable</td>
</tr>
<tr>
<td>age</td>
</tr>
<tr>
<td>family size (persons)</td>
</tr>
<tr>
<td>education level</td>
</tr>
<tr>
<td>Dutch nationality</td>
</tr>
<tr>
<td>region 1 (industrialized west)</td>
</tr>
<tr>
<td>region 2 (east)</td>
</tr>
<tr>
<td>region 3 (south)</td>
</tr>
<tr>
<td>region 4 (agricultural)</td>
</tr>
<tr>
<td>married</td>
</tr>
<tr>
<td>sector of education 1 (technical)</td>
</tr>
<tr>
<td>sector of education 2 (economic/administrative)</td>
</tr>
<tr>
<td>sector of education 3 (no specialization)</td>
</tr>
<tr>
<td>sector of education 4 (services)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table A.2 Means of the weekly income variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=3016</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>employed</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>wage</td>
</tr>
<tr>
<td>non-labour income</td>
</tr>
<tr>
<td>unemployed</td>
</tr>
<tr>
<td>benefit income</td>
</tr>
<tr>
<td>non-labour income</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table A.3 The wage equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>estimate</td>
</tr>
<tr>
<td>const</td>
</tr>
<tr>
<td>log(age)</td>
</tr>
<tr>
<td>square of log(age)</td>
</tr>
<tr>
<td>educ1</td>
</tr>
<tr>
<td>educ2</td>
</tr>
<tr>
<td>educ3</td>
</tr>
<tr>
<td>educ4</td>
</tr>
<tr>
<td>sec1, technical</td>
</tr>
<tr>
<td>sec2, econ. adm.</td>
</tr>
<tr>
<td>sec3, general</td>
</tr>
</tbody>
</table>
## Table A.4 Estimates of the employment equation and the search equations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Employment equation</th>
<th>Search equation employed</th>
<th>Search equation unemployed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>estimate</td>
<td>std err</td>
<td>estimate</td>
</tr>
<tr>
<td>const</td>
<td>-4.8</td>
<td>4.2</td>
<td>-17.3**</td>
</tr>
<tr>
<td>$\mu$</td>
<td>-0.0018**</td>
<td>0.0003</td>
<td>0.0007</td>
</tr>
<tr>
<td>log(fam. size)</td>
<td>0.12</td>
<td>0.07</td>
<td>-0.05</td>
</tr>
<tr>
<td>log(age)</td>
<td>3.5</td>
<td>2.4</td>
<td>10.6**</td>
</tr>
<tr>
<td>nationality</td>
<td>0.16</td>
<td>0.14</td>
<td>-0.11</td>
</tr>
<tr>
<td>educ1</td>
<td>-0.58**</td>
<td>0.22</td>
<td>-0.04</td>
</tr>
<tr>
<td>educ2</td>
<td>-0.27</td>
<td>0.19</td>
<td>-0.12</td>
</tr>
<tr>
<td>educ3</td>
<td>-0.06</td>
<td>0.18</td>
<td>-0.20</td>
</tr>
<tr>
<td>educ4</td>
<td>0.11</td>
<td>0.19</td>
<td>0.05</td>
</tr>
<tr>
<td>sec1, technical</td>
<td>-0.08</td>
<td>0.14</td>
<td>-0.13</td>
</tr>
<tr>
<td>sec2, econ. adm.</td>
<td>-0.03</td>
<td>0.17</td>
<td>-0.08</td>
</tr>
<tr>
<td>sec3, general</td>
<td>-0.23</td>
<td>0.16</td>
<td>-0.06</td>
</tr>
<tr>
<td>marital status</td>
<td>0.65**</td>
<td>0.11</td>
<td>-0.33**</td>
</tr>
<tr>
<td>region1 (west)</td>
<td>0.29**</td>
<td>0.14</td>
<td>-0.09</td>
</tr>
<tr>
<td>region2 (east)</td>
<td>0.04</td>
<td>0.14</td>
<td>-0.003</td>
</tr>
<tr>
<td>region3 (south)</td>
<td>0.17</td>
<td>0.15</td>
<td>-0.22**</td>
</tr>
<tr>
<td>square of log(age)</td>
<td>-0.53</td>
<td>0.34</td>
<td>-1.6**</td>
</tr>
</tbody>
</table>

