Public and private sector wages of male workers in Germany

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Abstract

We analyze several statistical assumptions used in empirical models on public–private sector wage structures. Based on data for Germany, which contain a large range of background variables usually not available in other studies, we investigate the sensitivity of results to various specification and identification assumptions. The standard switching regression model is extended to allow for endogeneity of education level, experience, and hours worked. These extensions lead to considerably different parameter estimates. We compare conditional and unconditional wage differentials between the public and the private sector for the various specifications. These differentials are sensitive to identification assumptions, but robust across specifications which do and do not allow for endogeneity of education, experience, and hours worked. © 1998 Elsevier Science B.V. All rights reserved.

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1. Introduction

In recent years, public sector employment conditions and the efficiency of the public sector versus the private sector has become an important policy issue.

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A number of empirical studies on the wage structure in the two sectors has emerged. While much of the earlier research uses least-squares regressions to compute and compare coefficients of wage regressions and predicted wages for the two sectors (e.g., Smith, 1976; Gunderson, 1979; Shapiro and Stelcner, 1989; Peng, 1992), most of the more recent literature takes account of possible non-random selection by estimating switching regression models. For example, Van der Gaag and Vijverberg (1988) analyze public–private sector employment for the Ivory Coast, Belman and Heywood (1989) for the US, Stelcner et al. (1989) for Peru, Brunello and Rizzi (1993) for Italy, Theeuwes et al. (1985), van Ophem (1993) and Hartog and Oosterbeek (1993) for the Netherlands, Zweimüller and Winter-Ebmer (1994) for Austria, Gindling (1991) for Costa Rica, and Terrell (1993) for Haiti.[1]

These studies address the following questions: First, what are the differences in the pay structure between the two sectors? Second, what are the conditional and unconditional wage differentials between the sectors? Third, what determines the selection between the private and the public sector? Conclusions vary considerably across the countries analyzed. This may reflect that wage structures, incentives and selection mechanisms between public and private sectors differ across countries, which is reasonable in view of the divergent institutional settings for private and public sector occupations.

However, sometimes conclusions also differ between studies for the same country. A reason for this could be that results are sensitive to model assumptions. Non-parametric identification of structural selection and wage equations requires exclusion restrictions on variables in both equations. In many studies, the data is not rich enough to provide appropriate instruments, and identification assumptions are sometimes dubious. For example, some studies use different education measures in the wage equations and in the selection equation, or age in one equation and potential experience in the other. Belman and Heywood (1989) use continuous measures of education in the wage regression and degrees in the selection equation. Van der Gaag and Vijverberg (1988) and Stelcner et al. (1989) do the opposite.

Furthermore, the assumption that other regressors are exogenous is maintained. However, this could be problematic with respect to some variables. An important predictor for sectoral choice is education, and nearly all studies find that education has a strong positive effect on the probability of working in the public sector. But specific occupations in both sectors require specific types of education. It is therefore likely that individuals choose the sector and their education simultaneously, and that the effect of education on sector choice is not structural, but reflects unobserved heterogeneity.

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[1] Pedersen et al. (1990) use panel data for Denmark. They allow for non-random selection through fixed individual effects.

In this paper, we analyze the sensitivity of the estimates of wage differentials and selection mechanism to identification assumptions of the selection equation, and exogeneity assumptions on variables concerning education, labour market experience, and hours worked. We use data from the West-German Socio-Economic Panel, which contains background information on parents' social and economic status and provides us with a rich set of instruments. We first investigate the sensitivity of coefficients in selection and wage equations to exogeneity assumptions. We then compute conditional and unconditional wage differentials for a number of specifications, which include those typically used in the literature. We use different model specifications and only one data set, and focus on the extent to which the choice of specification affects the results of interest.

We find that exogeneity of education in the selection equation is strongly rejected. This changes the conclusions about the effect of education on sector choice. It also questions the use of education variables for identification. We find that the assumption of exogeneity of education leads to a downward bias of the impact of education on wages. We also reject exogeneity of hours worked and experience. Our estimated wage differentials depend crucially on whether or not endogeneity of sector selection is taken into account. Furthermore, identification of the selection equation not based on instruments reflecting parental background information leads to considerably different conditional wage differentials. Thus the main methodological conclusion is that correcting for non-random selection is important, but is only useful if appropriate instrumental variables are available which play a role in the selection mechanism, but can be excluded from the wage equation. On the other hand, the differences in conditional and unconditional wage differentials appear to be rather robust with respect to the other specification assumptions such as exogeneity of education level. This suggests that the standard endogenous switching regression model is sufficient if wage differentials are the only issue of interest.

