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The Estimation of Reservation Wages: A Simulation-Based Comparison

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Abstract This paper examines the predictive power of different estimation approaches for reservation wages. It applies stochastic frontier models for employed workers and the approach from Kiefer and Neumann (1979b) for unemployed workers. Furthermore, the question of whether or not reservation wages decrease over the unemployment period is addressed. This is done by a pseudo-panel with known reservation wages which uses data from the German Socio-Economic Panel as a basis. The comparison of the estimators is carried out by a Monte Carlo simulation. The best results are achieved by the cross-sectional stochastic frontier model. The Kiefer-Neumann approach failed to predict the decreasing reservation wages correctly.

Keywords: Job search theory, Monte Carlo simulation, reservation wages, stochastic wage frontiers

JEL Classification: C21, C23, J64.

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1 Introduction

Unemployment and its determinants, this topic has been receiving increasing attention in many western countries since the financial crisis and the following economic crisis. During the crisis, unemployment, accompanied by all its negative impacts on the individual level as well as on macroeconomic levels, started to rise in nearly all countries. Thus, it is essential to reveal and understand the reasons for unemployment.

One theoretical model that tries to explain unemployment from a microeconomic point of view is the Search Theory, introduced by McCall (1970), which models the decision process to take up a job for unemployed persons with imperfect information. The Search Theory assumes that each unemployed person is faced with the decision to accept a job offer at a given wage or to remain unemployed and wait for a better offer in the next period. The final decision to decline a job offer and to stay unemployed or to accept a job offer is made by the use of individual reservation wages, which represent the minimum acceptable wage.

The reservation wages itself are not directly observable, so indirect measurement techniques have to be applied. According to Jensen et al. (2010), one of the following three possibilities can be chosen: direct questions, the approach of Kiefer and Neumann (1979b) and the estimation of reservation wages with the use of stochastic frontier models. In this paper, only the last two approaches are applied. The approach of Kiefer and Neumann uses information on accepted wages after spells of unemployment and tries to infer reservation wages for unemployed persons with the help of the Search Theory. This approach is used by Böheim (2002) for British data from the British Household Panel Survey, by Schmidt and Winkelmann (1993) for German data from the Zentralarchiv fuer Empirische Wirtschaftsforschung and by Christensen (2005) for German data from the German Socio-Economic Panel (GSOEP).

The second approach is the estimation of reservation wages for employed persons with the use of stochastic frontier estimators, which was conducted for the first time by Hoffler and Murphy (1994). It identifies reservation wages via the prediction of cost efficiency after a frontier estimation. Application of frontier models for the estimation of reservation wages can be found in Jensen et al. (2010) for German data from the Institute for Employment Research (IAB) and in Cornwell and Schneider (2000) for Germany with the GSOEP. Furthermore, two approaches of reservation wage estimation restricted to the financial service labor market are available. Webb et al. (2003) estimated the overpayment in the banking sector of the United Kingdom (UK) with data from the British Household Panel Survey by stochastic frontier techniques. They defined the overpayment as any wage which is located above the reservation wage. Closely related is the work from Watson and Webb (2008) which does the same estimation for German and British data from the European Community Household Panel Survey (ECHPS).

Apart from the estimation process, an often controversial issue is the behavior of persons during the unemployment period. The question is if they lower their reservation wages

during the period of unemployment or if they keep the reservation wage constant until they find an adequate job. The problem in estimation arises because constant reservation wages, as stated by the basic Search Theory, could lead to rising observed reservation wages with longer unemployment duration since only persons with high wage requests stay unemployed. However, the Search Theory can in fact be adjusted to "produce" decreasing reservation wages, for example by the use of duration-dependent stigmata of unemployed, such as found in the work of Vishwanath (1989). Several empirical studies have examined the question of constant reservation wages; to mention just two of them: Prasad (2003) using Dutch data, found no relationship with a simple ordinary least square (OLS) regression, but a positive relationship with instrumental variables (IV) regression, which could be interpreted as support for the constant reservation wage hypothesis. On the other hand, Maani and Studenmund (1986) found a decreasing reservation wage over the unemployment duration for Chile. Thus, it remains unclear what underlying nature prevails for the reservation wages. But the Kiefer-Neumann approach might be able to detect a decreasing or constant reservation wage if it is applied to different time periods; Christensen (2005) used it in this way.

Therefore, this paper examines the behavior of the different measurement techniques for reservation wages and, at the same time, analyzes whether or not these estimators are able to find the underlying reservation wage structure over the unemployment duration. This is done by a Monte Carlo simulation where a pseudo-panel with observable reservation wages is created. In a second step, the simulated data are used for the application of the different estimators. The objective is to simulate a panel data set which is reasonably close to a true panel like the GSOEP but with a known underlying process of employment transition. The GSOEP served as a base for the simulation design, delivering starting values for the simulation.

The plan of this paper is as follows. Sections 2 and 3 present the theoretical basis of the estimation approaches. Section 4 introduces the data set and the preceding wage estimation. Section 5 explains the simulation, which is built with the help of the obtained values from the wage estimation and section 6 provides the results. The paper concludes with chapter 7.

2 Kiefer-Neumann Estimator

The section at hand briefly introduces the estimation approach of Kiefer and Neumann, presented in the works of Kiefer and Neumann (1979a) and Kiefer and Neumann (1979b). A more detailed derivation of the estimator can be found in the works of Christensen (2005) and Schmidt and Winkelmann (1993). The approach is used to compare reservation wages for unemployed persons, using interview data, with estimated ones. The objective of this estimator is to not use requested reservation wage data, but to construct the reservation wages with the use of observable accepted wages and concepts of the Search Theory. As mentioned before, the estimation approach of Kiefer and Neumann is based on the reservation

wages derived from the Search Theory. This paper will present just the very basic thoughts of the search theory, a detailed survey can be found in Devine and Kiefer (1991).

A successful match is achieved if an unemployed person receives and accepts a job offer with a given wage offer. Normally, an unemployed person tries to find a new job during his/her period of unemployment. A wage offer is considered to be sufficient if it exceeds the reservation wage, which differs from one person to another since all labor market endowments (education, age etc.) are variable.

The optimal strategy for an unemployed person is to accept any job with a wage offer greater than his reservation wage. The reservation wage w^r is therefore modeled by equating the cost of rejecting a given wage offer of w^r with the expected return of a continued search if the wage exceeds the reservation wage w^r:

$$w^r - c = \frac{\delta}{r} \int_{w^r}^{b} (w - w^r) dF(w) \tag{1}$$

where c are unemployment payments, δ is the constant job offer arrival rate [1], $F(w)$ is the wage offer distribution which is located within the limits $[a; b]$ and r is the discount rate. Equation (1) can be rewritten to:

$$(w^r - c) \cdot r = (E[w^o | w^o \geq w^r] - w^r)[1 - F(w^r)] \tag{2}$$

with the offered wage w^o. The two wages, offered wage and reservation wage, are expressed separately and are assumed to be log-normal distributed:

$$w_i^o = x_i\beta + e_i^o; \qquad w_i^r = z_i\gamma + e_i^r \tag{3}$$

with their normal distributed error terms

$$e_i^o \sim N(0, \sigma_o^2); \qquad e_i^r \sim N(0, \sigma_r^2). \tag{4}$$

However, the reservation wage is unobservable and the distribution of the observed wage offer w_i^* (accepted wages) is truncated due to the fact that rejected offers are not reported. This problem can be solved with the use of the two-step estimator from Heckman (1979), estimating in the first step the probability of finding a job

$$P(\text{accepted offer}|x_i, z_i) = P\left(\frac{\epsilon_i}{\sigma} > \frac{z_i\gamma - x_i\beta}{\sigma}\right) = \Phi\left(\frac{x_i\beta - z_i\gamma}{\sigma}\right). \tag{5}$$

In the second step, the predicted inverse mills ratio $\hat{\lambda}_i$ is included into a equation for the accepted wages in order to correct for the sample selection bias

$$w_i^* = x_i\beta + \rho_{e^o\epsilon}\sigma_o\hat{\lambda}_i + u_i. \tag{6}$$

[1] In the following, δ is set to one.