## Table A.5 The covariances

<table>
<thead>
<tr>
<th>Covariance</th>
<th>estimate</th>
<th>standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_u$ (wage)</td>
<td>0.41**</td>
<td>0.002</td>
</tr>
<tr>
<td>$\sigma_{wu}$ (wage-employment)</td>
<td>-0.048</td>
<td>0.042</td>
</tr>
<tr>
<td>$\sigma_{wu}$ (wage-search)</td>
<td>-0.026</td>
<td>0.017</td>
</tr>
<tr>
<td>$\sigma_{wv}$ (employment-search)</td>
<td>-0.35</td>
<td>0.22</td>
</tr>
<tr>
<td>$\sigma_{uv}$ (employment-escape)</td>
<td>-0.87**</td>
<td>0.14</td>
</tr>
</tbody>
</table>
B The Bellman equations

First, the expression for the value function for unemployed individuals, \( V \), is derived. We consider the events in a small time interval of length \( At \). In the initial period, the individual is unemployed. Income consists of benefits, \( b \), and non-labour income \( \mu \). The within period utility flow in a time interval with length \( At \) is \( \omega u(b + \mu)At \). If the individual is searching during \( At \), the cost of search is \( c_u(s)At \). The current period contribution to \( V \) is \((\omega u(b + \mu) - c_u(s))At \). At the end of the interval the individual may or may not obtain a job offer. The number of job offers obtained in an interval of length \( At \) is Poisson distributed with parameter \((\alpha_u + \alpha_u's)\lambda uAt \), so the probability of receiving a job offer is \((\alpha_u + \alpha_u's)\lambda uAt + o(At)\), whereas the probability of receiving no job offer is \(1 - (\alpha_u + \alpha_u's)\lambda uAt + o(At)\). If a job offer with wage income \( x \) is obtained, a choice can be made between accepting the job, which leads to the value \( W(x) \), or rejecting, in which case the value of unemployment, \( V \), applies. Therefore, the expected future value is \( E, \max[V, W(x)] \). In the absence of a job offer the value will be the value of unemployment, \( V \). The discount factor is \( e^{-\rho At} \). The value function becomes:

\[
V = \max_{s \geq 0} [(u(b + \mu) - c_u(s))At + \frac{1}{1 + \rho At}((\alpha_u + \alpha_u's)\lambda uAtE_z \max[V, W(x)] + (1 - (\alpha_u + \alpha_u's)\lambda uAt)V) + o(At)]
\]

\[\text{(B.1)}\]

Rearranging terms yields:

\[
\frac{\rho}{1 + \rho At} V = \max_{s \geq 0} [(\omega u(b + p) - c_u(s)) + \lambda u((E, \max[V, W(x)] - V)) + o(At)]
\]

\[\text{(B.2)}\]

Letting \( \Delta t \to 0 \):

\[
\rho V = \max_{s \geq 0} [(\omega u(b + p) - c_u(s)) + \lambda u((E, \max[V, W(x)] - V))]
\]

\[\text{(B.3)}\]

Using the definition of the reservation wage \( \xi \), we can write

\[
E_z \max[V, W(x)] - V = \int_\xi^\infty [W(x) - W(\xi)]dF(x)
\]

\[\text{(B.4)}\]

Denoting optimal search intensity for someone unemployed by \( s^*_u \), and inserting (B.4) in (B.3) gives

\[
\rho V = \rho W(\xi) = \omega u(b + p) - c_u(s^*_u) + (\alpha_u + \alpha_u's^*_u)\lambda u\int_\xi^\infty [W(x) - W(\xi)]dF(x)
\]

\[\text{(B.5)}\]
For individuals who are currently working at wage $w$, the value function is denoted by $W(w)$. The initial contribution to the value function is $(u(w + \mu) - c_c(s))\Delta t$. At the end of interval $\Delta t$ four events may occur. With probability $((\alpha_{c0} + \alpha_c s)\lambda_c \Delta t + o(\Delta t))(1 - \sigma\Delta t + o(\Delta t)) = (\alpha_{c0} + \alpha_c s)\lambda_c \Delta t + o(\Delta t)$ a job offer with wage $x$ is obtained by the individual, while he is not laid off. The individual can choose to accept the offer and pay turnover costs $k$ (value $W(x) - k$), or to reject the offer and stay in the present job (value $W(w)$), or become unemployed (with value $V$). The individual chooses the alternative with the maximum value $(\max[V, W(x) - k, W(w)])$. The second event that may occur is that of getting a job offer and being laid off. The probability of the event is $((\alpha_{c0} + \alpha_c s)\lambda_c \Delta t + o(\Delta t))(\sigma\Delta t + o(\Delta t)) = o(\Delta t)$ with value $\max[V, W(x) - k]$. The third event is that of neither getting a job offer, nor being laid off. The probability is $(1 - (\alpha_{c0} + \alpha_c s)\lambda_c \Delta t + o(\Delta t))(1 - \sigma\Delta t + o(\Delta t)) = 1 - (\alpha_{c0} + \alpha_c s)\lambda_c \Delta t - \sigma\Delta t + o(\Delta t)$ with value $\max[V, W(w)] = W(w)$. Finally, the individual may be laid off without being a job offered. This event has probability $(1 - (\alpha_{c0} + \alpha_c s)\lambda_c \Delta t + o(\Delta t))(\sigma\Delta t + o(\Delta t)) = \sigma\Delta t + o(\Delta t)$. The value function becomes:

$$
W(w) = \\
\max_{x \geq 0} [(u(w + \mu) - c_c(s))\Delta t \\
+ \frac{1}{1+\sigma\Delta t} \{ (\alpha_{c0} + \alpha_c s)\lambda_c \Delta t E_x \max[V, W(x) - k, W(w)] + \\
(1 - (\alpha_{c0} + \alpha_c s)\lambda_c \Delta t - \sigma\Delta t)W(w) + \sigma\Delta t V \}] + o(\Delta t)
$$

Rearranging terms, dividing by $\Delta t$ and letting $\Delta t \to 0$ yields

$$
(\rho + \sigma)W(w) = \\
\max_{x \geq 0} [u(w + \mu) - c_c(s) + \lambda_c (\alpha_{c0} + \alpha_c s) \{ E_x \max[V, W(x) - k, W(w)] - W(w) \}] + \sigma V
$$

Using the definition for the reservation wage of working individuals, $\alpha(w)$, introduced in section 2.2, and realizing that choosing the state of unemployment is an irrelevant alternative for someone employed, we may write

$$
E_x \max[V, W(x) - k, W(w)] - W(w) = \int_{\alpha(\xi)}^{\infty} [W(x) - W(\alpha(\xi))]dF(x)
$$

Denoting optimal search intensity for someone working at wage $w$ by $s_c^*(w)$ and inserting (B.8) in (B.7) gives

$$
(\rho + \sigma)W(w) = u(w + \mu) - c_c(s) + \lambda_c (\alpha_{c0} + \alpha_c s) \int_{\alpha(\xi)}^{\infty} [W(x) - W(\alpha(\xi))]dF(x) + \sigma V
$$
Evaluating (B.9) in the reservation wage $\xi$ and combining it with (B.5) gives the reservation wage equation (2.3)

C  The stock sample density

The stock sample density of duration and search intensity, conditional on the backward recurrence time is derived. The analysis is based on Riddler (1984). The subindices $e$ and $v$, indicating the labour force state, will be suppressed. Let $f(t|s,w)$ denote the flow conditional density of duration, conditional on search intensity and the wage. To reduce the necessary notation, search intensity is treated as a observed continuous non-negative random variable here. The extension to multidimensional variables of the type in section 3.2 is straightforward. Let $f(s|w)$ denote the density of search intensity conditional on the wage, and let $g(w)$ denote the marginal density of observed wages. Then the joint flow density of duration, search intensity and observed wages is

$$f(t|s,w)f(s|w)g(w), 0 < t < \infty, 0 < s < \infty$$ (C.1)

Now assume that the inflow rate into the given labour force state is $i(-p,t)$, in which $-p$ denotes the time of inflow into the state, if the point of sampling is taken as reference, and $l$ is calendar time. The stock density is the flow density, conditional on entrance at $p$ time units ago, and conditional on duration $t$ exceeding the backward recurrence time $p$. Then the joint stock density of duration, backward-recurrence time, search intensity and observed wages is:

$$h(p,t,s,w) = \frac{i(-p,l)f(t|s,w)f(s|w)g(w)}{\int_0^\infty \int_0^\infty \int_0^\infty i(-\tilde{p},l)f(\tilde{p}|\tilde{s},\tilde{w})f(\tilde{s}|\tilde{w})g(\tilde{w})d\tilde{w}d\tilde{s}dp}$$ (C.2)

We are interested in the stock density of duration and search intensity, conditional on the wage and the backward recurrence time, i.e.

$$h(t,s|p,w) = \frac{h(p,t,s,w)}{h(p,w)}$$ (C.3)

\[20\text{Note that we treat the subsample of employment spells and the subsample of unemployment spells as two separate samples here. Treating them as one sample changes the selectivity correction in } h(p,t,s,w), \text{ but leaves the final result, i.e. the density conditional on backward recurrence times, unaffected.}\]
in which
\[ h(p, w) = \int_0^\infty \int_{\tilde{p}}^\infty h(p, \tilde{s}, \tilde{w}) d\tilde{d}\tilde{s} \] (C.4)

Combining (B.3) and (B.4) with (B.2) yields the required density:
\[ h(t, s, |p, w) = \frac{f(t|s, w)f(s|w)}{\int_0^\infty F(p|s, w)f(s|w) ds} \]
\[ 0 < s < \infty \]
\[ p < t < \infty \] (C.5)

**D Elasticities**

In this section we presented the expressions for the elasticities that serve as a basis for the computation of the elasticities in section 4.