The paper is structured as follows: in the next section we discuss the data, Section 3 describes the econometric model, the estimation results are discussed in Section 4, Section 5 analyses wage differentials, and Section 6 concludes.

2. Data

The empirical analysis is based on data from the German Socio-Economic Panel (SOEP). We focus on prime aged males in dependent employment who are of German nationality.[2] We extract all variables from the first (1984) wave of

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[2] For females, the participation decision should be taken into account, and this requires a different model. Immigrants are strongly underrepresented in the public sector because of access restrictions. Furthermore, their wage structure differs substantially from that of native Germans (see Dustmann, 1993), and a separate analysis would be needed to take this into account.

the panel, except for those referring to family background and parental characteristics when the individual was 15 years old. The latter information was collected in the third wave (1986).

The public sector in Germany distinguishes between two types of employees: civil servants proper (*Beamte*) and blue and white collar public sector employees. Civil servants account for about 41% of all public sector employees. Although civil servants are not allowed to become actively involved in wage negotiations, their wage increases are strongly linked to the results of wage negotiations of other public sector employees. The type of work of civil servants and other state employees is similar, except for some jobs reserved for civil servants only.[3] Pay scales are the same and apply to all public sector workers at the federal, state and local level (see Brandes et al., 1990). Therefore we shall not distinguish between the two categories of public sector employees in the empirical work. We define the public sector as civil servants and other public sector employees, and our sample contains 1306 employees in the private sector and 560 in the public sector.

Table 8 in Appendix B describes the variables used for the analysis and Table 9 provides summary statistics. The first two columns and the last two columns give means and, if appropriate, standard errors for private and public sector employees respectively. The education level variable is ordered, with values 1–6. It is constructed from detailed information about educational background. On average, public sector employees have a stronger educational background than private sector employees. Public sector employees are somewhat older and more experienced than private sector employees. Private sector employees work, on average, 1.8 hours per week more than public sector employees, but their hourly earnings are lower.

A number of family background variables are used. These reflect the labour market status of the father when the child was aged 15, whether the mother participated in the labour market or not, the age of father and mother when the individual was born, and the education level of father and mother.

3. The econometric model

We model the choice between public and private sector work and the hourly wage rate in the chosen sector, and for reasons explained above we want to allow for endogeneity of the education level. We therefore add an equation to explain this variable, in which the education levels of the parents are the main explanatory variables. We also allow for other endogenous regressors (such as hours worked or experience) and discuss this below. We first present the model

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[3] See Dustmann and van Soest (1997) for more details on the public sector in Germany.

in which these other variables are exogenous. This model consists of four equations, which explain education level, sector selection (i.e. the choice between public and private sector), and (potential) hourly earnings in the two sectors.

3.1. Education level

Education levels are coded from 1 to 6, in ascending order (see Table 8), and modeled as an ordered probit:[4]

$$E^* = X_E \beta_E + u_E; \quad E = j \text{ if } m_{j-1} < E^* \leq m_j \quad \text{for } j = 1, \ldots, 6, \quad (1)$$

where E denotes the educational level attained, and E^* is a latent variable. The vector of explanatory variables X_E contains information concerning the parents (see next section for details). Assumptions on the error term u_E are given below. The boundaries satisfy $-\infty = m_0 < m_1 < \cdots < m_5 < m_6 = \infty$. By means of normalization we assume $m_1 = 1.5$ and $m_5 = 5.5$; m_2, m_3 and m_4 are parameters to be estimated.

3.2. Selection

We model the binary choice between private sector ($S = 0$) and public sector work ($S = 1$). The equation for the underlying latent variable is given by

$$S^* = X_S \beta_S + DE \delta_E + u_S, \quad (2)$$

which relates to S as

$$S = \begin{cases} 0, & S^* < 0, \\ 1, & S^* \geq 0. \end{cases}$$

The vector X_S of explanatory variables includes, e.g., the father's occupational group. The vector DE contains dummies for the five highest education levels.