Equation (6) is estimated for all employed persons using GLS since the error u_i is heteroscedastic. With the attained estimation of the accepted wages, the next step is the identification of the parameters in the reservation wage equation which could be realized by the use of Search Theory and parameter restriction. Thus, the reservation wage equation in (3) is decomposed to

$$w_i^r = z_i\gamma + e_i^r = x_i^{o,r}\gamma_{o,r} + x_i^o\gamma_o + x_i^r\gamma_r + e_i^r \tag{7}$$

in order to distinguish between variables that affect the reservation wage via the wage offer only (x_i^o), via the search costs only (x_i^r) and variables that affect the reservation wage via both of them ($x_i^{o,r}$). The partial derivations of equation (7) with respect to the variables allow the replacement of the corresponding variables in the employment probit equation

$$\begin{aligned} w^o - w^r &= (x^{o,r}\beta_{o,r} + x^o\beta_o) - [x^{o,r}(m\beta_{o,r} + c_{o,r}) + x^o m\beta_o + x^r c_r] \\ &= x^{o,r}[(1-m)\beta_{o,r} - c_{o,r}] + x^o(1-m)\beta_o - x^r c_r \end{aligned} \tag{8}$$

where m is the derivation $\partial w^r/\partial x\beta$ in this new structural model. The replacement of $x\beta$ by its predicted value $\hat{w^o}$, attained by the estimation of equation (6), and some rearrangement yields the structural probit

$$\frac{w^o - w^r}{\sigma} = \hat{w^o}\frac{1-m}{\sigma} - x^{o,r}\frac{c_{o,r}}{\sigma} - x^r\frac{c_r}{\sigma} = \hat{w^o}\theta_1 + \tilde{x}\theta_2 \tag{9}$$

where

$$\tilde{x} = [x^{o,r}, x^r] \quad \text{and} \quad \theta_2 = \left[\frac{c_{o,r}}{\sigma}, \frac{c_r}{\sigma}\right].$$

The parameters $c_{o,r}$ and c_r can be identified with external information about m or σ. For this purpose, it is necessary to find an estimator for m by using the Search Theory. A connection between the information on the mean duration of unemployment, the discount rate and the shift of the reservation wage due to a change in the mean offered wage (m) is obtained by equation

$$\frac{\partial w^r}{\partial \mu} = \frac{[1 - F(w^r + \mu)]}{[1 - F(w^r + \mu) + r]} \underset{\mu \to 0}{\approx} \frac{[1 - F(w^r)]}{r + [1 - F(w^r)]} \tag{10}$$

which can be shown to be the derivation of (2). Since $1 - F(w^r)$ is the probability of accepting a given wage offer and every unemployed person receives one job offer per month, the term $1/1 - F(w^r)$ can be thought of as the expected duration of the unemployment spell. Therefore, with assumed values for r, it is possible to identify all unknown parameters and to predict the reservation wage. Finally, the estimated reservation wages are used in an auxiliary regression for the true reservation wage in order to examine the predictive power.

3 Frontier Estimators

The stochastic frontier models are the second possibility for estimating reservation wages, but with a focus on employed persons. The stochastic frontier models were introduced firstly and independently from each other by Aigner et al. (1977) and Meeusen and Broeck (1977). This section will give a very short view of into the topic, a good review of stochastic frontier models can be found in Kumbhakar and Lovell (2003).

In general, a production frontier is the maximum output that can be produced with a given input, or, as in case of a cost frontier, the minimum costs of input that are required for a given output. This implies that production is only cost efficient if it takes place exactly at the cost frontier (i.e. at minimum cost) because in all other cases the same amount of output could be produced at a lower cost level. The basic concept of stochastic frontier functions is transferred to reservation wages according to the work of Jensen et al. (2010); however, the first application to reservation wages was made by Hoffler and Murphy (1994). The first thing to notice is that the reservation wage W_{it}^r of worker i at time t can't be higher than his current wage W_{it} in the same period. Thus, the wage can be written as:

$$W_{it} = W_{it}^r \cdot q_{it} \tag{11}$$

where q_{it} is the wage gap between the wage and the reservation wage, named quasi-rent. This wage gap q_{it} is defined as the one sided efficiency term $exp(u_{it})$, known from standard application of stochastic frontier models. The assumed reservation wage

$$W_{it}^r = \exp(\beta_o) \cdot \prod_{j=1}^{k} \exp(\beta_j x_{jit}) \cdot \exp(v_{it}) \tag{12}$$

depends on a set of variables x_{jit}, for worker i at time t and variable j, that determine the reservation wage through search costs and wage offers. The error term $\exp(v_{it})$ is assumed to be specific for each individual and contains random shocks at time t. Inserting (12) into (11) and taking logs yields the stochastic wage frontier

$$w_{it} = \beta_0 + \sum_{j=1}^{k} \beta_j x_{jit} + v_{it} + u_{it} \tag{13}$$

with $w_{it} = \ln(W_{it})$ and $w_{it}^r = \ln(W_{it}^r)$. In the estimation process, the joint error $\epsilon_{it} = v_{it} + u_{it}$ is used instead of the single components. They have to be disentangled afterwards in order to identify the quasi-rent. The stochastic wage frontier can be estimated by different methods; however, only three of them are considered in this work: the cross-sectional estimation with a normal-half normal distributed error term, a panel model with time-varying decay and a panel model with time-invariant error. Thereafter, the estimated reservation wages of the different methods are compared with the true reservation wages by an auxiliary regression.

3.1 Cross Sectional Model

The first approach assumes that cross sectional data are used, therefore the index t is skipped in this part. Moreover, distributional assumptions about the error terms are required to use the model and to distinguish the error terms v_i and u_i. In general, v_i is assumed to be normal distributed but there exist four common possibilities to model the efficiency term u_i: the gamma distribution, the exponential distribution, the half normal distribution and the truncated normal distribution. Ritter and Simar (1997) have shown the bad performance of the gamma distribution. The truncated normal distribution often causes problems in achieving convergence as Greene (2005) pointed out. The exponential distribution is excluded due to weak results, as Jensen (2005) showed, leaving only the half-normal distribution for application in this work. After the choice of the distributional form, the standard assumptions on the error terms v_i and u_i are made, i.e. they are assumed to be independent from the x_{ji} and each other

$$v_i \sim N(0, \sigma_v^2); \qquad u_i \sim N^+(0, \sigma_u^2) \tag{14}$$

where N^+ describes the chosen half normal distribution restricted to the positive number range. Thus, the log-likelihood function for the estimation of the unknown parameters can be constructed

$$\ln L = \sum_{i=1}^{N} \left[\frac{1}{2} \ln \left(\frac{1}{\pi} \right) - \ln \sigma + \ln \Phi \left(\frac{\epsilon_i \lambda}{\sigma} \right) - \frac{\epsilon_i^2}{2\sigma^2} \right]. \tag{15}$$

with $\sigma = \sqrt{\sigma_u^2 + \sigma_v^2}$, $\lambda = \frac{\sigma_u}{\sigma_v}$ and the standard normal distribution function $\Phi(\cdot)$. After the iterative maximization of the log-likelihood, the problem remains to separate the variable of interest u_i from the joint error ϵ_i, i.e. identifying the quasi-rent q_{it}. This is done according to the approach from Jondrow et al. (1982), which uses the conditional distribution $f(u_i|\epsilon)$ of u_i given ϵ_i. But the final prediction of the cost efficiency is done by the more precise estimator of Battese and Coelli (1988):

$$E[\exp(u_i)|\epsilon_i] = \left[\frac{1 - \Phi(-\sigma_* - \mu_{*i}/\sigma_*)}{1 - \Phi(-\mu_{*i}/\sigma_*)} \right] \cdot \exp \left(\mu_{*i} + \frac{1}{2}\sigma_*^2 \right) \tag{16}$$

with $\sigma_* = \sigma_u^2 \sigma_v^2 / \sigma^2$ and $\mu_* = \epsilon \sigma_u^2 / \sigma^2$. Finally, the prediction of the efficiency for each person is used to get estimated reservation wages for all employed persons. Thereafter, the last step is to compare the estimated reservation wages to the simulated reservation wages with the use of a simple OLS regression.

3.2 Time-invariant Model

The next considered model is a panel model with time invariant efficiency. In general, the panel data models have an advantage over the cross sectional models in that they require less

restrictions for the error term. However, the restriction that the efficiency will not change over time is a difficult one as well.

Starting from equation (13), the additional assumption is made that the technical efficiency $u_{it} = u_i$ is time invariant. Therefore, the model assumes that the efficiency term differs only between the individuals and not within. The general assumptions about the error terms are

$$v_{it} \sim N(0, \sigma_v^2); \qquad u_i \sim N^+(\mu, \sigma_u^2) \tag{17}$$

with u_i following a truncated normal distribution with mean μ and variance σ_u^2 as Battese and Coelli (1988) and Battese et al. (1989) proposed for the use in panel models. The error term v_{it} is assumed to be normally distributed with a zero mean. Both error terms are assumed to be independently distributed from the x_{jit} and each other. The derived log-likelihood for the time invariant frontier estimator is

$$\begin{aligned}\ln L = &-\frac{1}{2}\sum_{i=1}^{N} T_i \ln(2\pi) - \frac{1}{2}\sum_{i=1}^{N}(T_i - 1)\ln(\sigma_v^2) - \frac{1}{2}\sum_{i=1}^{N}\ln(\sigma_v^2 + T_i\sigma_u^2) \\ &- N\ln[1 - \Phi(-\mu/\sigma_u)] + \sum_{i=1}^{N}\ln[1 - \Phi(-\mu_i^*/\sigma_i^*)] - \frac{1}{2}\sum_{i=1}^{N}(\epsilon_i'\epsilon_i/\sigma_v^2) \\ &- \frac{1}{2}N(\mu/\sigma_u)^2 + \frac{1}{2}\sum_{i=1}^{N}(\mu_i^*/\sigma_i^*)^2. \end{aligned} \tag{18}$$

The identification of the quasi-rent is carried out in a similar manner than for the cross-sectional estimator.