For the expression for the elasticities of the reservation wage of the unemployed, \( \xi \) with respect to the benefit level \( b \), we have
\[ \frac{b}{\xi} \frac{d\xi}{db} = \omega \frac{\rho + \sigma + \theta_{eq}(\xi) b}{\rho + \sigma + \theta_{ue} \xi} \] (D.1)
in which \( \theta_{eq}(\xi) \) represents the transition intensity of a job-to-job transition, evaluated in the reservation wage \( \xi \): \( \theta_{eq}(\xi) = (1 + \alpha_s \xi \lambda_c(\xi)) \lambda_c(\alpha(\xi)) \). In the derivation of (D.1), use has been made of the specification of the utility function in (4.7) and of the derivative of the value function for someone employed in (B.9) with respect to the wage, \( W'(w) \):
\[ W'(w) = \frac{1}{\rho + \sigma + \theta_{eq}(w)} \] (D.2)

Note that the sign of the elasticity in (D.1) is positive: a higher benefit level leads to a higher reservation wage, and consequently to a decrease in the job acceptance probability.

The elasticity of the underlying (latent) level of search intensity of search indicator \( j \) with respect to the benefit level \( b \) has been determined on basis of the first order condition for the optimal intensity of search for someone unemployed, in (2.5). In determining the derivative, use has been made of the derivative of \( \xi \) with respect to \( b \) (see (D.1)), the derivative of the value function \( W'(w) \) in (D.2), and the specification of the utility function (4.7). This leads to the following expression for the elasticity:
\[ \frac{b}{s_{uj}} \frac{ds_{uj} / db}{db} = -\frac{\alpha_{uj} \lambda_c(\xi)}{c_{uj}(s_{uj})} \frac{\rho + \sigma}{\rho + \sigma + \theta_{ue} \xi} \frac{b}{s_{uj}} \] (D.3)
Note that if the regularity condition in (2.2) on the sign of the second order derivative of the cost of search function is satisfied, the sign of the elasticity (D.3) is negative: a higher benefit level leads to a lower intensity of search.

The elasticity of the underlying (latent) level of search intensity of search indicator $f$ with respect to the factor $\lambda_u$, the exogenously determined part of the job offer arrival rate, has been determined by differentiation of the first order condition for optimal search intensity (2.5), the derivative of the value function (D.2), the utility specification (4.7), the specification of the cost of search function (4.1), and the derivative of the reservation wage $\xi$ with respect to $\lambda_u$ that was obtained by differentiating (2.3). This results in the following expression for the elasticity:

$$\frac{\lambda_u}{s_{ej} d s_{ej}} = \gamma_{0e, f} \frac{\rho + \sigma}{\rho + \sigma + \theta_{w}} \frac{1}{s_{w}} \quad \text{(D.4)}$$

The sign of the elasticity in (D.4) is positive: a higher value of $\lambda_u$ leads to a higher search intensity. However, an increase in $\lambda_u$ has two opposing effects on the level of search intensity. The (direct) positive effect is immediately clear from (2.5): a higher value of $\lambda_u$ leads to higher returns of search and therefore increases the incentive to search. The negative (indirect) effect runs through the reservation wage: a higher value of $\lambda_u$ increases the value of search, and therefore increases the reservation wage (the individual is tended to wait for a better offer). By (2.5), a higher reservation wage goes together with a lower level of search intensity. From (D.4) it follows that the positive effect dominates.\(^{21}\)

For employed individuals, we determined the effect of the current wage on the intensity to search. Use has been made of (D.2) as well as of the property $W'(\alpha(w)) = W'(w)$ since $W(\alpha(w)) = W(w) + k$. This results in the following elasticity:

$$\frac{w}{s_{ej} d w} = \frac{\alpha_{e,f} F(\alpha(w))}{\alpha_{e,f}(s_{ej}(w))(\rho + \sigma + \theta_{e})} \frac{w}{s_{ej}} \quad \text{(D.5)}$$

The sign of the elasticity (D.5) is positive: a higher current wage reduces the incentive to search.