Many studies follow a more structural approach and allow the wage differential between public and private sector wage to enter the selection equation explicitly. We experimented with that and found that the coefficient of the wage differential could not be estimated accurately (see Dustmann and van Soest, 1995). It also depended strongly on which variables are excluded from the selection equation. Moreover, since mobility between the two sectors is extremely low,[5] a life cycle wage differential would be more appropriate than the current wage differential which is commonly used. However, our experiments with this

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[4] For notational convenience, the index indicating the individual is omitted throughout.
[5] Less than one percent of all employees changed sector in each of the years 1984 till 1987. See Blossfeld and Becker (1989) for the various restrictions on changing between the sectors.

did not lead to convincing results either and we therefore exclude the wage differential in this study.

3.3. Wage rates

Potential before tax hourly wage rates are modeled for the private and public sector separately:

$$\ln W_j = X_W \beta_j + DE\alpha_{Ej} + u_j, \quad j = 0, 1, \tag{3}$$

where $j = 0$ and $j = 1$ denote the private and public sector, respectively. X_W contains explanatory variables such as age and experience. Properties of the error terms u_0 and u_1 are discussed below.

3.4. Distribution of error terms

The vector of error terms $u = (u_E, u_S, u_0, u_1)'$ is assumed to be independent of all explanatory variables in X_E, X_S, X_W and multivariate normal with mean zero and covariance matrix Σ. By means of normalization, $\Sigma(2,2) = \text{Var}(u_S)$ is set equal to one. $\Sigma(3,4) = \text{Cov}(u_0, u_1)$ is not identified. The other elements of Σ (three variances and five covariances) can be estimated.

If $\Sigma(1, j) = 0, j = 2, 3, 4$, the model simplifies to the standard switching regression model used in numerous studies. The model can then be estimated using Heckman's two stage estimator, or alternatively, by maximum likelihood (ML). The latter is straightforward and leads to consistent and asymptotically efficient estimates. If u_E is correlated with u_S, u_0, or u_1, ML can be applied to the system of four equations as a whole.

3.5. Endogeneity of continuous variables

In the discussion above, we have assumed that X_E, X_S, and X_W contain exogenous variables only. There are good reasons, however, to allow for endogeneity of some of their components. Following Hartog and Oosterbeek (1993), we allow the wage rate to depend upon hours worked. Since hours worked, according to labour supply theory, may depend upon the wage rate, it seems reasonable to allow for endogeneity of hours worked. Furthermore, (actual) experience is included in the wage equations. If the education level is endogenous, it seems reasonable to allow for endogeneity of experience as well, since those with more years of full-time education will usually have fewer years of labour market experience.

Endogeneity of continuous variables like hours worked and experience is incorporated as follows. We use reduced equations to model these variables, with only exogenous variables on the right-hand side. These auxiliary equations can be estimated by OLS. The OLS residuals are then added as regressors to the

four equations of the model introduced above. This is based on the underlying assumption of joint normality of the error terms in the auxiliary equations and the error terms $u = (u_E, u_S, u_0, u_1)'$. This assumption implies that, conditional upon the errors in the auxiliary equations, u is multivariate normal with fixed covariance matrix and with a mean which is linear in the errors of the auxiliary equations.

The four equations model can now be estimated by ML, with the OLS residuals as additional regressors. Significance levels of the residuals can be used to test for endogeneity (see Smith and Blundell, 1986). If exogeneity is rejected, however, the standard errors of the parameter estimates have to be corrected since the residuals are estimated. An alternative is to estimate the system as a whole by ML, including the auxiliary equations. This is the procedure we follow. It leads to efficient parameter estimates and to consistent estimates of their standard errors.[6]

3.6. Identification

To identify the model in another way than through the normality assumption on the error terms only, we need various exclusion restrictions. In the wage equations, we exclude all parental characteristics, thus assuming that the only sources of correlation between wages and observed parental characteristics are selection and education level. In the selection equation, we exclude education levels of the parents to identify endogeneity of education, but we retain the parents' occupational group variables. To investigate endogeneity of hours worked, we include typical labour supply variables like other income, and mortgage payment liabilities in the hours equation. These variables are not included in the rest of the model. The reduced form equation for actual experience includes the variables on parental education and employment status. To obtain parsimonious specifications, we also imposed several overidentifying restrictions which could not be rejected according to likelihood ratio tests.[7]

4. Estimation results

We consider seven different specifications. Models 1–5 differ in two respects. They impose different zero restrictions on the covariance matrix of all the error terms (u and the errors in the two auxiliary reduced form equations for hours

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[6] See Appendix A for details on the likelihood function. The two step estimates are used as starting values. Their consistency implies that one Newton–Raphson iteration in the direction of the likelihood maximum leads to an estimator which is asymptotically equivalent to ML.