3.3 Time-varying Decay Model

The last considered variant of the class of frontier estimators is the time-varying decay model for panel data. The model was developed by Battese and Coelli (1992) and assumes that the error term u_{it} has a time-varying part

$$u_{it} = \eta_{it}u_{it} = \exp[\eta(t - T_i)]u_i \tag{19}$$

which means that the cost efficiency term u_{it} is assumed to increase over time if $\eta < 0$, decrease if $\eta > 0$ or to remain constant if $\eta = 0$, thus, the model collapse to the time-invariant model in part (3.2) if $\eta = 0$. The assumptions about u_i and v_{it} are unchanged in comparison with the time-invariant model. The derivation of the log-likelihood is straightforward with

the final outcome:

$$\begin{aligned}\ln L = &-\frac{1}{2}\sum_{i=1}^{N} T_i \ln(2\pi) - \frac{1}{2}\sum_{i=1}^{N}(T_i - 1)\ln(\sigma_v^2) - \frac{1}{2}\sum_{i=1}^{N}\ln(\sigma_v^2 + \eta_i'\eta_i\sigma_u^2) \\ &- N\ln[1 - \Phi(-\mu/\sigma_u)] + \sum_{i=1}^{N}\ln[1 - \Phi(-\mu_i^*/\sigma_i^*)] - \frac{1}{2}\sum_{i=1}^{N}(\epsilon_i'\epsilon_i/\sigma_v^2) \\ &- \frac{1}{2}N(\mu/\sigma_u)^2 + \frac{1}{2}\sum_{i=1}^{N}(\mu_i^*/\sigma_i^*)^2 \end{aligned} \tag{20}$$

Again, the separation of the error term u_i from the joint error ϵ_i is done with the approach from Jondrow et al. (1982). The prediction of cost efficiency is done by the slightly modified equation:

$$E[\exp(u_i)|\epsilon_i] = \left[\frac{1 - \Phi(-\eta_{it}\sigma_i^* - \mu_i^*/\sigma_i^*)}{1 - \Phi(-\mu_i^*/\sigma_i^*)}\right] \cdot \exp\left(\eta_{it}\mu_i^* + \frac{1}{2}(\eta_{it}\sigma_i^*)^2\right). \tag{21}$$

4 Data

The comparison of the estimators is done by a simulation. In order to provide starting values, a wage regression based on real data is carried out. Those estimated coefficients are used in a subsequent step to generate reservation wages.

In this paper, the GSOEP is used which is provided by the German Institute for Economic Research (Deutsches Institut fuer Wirtschaftsforschung - DIW Berlin). See Wagner et al. (2007) for a detailed review. The GSOEP contains a huge number of topics on the microeconomic level, generated by the use of responses to the questionnaire. The households and the corresponding household members are followed over the years to create a panel, starting in 1984 and continuing until now. For this work, 26 waves from 1984 until 2009 of the GSOEP are used. The sample is restricted due to the following restrictions:

- Only West German households are included. This is done due to the special circumstances in the East German labor market after reunification, with impacts until the present.
- Women are excluded from the survey because the female labor market behavior differs in some important ways.
- Individuals younger than 30 or older than 55 are not included. The upper boundary on the age is set due to the early retirement schemes in Germany. For persons younger than 30, the problem is the probability of not having finished education and, therefore, the inability to take up a job. Thus, the composition of the educational level for younger people would be different than for older people, which have to be avoided for the following simulation.
- All early retired persons younger than 56 are excluded.
- Only full-time employed persons are considered in the sample, leading to an exclusion of part-time workers, occasionally employed persons and all persons who are still in some

kind of education programs (trainees etc.).

- A minimum amount of 30 hours of work per week have to be reported in order to assume a full-time employment.
- Only unemployed persons who are able to take up a job are included. Therefore, all persons in active labor market schemes or in military services are excluded. Furthermore, a regular secondary job but the lack of a primary job also leads to an exclusion because it is questionable if they are really searching for a primary job due to their time constraints.
- All self-employed persons are excluded from the survey. They obviously face a very different employment pattern then regular employed workers.
- All persons with a country of origin other than Germany are excluded. The increased problems of some groups of non-German residents in the labor market are well known and could therefore lead to distorted results.

After all restrictions, 42,603 observations can be used for the estimation. For these persons, corrected gross monthly wages are estimated to provide base values for the generation process of the reservation wage in the simulation. The monthly gross wages are adjusted by additional salary or bonuses: 13th and 14th monthly paychecks, Christmas bonus, vacation bonus, profit sharing, travel grant and other bonuses. According to Boll (2011), the information about the additional payments and the gross wages in the previous year can be used to correct the current gross wage.

The choice of the exogenous variables is made with regard to the following simulation, the chosen variables have to be applicable for this purpose as well. Finally, the following variables are used for the regression: the weekly hours of work. Regional variables are included for the south/north/west of Germany. The different qualification levels in Germany are measured by the following variables: no qualifications, vocational training, high vocational training, technical college and university. All persons without any qualifications different then the school diploma are classified into the variable "no qualifications". The variable "vocational training" accounts for all persons with a "Hauptschulabschluss" (low vocational training) or "Realschulabschluss" (medium vocational training) together with vocational training. "High vocational training" includes all persons with "Abitur" alongside vocational training. The last two qualification variables cover the different academic education in Germany. The unemployment experience (linear and quadratic), full-time experience (linear and quadratic) and tenure (linear and quadratic) are measured in years (month in decimal form) to cover the working history of the persons. The marital status is included as a dummy variable. Furthermore, the official unemployment rate for each year is implemented by external data from Statistisches Bundesamt Deutschland (2011) (Federal Statistical Office of Germany). The estimation of the log corrected gross wages is done with sample selection to correct for non-participation in the labor market. Thereafter, the result of the estimation is used to determine the personal reservation wages.

5 Simulation Design

The simulation of the labor market is built with the objective of getting a pseudo-panel with known reservation wages in order to examine the predictive power of the estimation approaches. The simulation is carried out nearly 1000 times, each time with a new randomly drawn subsample of 5000 observations out of the 42,603 total observations for two different scenarios of the reservation wages. The constant (decreasing) scenario assumes a stagnating (decreasing) reservation wage over the unemployment duration. The idea behind decreasing reservation wages is straightforward: an unsuccessful job searcher might lower his wage requests in order to improve his chance for re-employment. Both scenarios are designed such that they provide similar unemployment rates, since this would be observed in a real dataset without any prior knowledge of the underlying nature of the reservation wages.

The simulation design is presented below, an overview of the starting values for the constant (decreasing) scenario can be found in table 1. The simulation assumes that all persons are either employed or unemployed and are searching for a new job.

To determine the logarithmic reservation wages, the estimated β from the previous wage estimation are used [2]. The constant term is reduced by 0.4 and the estimated standard deviation has been shrunk by 90%. Furthermore, the reservation wages are set for 40 hours of work weekly and an unemployment rate of 7%. But before the defined reservation wages can be used, they have to be adjusted for outliers. Otherwise, very high reservation wages would determine an unemployment problem especially for persons with good labor market attraction. Thus, the reservation wages are cut for each of the qualification class at the mean of its reservation wages distribution plus 1.2 times its standard deviation.

The next preparatory variable concerns the number of layoffs per month. The only variable affecting the number of layoff is the assumed yearly GDP growth rate, which can be found in table 1. Since the simulation is based on monthly data, the weighted averages between the yearly assumed growth rates at time t and $t+1$ (with t=year) are used. The weights are set according to the position in time and will add up to one. The number of layoffs are determined for the constant (decreasing) scenario by a fixed base rate of 1.6 % (1.6%) of the total labor force and a variable rate of -0.1% (-0.1%) per 1% growth in the GDP. The base rate in empirical data is similar, for example Bachmann (2005) found a transition rate from employment to unemployment of 1.45% of the employed population while Elsby et al. (2008) found a rate of only 0.5% of labor force for Germany.

The outflow rate of unemployment, measured as percentage of the currently unemployed, consists of two different processes in this simulation: the probability of receiving a job offer and the probability that the offer is acceptable. Only the probability of receiving a job offer is determined in advance. The base rate is set to 25% (23%) of the unemployed while the

[2]The estimated β are: hours of work = 0.058; vocational training = 0.133; high vocational training = 0.1844; technical college = 0.3409; university = 0.4515; married = 0.0477; unemployment experience = -0.0991; unemployment experience^2 = 0.044; full-time experience = 0.0307; full-time experience^2 = -0.0005; tenure = 0.0046; tenure^2 = -0.0001; unemployment rate = -0.0029; lambda = 0.0705; constant = 7.3708.

variable component is set to 1 (1) percentage point per 1% change in the GDP growth. With these preparations, all required variables for the simulation are available. The simulation design is presented as a graphic in figure (1) and consists of 5 different steps, denoted by the circled number.

Step 1

The first step of the simulation is the job offer function. Since the number of offers is determined, only the allocation of the job offers to the unemployed persons remains. The main variable is the duration of the current unemployment spell up to its cubic form, it is assumed that people faces considerable problems reentering the labor market if they were unemployed long-time. The values for the function are $x * (-0.05)$, $x^2 * (-0.006)$ and $x^3 * (0.00028)$. Moreover, the whole function can be shifted upwards through higher education: vocational training yields 0.4 points more, high vocational training 0.5, technical college 0.8 and university 0.9 points. To ensure that the process remains random, an error term is added which is assumed to be normal distributed with mean 0 and standard deviation 4. The n persons with the highest total scores receive an offer.

Step 2

The next step is the determination of the wage offers. They are based on the reservation wage distribution for each qualification level in order to provide offers which are reasonable close to the reservation wages. The mean of each qualification group distribution is used as the mean of the corresponding wage offer distribution, whereas the standard deviation for each group is increased by the factor 2.5.

Together, step 1 and step 2 are determining the process of job search. Each person with a job offer decides thereafter to either accept the offer and to leave unemployment or to decline and to search further. The choice depends, of course, on the individual reservation wages.