---

\(^{21}\) In the expression for (D.4) we made use of the specification of the cost function in (4.1). It should be noted, however, that the specific functional form chosen in (4.1) is not the result of the positive sign of (D.4). Any other specification of cost of search that satisfies the regularity conditions in (2.2) will lead to a positive sign.
Finally, we determined the elasticities of the transition intensities with respect to the intensity of search. For the transition from unemployment into employment we have the following elasticity for search intensity indicator $j$:

$$\frac{s_{u\beta}}{\theta_{u\beta}} \frac{d\theta_{u\beta}}{ds_{u\beta}} = \left[ \alpha_{uj} \lambda_u \tilde{F}(\xi) + \frac{(1 + \alpha_{uj}) s_j}{\alpha_{uj} \tilde{F}(\xi)} f(\xi) c_{u\beta}^\prime(s_{u\beta})(\rho + \sigma + \theta_{e\beta}(\xi)) \right] s_{u\beta} \frac{d\theta_{u\beta}}{ds_{u\beta}} \quad (D.6)$$

In the derivation of (D.6) use has been made of (D.2), (4.7) and, for the determination of the relation between the reservation wage and the level of search intensity, of (2.5).

For job-to-job transitions, the elasticity is

$$\frac{s_{ej}}{\theta_{e\beta}} \frac{d\theta_{e\beta}}{ds_{ej}} = \left[ \alpha_{ej} \lambda_e \tilde{F}(\alpha(w)) + \frac{(1 + \alpha_{ej}) s_e}{\alpha_{ej} \tilde{F}(\alpha(w))} f(\alpha(w)) c_{e\beta}^\prime(s_{e\beta})(\rho + \sigma + \theta_{e\beta}(w)) \right] s_{e\beta} \frac{d\theta_{e\beta}}{ds_{e\beta}} \quad (D.7)$$

E Generalized residuals

It is a well-known result in duration analysis (see e.g. Cox ann Oakes (1984)) that if we define a random variable that is equal to the integrated hazard of a hazard rate model, this random variable follows the exponential distribution with parameter 1, provided that the model is correctly specified. In duration analysis, this result forms the basis for the analysis of the goodness-of-fit of the model. In the context of duration models, the random variable, constructed this way, is the generalized residual. By constructing the non-parametric Kaplan-Meier estimator of the survivor function of the residuals and comparing this to the exponential distribution with parameter 1, the model specification can be tested.

An additional complication in the computation of the generalized residuals in the present paper is that the density of duration contains a latent endogenous variable. We computed the hazard rate of the model by dividing the joint density of duration and search intensity by the joint survivor function of duration and search intensity. In terms of the notation in (4.17) and (4.18) this reads:

$$\frac{\int_A f_j(\tau|\tilde{s}_t^\ast) g(\tilde{s}_t; \Sigma_t) P(\tilde{s}_t | s_t^\ast > 0) d\tilde{s}_t}{\int_A \tilde{F}_j(\tau|\tilde{s}_t^\ast) g(\tilde{s}_t; \Sigma_t) P(\tilde{s}_t | s_t^\ast > 0) d\tilde{s}_t} \quad (E.1)$$

and

$$\frac{\int_A f_j(\tau|\tilde{s}_t^\ast) g(\tilde{s}_t; \Sigma_t) d\tilde{s}_t}{\int_A \tilde{F}_j(\tau|\tilde{s}_t^\ast) g(\tilde{s}_t; \Sigma_t) d\tilde{s}_t} \quad (E.2)$$
Recall that the region of integration\(^{22}\) in (E.1) and (E.2) is determined by the observed values of the search indicators.\(^{23}\) The generalized residuals are computed by determining the integrated hazard (evaluated in the observed duration, or in the forward or backward recurrence time, see section 4) on the basis (E.1) or (E.2).

\(^{22}\) Note that in a model in which the endogenous covariate is not latent, no integration appears, and the density of the endogenous covariate appearing in the numerator and the denominator would cancel, in which case the hazard is simply equal to the hazard of the conditional distribution of duration.

\(^{23}\) Alternatively, the hazard can be computed on basis of the marginal distribution of duration: in that case the expression for the hazard is similar to (E.1) and (E.2), but the region of integration becomes \((-\infty, +\infty)\). However, information in the residuals that is due to the spread across individuals due to different search behaviour will be lost if this procedure is followed.
References