[7] For example, the parents' levels of education were jointly insignificant in the sector choice equation, and the parental characteristics appeared to play no role in the wage equations.

worked and experience), and include or do not include hours worked as a regressor in the wage equations. Apart from that, these models contain the same regressors in all the equations. The choice of regressors is based upon preliminary estimations to obtain a parsimonious specification, particularly for the auxiliary equations explaining education level, hours worked, and experience. Models 6 and 7 use different regressors in one of the equations. They are used to check the sensitivity of the wage differentials for the choice of regressors, and are discussed in the next section.

Table 1 presents models 1–5. Models 1–4 are nested in model 5. This is a generalized switching regression model which allows for endogeneity of education level, hours worked, and experience.[8] The number of parameter restrictions in models 1–4 and the likelihood difference with model 5 are presented in the final two columns of Table 1. Likelihood ratio tests based on this table lead to the conclusion that these models are rejected against model 5. Moreover, for all pairs of models that are nested, the more restrictive model is rejected against the more general one.[9]

We do not present detailed estimation results for all models. We focus on the differences between the results for the standard switching regression model, the common model in the literature (although identification is sometimes weaker, see below), and the most general model, preferred according to Table 1. For the three equations of our main interest (choice between public and private sector, wages in the private sector, and wages in the public sector), we present the results

Table 1
Model specifications and likelihood differences

Model	Model description	Number restrictions	Likelihood difference
M1	No correlations between errors Hours worked not in wage equations	15	− 471.9
M2	Standard switching regression model Hours worked not in wage equations	13	− 467.4
M3	No correlations between errors Hours worked in wage equations	13	− 353.7
M4	Standard switching regression model Hours worked in wage equations	11	− 348.1
M5	Educ. level, hours worked, and experience endogenous Hours worked in wage equations	0	0

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[8] In all models, we have imposed zero correlation between the errors in the equations for experience and hours worked. Relaxing this in model 5 yields an estimate of the correlation coefficient which is close to zero, with t-value 0.03.

[9] Unless stated otherwise, we use a significance level of 5%.

for models 4 and 5, and briefly mention some findings for the other models. For the auxiliary equations (education level, hours worked, experience), the results for all models are very similar, and we only present the estimates for model 5.

We first present the results for the correlation structure of the error terms in model 5 (Table 2). The first part of the table presents the correlation matrix of u, conditional upon the errors in the auxiliary equations.[10] $\rho(u_S, u_1)$ is positive and significant. $\rho(u_S, u_0)$ is positive but smaller and insignificant. These results are similar for the other models allowing for selectivity. Along the lines of Roy (1951), this indicates that the mean wage of those who work in the public sector is larger than the expected public sector wage of an arbitrary individual with the same observed characteristics. Positive selection into the public sector, but no selection into the private sector, is also found by van Ophem (1993) and Hartog and Oosterbeek (1993). Van der Gaag and Vijverberg (1988) find positive selection into both sectors.[11]

We also find a significantly positive estimate of $\rho(u_S, u_E)$. This confirms our conjecture that education is endogenous to the choice between the public and the private sector. The correlation between u_E and the errors in the wage equations is negative, and significant for the public sector. This may reflect an errors in variables problem, due to imperfect measurement of the education level.

The bottom panel of Table 2 presents the covariances of u with the errors in the equations for hours of work (u_H) and experience (u_X), again for model 5.