Step 3

The third step covers the job loss process. Only the identification of the workers who lose their jobs is left since the number of job losses is calculated in advance. This is done by a function subject to the following variables and loadings: 0.5 for each year of unemployment experience, -0.025 for the squared unemployment experience, -0.25 for the tenure, 0.004 for the squared tenure. The idea behind choosing the unemployment experience is the concept of scars from unemployment and that previously laid-off workers might have attributes which make a new dismissal more likely. The tenure is working in the contrary direction since the theory of human capital states those longer employed workers are more useful for a firm. Furthermore, an error term and the qualification variables are included as well in the layoff function, see table 1 for the values. Again, as in step 2 the workers with the highest combined values in the above described variables lose their jobs.

Step 4

The fourth step covers the adjustment of variables. Most obviously, the employment status is changed each month depending on the previously described steps. Also the variables on

tenure, squared tenure, full-time experience, squared full-time experience, unemployment experience and squared unemployment experience are changed according to the employment status of the person. Furthermore, the unemployment duration and tenure are adjusted. The last thing to replace are the reservation wages for reemployed persons. This is done in order to ensure that the overall level of reservation wages for employed workers is not tending towards zero in the decreasing scenario. If the generated reservation wage is above the accepted wage offer, the wage offer is used instead as the new reservation wage.

Step 5

Every 12 months, the age is increased by one which would lead to a problem with the age distribution in the sample. Since the range of the sample is restricted to those aged of 30-55, the first increase would delete the oldest workers and would simultaneously cause the disappearance of the class of 30 year old persons. To solve this problem and to maintain the original sample size of 5000 observations it is necessary to conduct an age transformation, i.e. rewriting the age of all 56 year old people to 30. Most of their variables have to be changed as well. What remains unchanged are the qualification level (and regional dummies, marital status) for reasons of simplification but the tenure, unemployment experience, and full-time experience are replaced. This is done according to the qualification level of the person. For each of the replaced variables, the real distribution for the 30 year olds in its corresponding qualification group in the GSOEP is analyzed. Based on this real distribution, each person "draws" a value out of it. The employment status is arbitrarily set to the original status of the person in the GSOEP. Of course, all transformed persons get a new reservation wage and a new wage in the case that they are employed. Like before, new reservation wages are controlled for outliers.

After the age transformation, some adjustments for all other persons in the sample are made. Once every 12 months, their wages and reservation wages are adjusted in order to accommodate changes in variables like tenure or full-time experience. This is done by calculating the change from the previous year until the current year for all metric variables and multiplying these changes by their corresponding coefficients.

The last step in the panel simulation is the storage of the data each year, given that the calibration phase of 50 years is completed.

For decreasing reservation wages, an additional step is included in the simulation. In this case, the duration of unemployment is assumed to have an influence on the reservation wages. More precisely, the reservation wages are assumed to decrease by 1% every month of unemployment for persons with medium or low reservation wages. High reservation wages are decreasing by 2% each month. This is done since it is assumed that persons with comparable high reservation wages will recognize their exaggerated wage requests and therefore lower the level more quickly. The affiliation to the quickly decreasing group is determined through the relative position of persons compared to all other persons in the same qualification group, regardless of their labor market status. If a person exceeds the maximum reservation wage defined by the group mean plus the group standard deviation, he will belong to the fast

decreasing group until he falls short of it again.

The final outcome in both scenarios is a panel of seven years, consisting of 35,000 observations by merging the saved data from each year together. But in advance of the seven simulated years used, a calibration period of 50 years is conducted. Thereafter, the estimators are applied on the pseudo-panel and the whole process is repeated approx. 1000 times in the Monte Carlo simulation.

6 Results

The results of the Monte Carlo simulation are presented in two parts. The first part discusses the scenario with constant reservation wages and the second part with decreasing reservation wages. For both scenarios, the results from the different estimation approaches are compared. The subsample for the Kiefer-Neumann approach is restricted in a similar manner to Christensen (2005). Thus, observations are only used if they are unemployed but had a visible job spell before, or if they even found a new job. The restriction about the existence of a previous employment spell is necessary since the wage before unemployment is used as a regressor. Furthermore, the Kiefer-Neumann approach assumes that the reservation wages are affected by three different groups of variables. The first group (denoted by x_i^o) is assumed to affect the search costs only, the second group (x_i^o) to affect the wage offer only and the third group ($x_i^{o,r}$) to affect both. Search costs are assumed to have a direct influence on reservation wages, which can be easily seen from equation (1). The second group influences the reservation wages through a change in the mean wage offer and the third group via both channels. The first group consists solely of the unemployment rate which is separated by qualification levels. The second group consists of the (log) last wage before unemployment and the marital status. The influence of the last wage before unemployment is quite obvious, since newly employed persons will stay, in many cases, reasonably close to their previous wage. The marital status is included as many studies estimate a relationship between marriage and income, for example Antonovics and Town (2004) supports these findings. The third group of variables is assumed to affect the reservation wage through both possibilities and consists of the following variables: full-time experience, squared full-time experience, tenure before unemployment, squared tenure before unemployment, unemployment experience, squared unemployment experience, qualification (low vocational, medium vocational, high vocational, technical college, university) and the GDP growth rate.

The remainder of the paper presents the predictive power for the different estimation approaches and different reservation wage scenarios[3]. This is examined by an auxiliary regression of the predicted (log) reservation wages on the true simulated (log) reservation wages, using the explained part of the total variance as a measure for the predicting power alongside with the prediction itself. Prior to that, the individual reservation wages have to

[3]The estimated coefficients of both approaches in both scenarios are not presented in this work. They are available upon request from the author.

be calculated according to equation (11) by using the predicted cost efficiency $\widehat{q_i}$. But in order to improve the comparability with the Kiefer Neumann estimators, the log version of equation (11) is taken

$$w_{it}^r = w_{it} - ln(q_{it}) \tag{22}$$

where w_{it} and w_{it}^r are the logarithm of the corresponding values.

The results are compared for different subsamples of the simulated data: five-year age-group, for a boom cycle of the GDP growth in the simulation years 51-54 and for a bust cycle in the years 55-57 [4]. Furthermore, a distinction between qualification groups is made where "low qualification" corresponds to persons with low or medium vocational training, "medium qualification" corresponds to persons with high vocational training and "high qualification" to persons with academic qualification.

All wages and reservation wages are estimated in logs but presented in non-log to facilitate the comparison. The r-squares in the outputs refer to a regression of the log-predicted reservation wage on the log-simulated reservation wage.

6.1 Constant Reservation Wages

The constant scenario assumes stable reservation wages over the unemployment period. The summary statistics over all 996 simulated samples can be found in the upper part of table 3. The mean unemployment rate of 9.4% and the mean unemployment duration of 7.8 months provide a sufficient base for an adequate transition between unemployment and employment. The average simulated reservation wage is located at 1800.2€ while the average simulated labor income is located slightly higher at 2083.7€.

The results for the frontier estimators are presented first. For them in general, a correct and sufficient skewness of the error term is essential. A negative skewness would lead to production frontier estimators and a positive skewness to cost frontier estimators. Since the objective is to predict reservation wages which are located below the log-wage, a regression of all exogenous variables on the log-wage should result in positively skewed error terms. Indeed, the results for the Monte Carlo simulation reveal a positive average skewness of 0.65 which is larger than 0 for all repetitions.

The results for the frontier estimator with normal-half normal distributed error terms in column 3 of tables 4-6 indicate a fairly good prediction of the reservation wages. The mean reservation wage is predicted in the main model with 1746.6€ which is slightly lower than the true mean reservation wage at 1833.4€. Nevertheless, the half-normal frontier model is able to explain 83 % of the variance of the true simulated reservation wages. The subgroup analysis reveals no remarkable drop in the quality of the prediction for the age-groups and the business cycles, the r-squared stays always above or equal to 80%. A sharp drop in the r-squared can be observed with regard to the qualification subgroups but with still a good mean prediction of the reservation wage. The lower r-squared is caused by the dropout of

[4] The first 50 years are the calibration phase.

the qualification variables which was one of the most important variables in the simulation design.

The second frontier model is the time-invariant model. Compared to the previous model, the additional restriction is imposed that the cost efficiency will not change over time, i.e. that the quasi-rents remain constant. Furthermore, the efficiency term is assumed to follow a truncated normal distribution which necessitates the estimation of the additional parameter μ, the mean of the efficiency term. The results for the prediction are presented in column 4 of tables 4-6 [5]. The first striking difference in the results is the higher underestimation of the true average reservation wage with an outcome of 1697.2€ in the main model. Furthermore, the r-squared is low with only 53%. The different subgroups indicate a slightly decreasing accuracy of the prediction for older age groups. The r-squared for the qualification groups is practically zero, except for the highest two groups where 15% and 39% are attained. Altogether, the results are disappointing if they are compared to the first frontier estimator.

The last model of the frontier class is the time-varying decay model whose results are presented in column 5 of tables 4-6[6]. The special assumption in this model is the decreasing, increasing or constant efficiency term, thus the quasi-rents are allowed to differ over time within one person according to $u_{it} = \eta_{it} u_{it} = \exp[\eta(t - T_i)]u_i$. Compared to the cross sectional normal-half normal model, the additional parameter of μ and η have to be estimated which denotes the mean of the efficiency and time decay, respectively. The results for the main model show a predicted mean reservation wage of 1668.7€ which is even lower than the result for the time-invariant model. Nevertheless, the r-squared is somewhat better with 65% but still worse than the results from the half-normal frontier estimator. The subgroup analysis reveals practically no differences between the main model and the different age groups and business cycles. The division of the simulated sample in different qualification groups can be found in in table 6. The results show a low r-squared and persistent underestimation of the mean simulated reservation wage, comparable with the time-invariant model. The slightly higher r-squared compared with the previous model does not hide the fact that the model got most of its predictive power from the qualification model. Moreover, the time-varying model has a higher standard deviation of its prediction over the Monte Carlo simulation, even if the sample size is exactly the same as with the other two frontier models. This finding of increased instability is underlined by the fact that the estimator did not converge for 13 repetitions.