Table 2
Correlation structure, model 5

	u_E	u_S	u_0	u_1
Correlation matrix of $u = (u_E, u_S, u_0, u_1)$ given u_H and u_X				
u_E	1	0.207*	− 0.128	− 0.492*
u_S		1	0.255	0.626*
u_0			1	ni
u_1				1
Covariances				
u_H	0.04	− 1.24*	− 1.99*	− 3.70*
u_X	− 2.61*	− 0.82*	0.12	0.07

* Significant at two-sided 5% level.
ni: not identified.

[10] Conditioning corrects for spurious correlation through the errors in the hours worked and experience equations. The unconditional correlations have the same sign and similar significance levels in all cases.

[11] The same results were found when the systematic part of the equations was changed by using different age, experience, or education functions.

$\mathrm{Cov}(u_E, u_X)$ is strongly negative, since those with a high education level enter the labour market later, and thus have a lower experience. It is not clear why $\mathrm{Cov}(u_S, u_X)$ is also negative. The negative sign of $\mathrm{Cov}(u_S, u_H)$ may reflect that working overtime is less common in the public sector than in the private sector, and corresponds to the difference in average hours worked between the two sectors in the raw data. The negative correlations between u_H and the errors in the wage equations can reflect measurement error in the hours variable.

4.1. Choice between private and public sector

In Table 3 we present the results for the selection equation in the standard model (model 4) and the general model (model 5). The main difference between the two models is that the education level is allowed to be endogenous in model 5. This is reflected in the estimates: those for the educational dummies are substantially different, while the other slope parameters are similar in terms of sign, magnitude and significance level. If education level is taken exogenous, the probability of being in the public sector increases with education, a common finding in the literature. An exception is level 5, which measures specific training

Table 3
Public sector choice (Eq. (2))

Variable	Model 4		Model 5	
	Coefficient	*t*-value	Coefficient	*t*-value
constant	− 2.168	− 4.94	− 2.093	− 4.35
age 15–25	0.724	1.60	0.725	1.51
age 25–35	0.093	0.61	0.261	1.62
age 35–45	0.168	1.35	− 0.010	− 0.07
age 45–55	0.100	0.72	0.116	0.78
age 55–65	0.142	0.41	0.092	0.25
l2par	0.122	1.13	0.147	1.22
f blue	− 0.019	− 0.19	− 0.094	− 0.88
f white	0.036	0.30	0.251	1.90
f self	0.129	1.08	0.204	1.60
f civil	0.457	3.53	0.721	4.83
m worked	0.340	2.68	0.645	3.95
m no work	0.276	2.14	0.709	4.29
ed level 2	0.181	1.44	− 0.195	− 1.02
ed level 3	0.697	5.00	0.018	0.06
ed level 4	0.651	3.95	− 0.165	− 0.52
ed level 5	0.078	0.34	− 0.869	− 2.19
ed level 6	1.254	7.52	0.092	0.22

for jobs that are typically found in the private sector. If endogeneity of education is allowed for, however, the positive relation between public sector choice and education disappears. What remains is a negative effect of education level 5. The interpretation is that the positive relation between education level and public sector choice found in the standard model is due to unobserved heterogeneity instead of a structural effect. This casts doubt on the results from other studies on the effect of education on sectorial choice. It also suggests that estimates of wage equations might be biased, since correction for selectivity is often identified through the use of different specifications of the educational variables in selection and wage equations.

We allow for a linear spline in age.[12] The probability of working in the public sector increases with age, particularly for younger cohorts. The lack of mobility between sectors suggests that this is a cohort effect rather than a pure age effect. None of the age terms is significant, however.

The variables on the father's occupation are excluded from the wage equations and are therefore important for estimating the selection bias. Those whose father was a civil servant are significantly more likely to have a public sector job than others, and in particular than those whose father had a blue-collar job or no job (the reference group).

4.2. Wage equations

Estimates for public and private sector wage equations are given in Table 4 again for models 4 and 5. Both models yield similar results for marital status and blue versus white collar workers. In the public sector, blue collar workers earn about 7% less than white collar workers. In the private sector, this difference amounts to 16% (ceteris paribus). As common in the wage literature, we find that married men earn more than unmarried men. We find that this differential is larger in the public than in the private sector.