The approach from Kiefer and Neumann focuses on the prediction of reservation wages for unemployed persons. Three different realizations of the estimator are presented in this work[7]. The results from the first one can be found in column 6 of tables 4-6, it uses all available observations that fulfill the defined restrictions. In addition, the second model is restricted

[5] Results are based on 994 observations. The estimator did not converged for 2 repetitions.

[6] Results are based on 983 observations. The estimator did not converged for 13 repetitions.

[7] Repetitions are dropped if the estimated reservation wage is greater than 5000€ which indicates problems with estimation. First model: 7 repetitions dropped. Second model: 8 repetitions dropped. Third model: 43 repetitions dropped.

to observations with less than 13 month of current unemployment duration or less than 13 month of completed unemployment duration. The results can be found in column 7 of tables 4-6. The third model is restricted to completed and current unemployment durations of 13 to 24 months and is presented in column 8 of tables 4-6. The separation in sub-models two and three is done in order to examine the ability of the Kiefer-Neumann approach to detect decreasing or constant reservation wages. The overall low level of the simulated reservation wages in the Kiefer-Neumann sample of 1474.6€ compared to the reservation wages in the full sample of 1833.4€ is caused by the lack of persons with good affiliation to the labor market in the subsample. In the simulation, persons with good affiliation (wages) to the labor market are very likely to stay employed or to quickly find a new job.

The full main model in column 6 reveals overestimation of the mean reservation wage. The average prediction is with 1971.9€ remarkably higher than the mean simulated reservation wage of 1474.6€. Nevertheless, the prediction from the full Kiefer-Neumann estimator is able to explain 77 % of the variance of the true simulated reservation wages in the subsample of 2046 unemployed observations. The subgroup analysis reveals a nearly constant r-squared over the age groups with only small changes for the average predicted and simulated reservation wage. But the Kiefer-Neumann estimator seems to have increased problems estimating the reservation wages in the case of higher education, a somewhat reversed result compared to the frontier models.

The question of decreasing or constant reservation wages is addressed by the sub-models for different length of unemployment duration, listed in the columns 7 and 8 of tables 4-6. The difference of the real reservation wages between the short unemployment sub-model and the long unemployment sub-model is small at 1449.6€ to 1482€. The slight observable increase is caused by the fact that persons with higher reservation wages are faced with more problems finding a new job. However, the Kiefer-Neumann estimator predicts a decrease of the average reservation wage from 1989.5€ to 1946€ and is less able to explain the true reservation wages. The r-squared decreases from 76% for persons with a short unemployment period to 55% for persons a longer unemployment period. Furthermore, the standard deviations increase remarkably for longer unemployment duration, which is caused by the very small subsamples of data. The simulated sample offers on average only 359 observations with current unemployment duration longer than 12 months, a fairly small number if it is compared to the 31696.5 observations which could be used by the frontier models. Moreover, the Monte Carlo simulation produces changing subgroups over the repetitions which cause great volatility in the predicted reservation wages as well.

6.2 Decreasing Reservation Wages

The decreasing scenario assumes declining reservation wages over the unemployment period. The summary statistics over the 969 simulated samples can be found in the lower part of table 3. Compared to the constant reservation wages, some differences which are caused by

the simulation design can be observed. The average unemployment rate is, at 9.6%, nearly similar to those of the constant scenario, but the average unemployment duration and the average reservation wage is, unsurprisingly, lower. Furthermore, the simulated wage is, at 2077€, lower in the current scenario.

The results for the three frontier estimators can be found in columns 3 - 5 of tables 7 - 9. Again, the auxiliary regression (22) is used to determine the accuracy of the estimators and the results are reported for different subgroups. The required skewness of the error term distribution of a log-wage regression with all exogenous variables is given with a mean value of 0.646. Thus, the cost frontier models are applicable.

The main model of the normal-half normal frontier estimator (column 3) shows a nearly unchanged average prediction of the reservation wages, but with a higher r-squared of the auxiliary regression compared to the constant scenario. More detailed, the average predicted reservation wage is, at 1736.2€, again close to the true simulated value of 1837.7€, and the model is able to explain 87% of the variance. The outcome of a better explanation of the variance compared to the constant scenario carries over for the subgroup analysis of age, business cycles and qualification groups.

The panel estimator with time-invariant quasi-rents is viewed next, results are listed in column 4 of tables 7 - 9. The main model shows less evidence of underestimation in the decreasing scenario, the mean predicted reservation wage is, at 1717€, closer to the true value. Nevertheless, the r-squared of the auxiliary regression for the main model remains low at 58%. Compared to the constant scenario, the results of the time-invariant estimator are slightly improved for the different subgroups.

The same holds for the time-varying decay model whose results can be found in column 5 of tables 7 - 9[8]. The quality of the predictions are slightly increased for all subgroups. The main model exhibits an r-squared of 70% but still suffers from the problem of underestimation. Since better working stochastic frontier estimators are available, the result is not impressively high.

The small differences between the reservation wage scenarios of the frontier estimators are neither astonishing nor unexpected since the frontier estimator uses only information on employed persons. Thus, a change in the reservation wages for unemployed persons can hardly be detected. This is caused by the simulation design, since an unemployed person who accepts a job offer will be paid with exactly that accepted wage. Thus, the only possibility for the frontier estimator to detect lower reservation wages is through decreased accepted wages but the fraction of newly employed workers in the sample is limited. Furthermore, it has to be kept in mind that the reservation for new employed workers is set to some value below the accepted wage but possibly above their current reservation wage during unemployment which could have been markedly decreased. Altogether, the frontier models are faced with similar problems than in the constant simulation scenario. The prediction quality from the panel estimators is somewhat lower and their variance is significantly higher (on average

[8]Results are based on 931 observations. The estimator did not converged for 38 repetitions.

over all simulations), indicating problems with instability. Only the normal-half normal stochastic frontier estimator shows acceptable results, but it overestimates the reservation wages as well. However, the simplest model of the frontier estimators seems to produce the best results.

The Kiefer-Neumann estimator, listed in columns 6 - 8 of tables 7 - 9, is faced with the same problems as in the constant scenario[9]. A high overestimation of the average reservation wage and a high standard deviation over the different repetition of the simulation through changing subsamples can be seen. The sample size of unemployed persons which fulfill the restrictions consists, on average, of 1874 observations with an unemployment duration lower than 12 months and 326 observations with a duration longer than 24 months.

The results for the full main model reveal the nearly unchanged fraction of explained variance of 73% compared to the constant reservation wage scenario. This carries over to the analysis of the subsamples, neither of which exhibit much change. Concerning the question of a detection of decreasing reservation wages, the Kiefer-Neumann estimator is able to predict the direction correctly (column 7 and 8). But this was already attained for nearly the same amount in the constant scenario where the real average reservation wage stayed nearly constant for the different unemployment durations. In the current scenario, the reservation wage is decreasing by construction which can be confirmed from average real values. Thus, the Kiefer-Neumann estimator is, at least in the chosen simulation setting, not a reliable predictor of decreasing reservation wages. But it has to be mentioned that the standard deviations between the simulations are very high, thus even small changes in the attributes of the persons in the sample would lead to significant differences in the estimation outcome.

A striking fact of the Kiefer-Neumann estimator is the low r-squared of the auxiliary regression for higher unemployment durations. Increased problems estimating the reservation wages for the long-term unemployed were found elsewhere as well, i.e. in the work of Christensen (2005). One reason for the problem is, of course, the low number of observations compared to short-term unemployed estimation. But another reason might be the estimation design. Like all other discussed works with an application of the Kiefer-Neumann estimator, this work assumes that the offer arrival rate equals one even if it is known from the simulation design that this is a wrong assumption. The Kiefer-Neumann approach tries to estimate the probability of accepting a given job offer in the first step in order to detect in a second step a sample selection bias in the accepted wage regression. But in the case of an offer arrival rate smaller than one, the probit will estimate not only the probability that the wage offer is greater than the reservation wage but also the probability of receiving an job offer at the same time. This fact is very likely to occur in a real labor market as well since it is known that long-term unemployed are faced with problems receiving any offers at all. Altogether, these two facts might explain the problems the Kiefer-Neumann estimator

[9]Repetitions are dropped if the estimated reservation wage is greater than 5000€. First model: 36 repetitions dropped. Second model: 42 repetitions dropped. Third model: 93 repetitions dropped.

has to find correct reservation wages for long-term unemployed persons and to provide an reliable measure of constant or decreasing reservation wages.

7 Conclusion

This paper has analyzed the predictive power of different estimation methods for individual reservation wages. The first class of models consisted of stochastic frontier models. More precisely, a frontier model with normal-half normal error terms, a panel data stochastic frontier with constant quasi-rent and a panel data stochastic frontier with time-invariant quasi-rents were used. All of these models used a one-sided error to predict the reservation wages for employed persons. The second class of models used the approach from Kiefer and Neumann in order to predict the reservation wages for unemployed persons. This allowed the consideration of the question of decreasing/constant reservation wages over the unemployment duration. The comparison was carried out by a Monte Carlo simulation which used the German Socio-Economic Panel as a basic framework for the simulation of a labor market. The simulation itself modeled reservation wages and working wages alongside with a transition path from unemployment to employment and vice versa. For testing the ability to detect constant/decreasing reservation wages over the unemployment period, two different simulation scenarios were considered with different specifications of the reservation wages. The predictive power of all approaches in both scenarios was compared by the average results over all repetitions from an auxiliary regression.