The other coefficients show substantial differences between models 4 and 5. For example, the effect of hours worked on the (before tax) hourly wage rate is significantly negative for both sectors according to model 4. A negative effect of hours worked on wages is also found by Hartog and Oosterbeek (1993). It becomes significantly positive, however, if endogeneity of hours worked is allowed for. This confirms the importance of correcting for the division bias due to measurement error in hours worked. The positive sign corresponds to the notion that the wage rate for working overtime is higher than the regular wage rate. The effect seems quite high. Perhaps this is due to the lack of explanatory power in the hours equation (see below), which implies that the normality

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[12] Due to its continuity, this is less sensitive to the choice of age categories than age group dummies.

Table 4
Wage equations (Eq. (3))

Variable	Private sector				Public sector			
	Model 4		Model 5		Model 4		Model 5	
	Coef.	*t*-value	Coef.	*t*-value	Coef.	*t*-value	Coef.	*t*-value
constant	3.589	28.20	1.592	2.56	3.679	13.75	0.541	0.62
ed level 2	0.116	3.87	0.172	3.51	0.027	0.51	0.271	4.49
ed level 3	0.198	4.15	0.305	3.67	0.201	3.55	0.613	7.23
ed level 4	0.342	6.19	0.459	4.74	0.378	5.66	0.837	8.81
ed level 5	0.379	7.42	0.507	5.14	0.340	3.07	0.909	6.48
ed level 6	0.457	5.55	0.631	4.81	0.640	9.14	1.286	10.41
married	0.081	3.64	0.088	2.94	0.093	3.63	0.119	2.77
Exp/10	0.079	1.48	0.013	0.14	0.236	3.23	0.438	4.35
Exp/10 sqrd	− 0.033	− 3.21	− 0.027	− 2.36	− 0.047	− 3.84	− 0.037	− 2.98
Age/10	0.476	5.61	0.497	3.95	0.257	1.91	− 0.123	− 0.67
Age/10 sqrd	− 0.041	− 4.32	− 0.036	− 3.23	− 0.016	− 1.15	0.003	0.22
blue	− 0.164	− 8.81	− 0.157	− 8.24	− 0.076	− 2.54	− 0.065	− 2.25
hours	− 0.012	− 17.12	0.032	2.42	− 0.019	− 11.57	0.061	3.27
$\mathrm{Var}(u_j)^{1/2}$	0.256	53.38	0.260	27.31	0.286	16.65	0.314	14.93

assumption may be important for identification. In order to find out whether this has any effect on the wage differentials, we have also estimated models which exclude hours of work from the wage rate equations.

For both specifications and sectors, the wage increases with education level. In the general model, the impact of education level is stronger than in the models which do not allow for endogeneity of education. This holds particularly for the public sector, where the education differentials are larger than in the private sector.

We have included a quadratic function of both age and actual experience. Including age terms apart from experience terms leads to a significant improvement of the likelihood. The age variables may reflect both cohort and life cycle effects. Still, age and experience are strongly correlated, and it seems too much to ask from the data to identify them separately, certainly if experience is allowed to be endogenous. This may explain why we find an implausible negative experience pattern in the private sector according to model 5. In this model also, we find that age would play no role in the public sector, though it is significantly positive in the private sector.

In Fig. 1, we have combined the information on age and experience. Expected log wage rates according to model 5 in both sectors are sketched as a function of
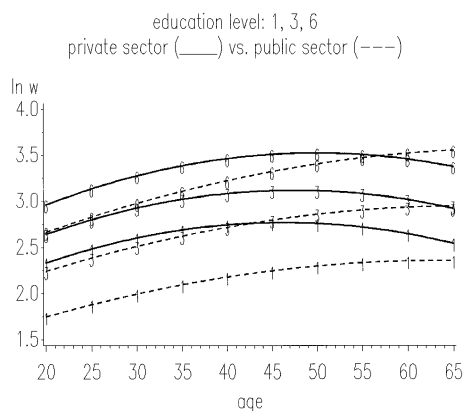
Fig. 1. Log wage rates; model 5.

education level and age.[13] Experience is replaced by its best linear prediction, given age and education level. Other variables are set equal to their sample means. For public sector wages an increasing pattern emerges. Private sector wages show a much flatter pattern. For young workers with little experience, the private sector pays much better than the public sector. For the oldest age group, the difference is negligible. For model 4, a similar pattern evolves, but the education differentials are smaller than in model 5, particularly in the public sector.

4.3. Hours worked and education

Table 5 reports the results for the education equation, and for the hours equation. In the former, both the father's and the mother's education level have a significant positive effect, with that of the father being more important. The occupational category of the father also matters; if he was a civil servant, this improves education (the reference group is 'no father' or 'father is blue collar worker'). Age is again incorporated as a linear spline function, accounting for cohort effects in a flexible way. It appears that educational achievement is relatively low for those who started their education during the second world war.

Hours worked for pay are positively related to mortgage liabilities, a typically negative income effect. The effect of interest income, however, is insignificant. The number of children is positively related to hours worked, a finding which is not unusual in the literature on male labour supply. It may be related

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[13] Error terms are ignored here. See next section for an alternative procedure.

Table 5

Variable	Coefficient	t-value
(a) Education level (Eq. (1)), Model 5		
constant	0.369	0.71
fs2	0.580	4.64
fs3	0.915	4.44
ft1	0.293	3.17
ft2	0.999	3.24
ft3	0.892	3.05
ms2	0.332	2.58
ms3	0.609	2.05
mt1	0.318	4.14
mt2	0.323	0.43
mt3	− 0.170	− 0.27
age 15–25	1.566	2.89
age 25–35	0.299	1.74
age 35–45	− 0.463	− 3.40
age 45–55	− 0.196	− 1.24
age 55–65	0.306	0.78
l2par	− 0.050	− 0.41
f blue	− 0.242	− 2.17
f white	0.339	2.55
f self	0.184	1.37
f civil	0.574	3.75
m worked	0.829	6.22
m no work	1.013	7.82
$\mathrm{Var}(u_E)^{1/2}$	1.045	43.33
m_1	1.500	—
m_2	3.685	69.48
m_3	4.585	81.42
m_4	5.213	129.17
m_5	5.500	—
(b) Hours worked, Model 5		
constant	43.523	48.05
married	− 0.895	− 1.89
head	1.008	2.04
mortg/100	0.120	4.75
intinc/100	0.030	0.56
child	0.309	2.47
age	− 0.033	− 1.71
fs 2	− 0.879	− 2.33
fs 3	− 1.189	− 2.58
ft 1	− 0.217	− 0.87
ft 2	− 0.543	− 0.76
ft 3	− 0.957	− 1.25
$\mathrm{Var}(u_H)^{1/2}$	6.605	90.39

to the negative effect of children on female labour supply. If the wife withdraws from the labour market, the husband works more to compensate for the income loss. An explanation of the negative effect of the father's education level may be that his higher education increases the individual's own education level, and paid overtime is less common among the higher educated. Age has a negative effect, as expected.

5. Wage differentials

In this section we discuss two types of wage differentials (see, e.g., Heckman (1990) for a discussion of various definitions). First, we consider the expected wage rates in the public and the private sector for reference individuals, with given age and education level. These are based upon the estimated systematic parts of the wage equations, and no account is taken of the error terms. Second, we will look at average differentials between potential public and private wages for all workers, and for workers in the public and private sector. This is based upon simulations which take account of the full structure of the model.

Apart from the models 1–5 discussed above, we consider two alternative models. Model 6 differs from model 5 in the specification of the wage equations: it does not include experience or its square, but includes the more flexible linear spline in age which is also used in other equations. This is because experience is replaced by its prediction for most purposes anyhow, and it is not clear whether including experience and allowing for its endogeneity is worthwhile. The likelihood of model 6 is slightly smaller than that of model 5. Model 7 is the standard model (model 4) without parental characteristics in the sector selection equation. This model is rejected against model 4. Model 7 is of interest since it is similar to most studies in the literature, which do not use parental characteristics for identification. Identification of this model relies on the normality of the error terms.[14]

Table 6 shows the estimated wage differentials for some reference individuals. The base case is a 35 year old male with education level 2 (the mode of the education levels). The other individuals considered have the same age but another education level, or another age but the same education level. In all cases, experience is replaced by its best prediction based upon age and education. Other variables are set equal to their sample means. The computation of the wage differentials is thus in line with that of the wage rates in Fig. 1.

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[14] In model 7, the age pattern in the selection equation is different from that in the wage equations. This yields an additional overidentifying restriction. We also estimated model 7 with the linear age spline in the wage equations (as in model 6). Resulting wage differentials were similar to those of model 7 presented here.