For employed persons, the paper showed the best results for the most simple stochastic frontier model with normal-half normal distributed error terms. Both panel models failed to attain the same level of explained variance and showed a higher underestimation of the reservation wages. This finding held for both simulation designs and for all subgroup analyses. For unemployed persons, the Kiefer-Neumann estimator was unable to provide the same level of r-squared as the simple stochastic frontier model did for employed. Furthermore, the Kiefer-Neumann estimator suffered from a severe overestimation of the average reservation wage in both scenarios. In addition, the paper showed the unreliability of the Kiefer-Neumann estimator to detect decreasing reservation wages over the unemployment period. The estimator predicted decreasing reservation wages for long-term unemployed in both scenarios. However, the approach from Kiefer and Neumann suffered from two drawbacks. The first was the known and wanted misspecification of the job offer probability, which is used frequently in application. The second evolved from the fairly small number of observations which could be used for the estimation, especially the lack of long-term unemployed persons.

A Appendix

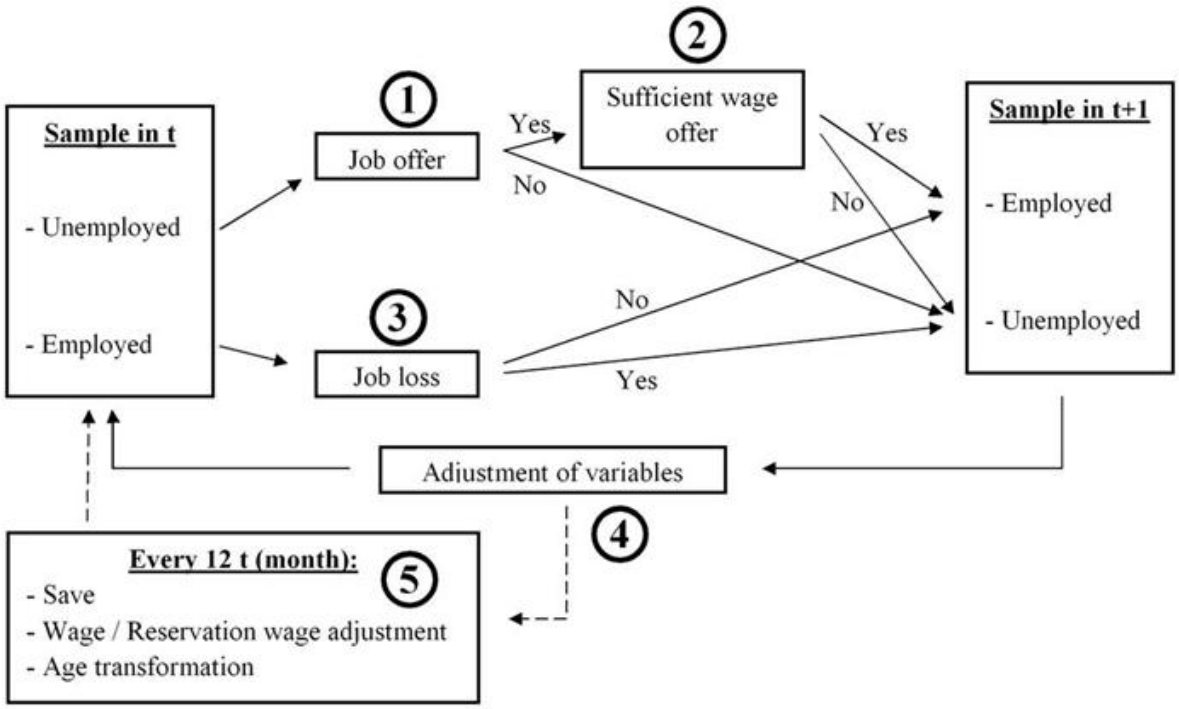

Figure 1: Simulation Design

Table 1: Simulation Values

Variable	Constant	Decreasing
Growth rate of GDP		
Year 1-51	1	1
Year 52	1.3	1.3
Year 53	-2.5	-2.5
Year 54	0.3	0.3
Year 55	3.6	3.6
Year 56	2.1	2.1
Year 57	1.8	1.8
Year 58	2.3	2.3
Pseudo Wage:		
SD in % of original SD	10	10
Layoff rate:		
Base rate (% of labor force)	1.5	1.6
GDP influence	-0.1	-0.1
Layoff function		
Unemployment experience (x^1)	0.5	0.5
Unemployment experience (x^2)	-0.025	-0.025
Tenure (x^1)	-0.25	-0.25
Tenure (x^2)	0.004	0.004
Low vocational	-0.10	-0.10
Medium vocational	-0.13	-0.13
High vocational	-0.18	-0.18
Technical college	-0.25	-0.25
University	-0.20	-0.20
Potential experience	0.06	0.06
Standard deviation	2.2	2.2
Job offer rate:		
Base rate (% of unemployed)	25	23
GDP influence	1	1
Job offer function:		
Standard deviation	2	2
Unemployment duration (x^1)	-0.05	-0.05
Unemployment duration (x^2)	-0.006	-0.006
Unemployment duration (x^3)	0.00028	0.00028
Low vocational	0.15	0.15
Medium vocational	0.18	0.18
High vocational	0.20	0.20
Technical college	0.25	0.25
University	0.25	0.25
Wage offer distribution:		
Mean in % of the mean reservation wage	100	100
SD in % of the SD of the reservation wage	250	250

Table 2: Descriptive Statistics (GSOEP)

Variable	Mean	Std. dev.	Min	Max
Log wage	8.190	0.408	6.685	10.902
Potential experience	23.604	7.827	6	42
Potential experience^2	618.406	378.230	36	1764
Full-time experience	19.251	8.644	0	40
Full-time experience^2	445.336	347.579	0	1600
Tenure	12.527	9.779	0	41.4
Tenure^2	252.561	316.277	0	1713.96
Unemployment experience	0.445	1.478	0	28
Unemployment experience^2	2.384	18.715	0	784
Hours of work	44.360	7.130	30	80
North Germany*	0.205	0.404	0	1
West Germany*	0.357	0.479	0	1
South Germany*	0.437	0.496	0	1
Marital status*	0.764	0.425	0	1
No qualifications*	0.082	0.275	0	1
Vocational training*	0.617	0.486	0	1
High vocational training*	0.074	0.262	0	1
Technical college*	0.084	0.274	0	1
University*	0.143	0.35	0	1
Migration background*	0.033	0.18	0	1
House owner*	0.545	0.498	0	1
Unemployment rate	8.802	1.147	6.2	11

*=Dummy variable
Sources: GSOEP (2010); own calculations.

Table 3: Descriptive Statistics for the simulated data
Average results over all simulations for the full sample

Variable	Mean	Std. dev.	Min	Max
Constant scenario				
Unemployment rate	9.439	0.124	8.994	9.837
Duration of unemployment	7.862	0.145	7.346	8.392
Wage	2083.747	22.63	2021.245	2134.668
Reservation wage	1800.238	24.706	1720.737	1863.854
Full-time experience	18.682	0.19	17.960	19.236
Full-time experience^2	406.748	7.339	378.604	429.498
Tenure	13.058	0.269	12.251	14.041
Tenure^2	272.126	9.768	244	308.346
Unemployment experience	1.663	0.156	1.259	2.272
Unemployment experience^2	10.73	1.763	6.52	17.891
Marital Status*	0.764	0.005	0.746	0.778
No qualifications*	0.082	0.004	0.07	0.094
Low vocational*	0.4	0.006	0.379	0.419
Medium vocational*	0.217	0.005	0.199	0.235
High vocational*	0.074	0.003	0.063	0.09
Technical college*	0.084	0.004	0.073	0.094
University*	0.143	0.004	0.129	0.158
Decreasing scenario				
Unemployment rate	9.6	0.117	9.249	9.934
Duration of unemployment	7.349	0.104	7.003	7.651
Wage	2077.285	21.1514	2014.201	2131.211
Reservation wage	1793.005	23.138	1721.419	1857.572
Full-time experience	18.660	0.197	8.087	19.309
Full-time experience^2	405.806	7.462	385.634	431.191
Tenure	12.978	0.263	12.209	13.810
Tenure^2	270.22	9.403	241.911	298.168
Unemployment experience	1.686	0.161	1.216	2.191
Unemployment experience^2	11.141	1.872	6.271	17.962
Marital Status*	0.763	0.005	0.743	0.781
No qualifications*	0.082	0.004	0.071	0.093
Low vocational*	0.4	0.007	0.383	0.421
Medium vocational*	0.217	0.006	0.197	0.233
High vocational*	0.074	0.003	0.064	0.084
Technical college*	0.084	0.0038	0.0734	0.098
University*	0.143	0.005	0.127	0.158

*=Dummy variable

Sources: GSOEP (2010); own calculations.

Table 4: Constant scenario: comparison part 1
Means of estimated coefficients, standard deviations in parenthesis

		Frontier estimators			Kiefer-Neumann estimators		
	Variable	Half Normal	Time-invariant	Time-varying	Full model	Duration ≤ 12	Duration > 12
Main model	Real res. wage	1833.37	1833.37	1833.37	1474.64	1449.61	1482.45
		(24.12)	(24.12)	(24.12)	(42.37)	(40.04)	(40.73)
	Est. res. wage	1746.63	1697.21	1668.7	1971.9	1989.46	1945.99
		(25.81)	(53.06)	(94.25)	(382.18)	(422.6)	(841.23)
	R-squared	0.83	0.53	0.65	0.77	0.76	0.55
		(0.02)	(0.05)	(0.03)	(0.14)	(0.16)	(0.24)
	Obs.	31696.49	31696.49	31696.49	2146.23	1787.02	359.04
		(43.57)	(43.57)	(43.57)	(40.11)	(32.44)	(20.22)
Age<36	Real res. wage	1814.86	1814.86	1814.86	1553.16	1534.21	1651.56
		(25.84)	(25.84)	(25.84)	(61.54)	(61.16)	(81.22)
	Est. res. wage	1716.23	1814.85	1640.86	2014.28	2034.57	1983.13
		(27.74)	(25.86)	(92.3)	(359.27)	(401.44)	(802.13)
	R-squared	0.8	0.55	0.66	0.75	0.76	0.56
		(0.02)	(0.05)	(0.04)	(0.14)	(0.15)	(0.24)
	Obs.	7291.67	7291.67	7291.67	219.39	183.54	35.88
		(130.06)	(130.06)	(130.06)	(21.45)	(17.66)	(7.02)
35<age<41	Real res. wage	1823.26	1823.26	1823.26	1482.68	1461.58	1581.03
		(24.83)	(24.83)	(24.83)	(52.87)	(51.62)	(70.73)
	Est. res. wage	1735.29	1685.74	1659.36	1980.92	2002.04	1963.24
		(26.69)	(53.09)	(93.5)	(368.65)	(413.81)	(819.62)
	R-squared	0.82	0.54	0.65	0.76	0.76	0.57
		(0.02)	(0.05)	(0.04)	(0.14)	(0.16)	(0.24)
	Obs.	6881.25	6881.25	6881.25	339.12	278.48	60.44
		(112.33)	(112.33)	(112.33)	(28.08)	(22.61)	(9.73)
40<age<46	Real res. wage	1840.59	1840.59	1840.59	1471.63	1448.37	1583.48
		(24.79)	(24.79)	(24.79)	(48.73)	(46.64)	(68.89)
	Est. res. wage	1752.54	1703.06	1675.07	1968.65	1989.27	1971.79
		(26.24)	(53.73)	(94.88)	(379.36)	(421.29)	(863.34)
	R-squared	0.84	0.53	0.66	0.77	0.77	0.59
		(0.02)	(0.05)	(0.03)	(0.15)	(0.16)	(0.24)
	Obs.	6533.81	6533.81	6533.81	449.95	372.11	77.78
		(111.84)	(111.84)	(111.84)	(28.49)	(23.96)	(10.06)

Table 5: Constant scenario: comparison part 2
Means of estimated coefficients, standard deviations in parenthesis

		Frontier estimators			Kiefer-Neumann estimators		
	Variable	Half Normal	Time-invariant	Time-varying	Full model	Duration ≤ 12	Duration > 12
45<age<51	Real res. wage	1848.56	1848.56	1848.56	1463.92	1436.64	1600.35
		(24.42)	(24.42)	(24.42)	(45.01)	(41.24)	(73.17)
	Est. res. wage	1765.91	1717	1686.46	1962.5	1981.05	1990.71
		(25.49)	(53.54)	(95.74)	(392.27)	(428.33)	(908.69)
	R-squared	0.86	0.5	0.66	0.78	0.77	0.6
		(0.01)	(0.05)	(0.03)	(0.15)	(0.16)	(0.2)
	Obs.	5886.3	5886.3	5886.3	544.27	453.57	90.64
		(115.26)	(115.26)	(115.26)	(30.64)	(25.82)	(10.98)
Age>50	Real res. wage	1846.67	1846.67	1846.67	1453.75	1425.44	1603.63
		(25.09)	(25.09)	(25.09)	(39.79)	(35.73)	(77.04)
	Est. res. wage	1775.48	1722.14	1692.44	1963.01	1974.28	2012.32
		(25.69)	(54.41)	(96.61)	(417.94)	(434.71)	(966.63)
	R-squared	0.86	0.5	0.67	0.77	0.75	0.59
		(0.01)	(0.05)	(0.03)	(0.15)	(0.16)	(0.26)
	Obs.	5103.46	5103.46	5103.46	593.49	499.31	94.29
		(105.13)	(105.13)	(105.13)	(34.14)	(29.25)	(11.24)
Year 1-4	Real res. wage	1837.47	1837.47	1837.47	1489.4	1475.86	1580.22
		(24.16)	(24.16)	(24.16)	(44.61)	(43.37)	(58)
	Est. res. wage	1748.38	1698.16	1670.09	1989.19	2013.57	1988.71
		(25.79)	(53.23)	(94.41)	(427.18)	(479.71)	(893.41)
	R-squared	0.83	0.54	0.66	0.78	0.77	0.58
		(0.02)	(0.04)	(0.03)	(0.14)	(0.15)	(0.25)
	Obs.	17941.87	17941.87	17941.87	1064.92	926	138.8
		(30.38)	(30.38)	(30.38)	(26.75)	(22.54)	(11.15)
Year 5-7	Real res. wage	1828.03	1828.03	1828.03	1460.08	1421.37	1611.99
		(24.1)	(24.1)	(24.1)	(41.2)	(37.54)	(59.33)
	Est. res. wage	1744.35	1695.97	1666.89	1954.87	1963.52	1985.91
		(25.86)	(52.86)	(94.05)	(343.6)	(364.63)	(881.40)
	R-squared	0.84	0.51	0.65	0.77	0.78	0.57
		(0.02)	(0.05)	(0.03)	(0.14)	(0.15)	(0.24)
	Obs.	13754.62	13754.62	13754.62	1081.31	861.02	220.23
		(22.58)	(22.58)	(22.58)	(23.99)	(19.42)	(15.19)

Table 6: Constant scenario: comparison part 3
Means of estimated coefficients, standard deviations in parenthesis

		Frontier estimators			Kiefer-Neumann estimators		
	Variable	Half Normal	Time-invariant	Time-varying	Full model	Duration ≤ 12	Duration > 12
No qualifications	Real res. wage	1474.08	1474.08	1474.08	1275.17	1257.10	1351.81
		(57.42)	(57.42)	(57.42)	(47.49)	(45.41)	(62.69)
	Est. res. wage	1462.47	1488.62	1417.34	1818.78	1841.63	1824.33
		(47.92)	(47.62)	(80.96)	(383.25)	(414.27)	(851.18)
	R-squared	0.76	0.04	0.22	0.69	0.68	0.46
		(0.05)	(0.03)	(0.05)	(0.2)	(0.21)	(0.27)
	Obs.	2064.41	2064.41	2064.41	488.39	393.43	94.68
		(161.6)	(161.6)	(161.6)	(77.83)	(61.48)	(19.13)
Low qualifications	Real res. wage	1679.26	1679.26	1679.26	1459.92	1438.27	1580.18
		(28.99)	(28.99)	(28.99)	(43.9)	(41.43)	(58.22)
(low vocational and	Est. res. wage	1610.26	1567.84	1538.6	1955.84	1973.35	1958.52
medium vocational)		(28.86)	(48.42)	(86.18)	(373.03)	(412.79)	(857.86)
	R-squared	0.59	0.05	0.19	0.65	0.63	0.4
		(0.06)	(0.03)	(0.06)	(0.18)	(0.2)	(0.24)
	Obs.	19391.31	19391.31	19391.31	1469.09	1245.24	223.81
		(254.22)	(254.22)	(254.22)	(97.21)	(83.47)	(20.04)
Medium qualifications	Real res. wage	1932.88	1932.88	1932.88	1863.41	1829.41	2001.09
		(49.01)	(49.01)	(49.01)	(78.129)	(72.2)	(115.47)
(high vocational)	Est. res. wage	1818.66	1747.88	1730.37	2243.55	2270	2253.97
		(43.05)	(66.69)	(105.65)	(427.07)	(486.9)	(1005.94)
	R-squared	0.49	0.15	0.23	0.56	0.6	0.38
		(0.08)	(0.06)	(0.07)	(0.2)	(0.22)	(0.29)
	Obs.	2505.91	2505.91	2505.91	57.07	45.91	11.12
		(119.01)	(119.01)	(119.01)	(21.96)	(18.03)	(5.23)
High qualifications	Real res. wage	2282.09	2282.09	2282.09	2266.04	2215.09	2441.49
		(39.63)	(39.63)	(39.63)	(77.21)	(73.54)	(96.14)
(academic education)	Est. res. wage	2140.12	2060.20	2041.19	2641.38	2664.43	2645.89
		(36.15)	(73.71)	(123.00)	(512.16)	(578.7)	(1165.37)
	R-squared	0.63	0.39	0.46	0.51	0.57	0.30
		(0.07)	(0.09)	(0.08)	(0.17)	(0.19)	(0.23)
	Obs.	7734.86	7734.86	7734.86	131.69	102.43	29.42
		(195.54)	(195.54)	(195.54)	(38.85)	(31.54)	(9.57)

Table 7: Decreasing scenario: comparison part 1
Means of estimated coefficients, standard deviations in parenthesis

		Frontier estimators			Kiefer-Neumann estimators		
	Variable	Half Normal	Time-invariant	Time-varying	Full model	Duration ≤ 12	Duration > 12
Main model	Real res. wage	1837.72	1837.72	1837.72	1374.31	1395.5	1371.81
		(22.68)	(22.68)	(22.68)	(37.63)	(37.67)	(35.76)
	Est. res. wage	1736.19	1716.96	1679.72	1961.53	2007.35	1899.65
		(24.19)	(27.03)	(106.07)	(418.77)	(454.52)	(826.22)
	R-squared	0.87	0.58	0.7	0.73	0.73	0.5
		(0.01)	(0.03)	(0.03)	(0.14)	(0.15)	(0)
	Obs.	31639.86	31639.86	31639.86	2200.34	1874.29	325.99
		(40.81)	(40.81)	(40.81)	(41.24)	(32.51)	(17.82)
Age<36	Real res. wage	1817.47	1817.47	1817.47	1444.75	1466.59	1313.26
		(24.11)	(24.11)	(24.11)	(55.09)	(56.22)	(67.45)
	Est. res. wage	1705.73	1686.57	1651.21	1989.59	2035.24	1896.46
		(25.87)	(27.74)	(103.79)	(384.84)	(432.36)	(767.25)
	R-squared	0.83	0.6	0.69	0.76	0.74	0.53
		(0.02)	(0.03)	(0.03)	(0.14)	(0.15)	(0.24)
	Obs.	7299.91	7299.91	7299.91	228.53	196.64	31.85
		(127.98)	(127.98)	(127.98)	(23.14)	(19.43)	(6.48)
35<age<41	Real res. wage	1827.38	1827.38	1827.38	1378.93	1402.78	1253.72
		(23.13)	(23.13)	(23.13)	(46.69)	(47.65)	(52.78)
	Est. res. wage	1724.84	1704.22	1669.94	1961.34	2009.18	1878.35
		(24.86)	(27.42)	(105.15)	(397.33)	(445.52)	(787.55)
	R-squared	0.86	0.59	0.68	0.75	0.74	0.54
		(0.01)	(0.03)	(0.03)	(0.15)	(0.16)	(0.23)
	Obs.	6869.7	6869.7	6869.7	353.66	297.72	56.08
		(113.14)	(113.14)	(113.14)	(27.73)	(22.93)	(8.69)
40<age<46	Real res. wage	1844.73	1844.73	1844.73	1369.15	1391.42	1247.35
		(23.51)	(23.51)	(23.51)	(42.98)	(43.13)	(51.36)
	Est. res. wage	1741.94	1722.75	1685.71	1956.75	2003.33	1885.64
		(24.79)	(27.42)	(106.69)	(412.39)	(452.91)	(824.68)
	R-squared	0.88	0.58	0.7	0.75	0.75	0.55
		(0.01)	(0.03)	(0.03)	(0.15)	(0.16)	(0.23)
	Obs.	6521.29	6521.29	6521.29	461.83	391.07	70.88
		(117.58)	(117.58)	(117.58)	(28.62)	(24.23)	(9.46)

Table 8: Decreasing scenario: comparison part 2
Means of estimated coefficients, standard deviations in parenthesis

		Frontier estimators			Kiefer-Neumann estimators		
	Variable	Half Normal	Time-invariant	Time-varying	Full model	Duration ≤ 12	Duration > 12
45<age<51	Real res. wage	1854.17	1854.17	1854.17	1362.63	1382.78	1247.71
		(24.01)	(24.01)	(24.01)	(39.71)	(39.51)	(49.22)
	Est. res. wage	1756.06	1738.74	1698.36	1955.96	2001.4	1899.93
		(24.66)	(27.58)	(107.95)	(426.89)	(460.76)	(862.46)
	R-squared	0.89	0.56	0.7	0.73	0.74	0.53
		(0.01)	(0.03)	(0.03)	(0.15)	(0.16)	(0.22)
	Obs.	5863.87	5863.87	5863.87	553.88	472.02	81.80
		(108.87)	(108.87)	(108.87)	(32.12)	(27.37)	(9.71)
Age>50	Real res. wage	1852.78	1852.78	1852.78	1360.5	1379.9	1244.24
		(23.29)	(23.29)	(23.29)	(35.29)	(34.83)	(46.99)
	Est. res. wage	1764.93	1745.23	1704.67	1960.32	2004.96	1920.49
		(23.9)	(27.77)	(108.66)	(446.63)	(466.73)	(911.55)
	R-squared	0.89	0.57	0.72	0.7	0.72	0.48
		(0.01)	(0.03)	(0.03)	(0.15)	(0.16)	(0.23)
	Obs.	5085.08	5085.08	5085.08	602.43	516.85	85.38
		(105.15)	(105.15)	(105.15)	(34.15)	(29.53)	(10.29)
Year 1-4	Real res. wage	1842.09	1842.09	1842.09	1401.48	1419.74	1273.04
		(22.76)	(22.76)	(22.769)	(40.65)	(40.69)	(45.31)
	Est. res. wage	1738.56	1718.89	1682.04	1986.07	2039.39	1912.03
		(24.21)	(27.12)	(106.37)	(470.86)	(510.77)	(870.43)
	R-squared	0.86	0.59	0.70	0.75	0.75	0.51
		(0.01)	(0.03)	(0.03)	(0.13)	(0.14)	(0.22)
	Obs.	17894.84	17894.84	17894.84	01103.34	967.53	135.69
		(28.25)	(28.25)	(128.25)	(27.61)	(23.5)	(10.84)
Year 5-7	Real res. wage	1832.04	1832.04	1832.04	1347	1369.64	1240.18
		(22.62)	(22.62)	(22.62)	(35.5)	(35.44)	(40.13)
	Est. res. wage	1733.1	1714.43	1676.7	1936.92	1973.16	1888.52
		(24.17)	(26.94)	(105.7)	(369.72)	(397.29)	(825.13)
	R-squared	0.87	0.57	0.7	0.73	0.75	0.5
		(0.01)	(0.03)	(0.03)	(0.14)	(0.15)	(0.21)
	Obs.	13745.02	13745.02	13745.02	1097	906.76	190.3
		(20.74)	(20.74)	(20.74)	(23.18)	(18.83)	(12.77)

Table 9: Decreasing scenario: comparison part 3
Means of estimated coefficients, standard deviations in parenthesis

		Frontier estimators			Kiefer-Neumann estimators		
	Variable	Half Normal	Time-invariant	Time-varying	Full model	Duration ≤ 12	Duration > 12
No qualifications	Real res. wage	1477.75	1477.75	1477.75	1183.72	1206.87	1084.89
		(55.77)	(55.77)	(55.77)	(43.61)	(43.12)	(45.91)
	Est. res. wage	1435.25	1484.64	1406.2	1811.81	1856.8	1782.07
		(49.82)	(41.53)	(92.04)	(406.79)	(443.39)	(844.26)
	R-squared	0.81	0.08	0.29	0.6	0.63	0.35
		(0.04)	(0.3)	(0.05)	(0.18)	(0.2)	(0.22)
	Obs.	2039.65	2039.65	2039.65	505.79	409.12	96.48
		(152.75)	(152.75)	(152.75)	(78)	(61.05)	(18.98)
Low qualifications	Real res. wage	1681.08	1681.08	1681.08	1371.52	1387.31	1272
		(27.77)	(27.77)	(27.77)	(39.49)	(38.94)	(43.06)
(low vocational and medium vocational)	Est. res. wage	1598.69	1584.53	1547.21	1956.71	1998.28	1901.23
		(27.88)	(27.29)	(96.52)	(417.83)	(449.83)	(834.75)
	R-squared	0.69	0.11	0.27	0.6	0.59	0.33
		(0.04)	(0.03)	(0.06)	(0.18)	(0.19)	(0.21)
	Obs.	19321.88	19321.88	19321.88	1524.63	1318.43	206.11
		(254.55)	(254.55)	(254.55)	(102.33)	(84.12)	(22.28)
Medium qualifications	Real res. wage	1935.18	1935.18	1935.18	1747.99	1770.68	1609.45
		(48.84)	(48.84)	(48.84)	(65.37)	(66.88)	(90.5)
(high vocational)	Est. res. wage	1809.04	1768.28	1741.18	2214.46	2263.93	2118.34
		(43.20)	(46.35)	(117.6)	(426.67)	(481.27)	(850.83)
	R-squared	0.55	0.22	0.3	0.56	0.54	0.44
		(0.08)	(0.06)	(0.07)	(0.21)	(0.23)	(0.32)
	Obs.	2511.35	2511.35	2511.355	54.74	47.17	7.66
		(116.86)	(116.86)	(116.86)	(22.41)	(19.23)	(4.17)
High qualifications	Real res. wage	2289.3	2289.3	2289.3	2130.47	2158.08	1954.29
		(37.05)	(37.05)	(37.05)	(68.07)	(69.36)	(76.17)
(academic education)	Est. res. wage	2132.81	2090.21	2060.59	2599.5	2659.8	2489.38
		(34.24)	(39.13)	(138)	(506.57)	(572.82)	(989.24)
	R-squared	0.63	0.45	0.49	0.52	0.50	0.33
		(0.07)	(0.08)	(0.08)	(0.18)	(0.2)	(0.25)
	Obs.	7766.97	7766.97	7766.97	115.18	99.57	15.75
		(195.95)	(195.95)	(195.95)	(36.06)	(30.92)	(6.51)

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