Table 6
Estimated wage differentials between public and private sector (in %) for reference individuals, models 1–7

Model	M 1	M 2	M 3	M 4	M 5	M 6	M 7
Age 35, ed. 2	− 9.73	− 33.51	− 13.20	− 33.86	− 39.18	− 41.62	− 30.17
	2.85	4.36	2.37	3.61	3.34	2.89	3.05
Age 25, ed. 2	− 16.94	− 42.54	− 16.90	− 38.68	− 39.91	− 43.00	− 38.10
	4.55	5.16	4.57	4.87	5.65	7.00	4.69
Age 45, ed. 2	2.76	− 21.98	1.63	− 21.26	− 19.63	− 24.65	− 15.78
	4.75	7.04	4.28	5.78	5.90	5.88	5.02
Age 35, ed. 1	1.18	− 27.35	− 1.99	− 27.61	− 43.11	− 44.07	− 23.86
	7.44	6.73	5.55	5.50	4.66	5.85	5.80
Age 35, ed. 3	− 7.53	− 26.06	− 12.71	− 28.98	− 30.50	− 31.44	− 20.78
	3.97	6.64	3.34	5.28	4.22	4.30	4.43
Age 35, ed. 4	− 8.45	− 26.44	− 11.01	− 28.08	− 32.24	− 28.48	− 19.80
	5.60	7.51	4.02	5.84	5.40	5.87	5.39
Age 35, ed. 5	− 5.06	− 32.50	− 10.73	− 34.66	− 31.88	− 29.13	− 29.16
	10.76	8.78	9.10	7.26	7.62	8.26	7.43
Age 35, ed. 6	− 3.41	− 18.58	− 6.70	− 19.65	− 20.34	− 11.16	− 4.34
	3.58	9.81	4.03	8.80	9.18	8.72	5.54

Note: first line: estimate; second line: standard error.

For the base case, we find a negative wage differential of more than 30% for most models. Only for models 1 and 3, which do not allow for correlation between the error terms in the selection and the wage equations, the size of the differential is much smaller, though it remains negative and significant. Similar conclusions can be drawn for the other cases. For all models other than models 1 and 3, wage differentials are significantly negative for all education levels except the highest. Model 7, with its substantially different selection equation and weaker identifying assumptions, leads to smaller differentials than other models allowing for selectivity. According to all models, the wage differentials decrease with age, but the estimated age pattern differs across specifications. For example, according to model 2, the standard model without hours worked, the differential between age 25 and age 35 is substantial and almost as large as that between age 35 and 45. In model 5 on the other hand, there is hardly any difference between wage differentials at age 25 and age 35, but the differential at age 45 is much smaller.

All models show that the differentials are largest for the two lowest education levels, and smallest for the highest level. Differences between differentials for education levels 1 and 2 are small in all but the two 'simplest' models 1 and 3, and the sign of this difference varies with the model. A similar remark applies to differences between differentials for education levels 3, 4 and 5.

From Table 1 we concluded that model 4 is strongly rejected against the more general model 5. In spite of this, we find that the estimates of the wage differentials are quite similar. On the other hand, the differences with model 7 show that the results are rather sensitive to the specification of the selection equation, and the use of identifying exclusion restrictions therein.

Aggregate wages and wage differentials based upon simulations using the complete model are presented in Table 7.[15] We consider unconditional and conditional wage predictions. The unconditional (public or private sector) prediction is defined as the average[16] predicted value of the (public or private) wage rate for all individuals in the sample. It estimates $E\{\ln(W_j)\}$, $j = 0, 1$, the mean prior to the choice of sector. The conditional wage prediction is a weighted sample average of the predictions of all individuals in the sample, where the weights are the estimated probabilities of the sectors. It estimates the means for given sector choices: $E\{\ln(W_0)|S = 0\}$, $E\{\ln(W_1)|S = 1\}$, $E\{\ln(W_0)|S = 1\}$, and $E\{\ln(W_1)|S = 0\}$. The former two reflect the sample means of the private and public sector workers, while the latter two are the so-called counter–factuals which have no observed counterpart. Thus $E\{\ln(W_1)|S = 0\}$ is the expected potential public sector wage for an arbitrary private sector worker, etc.

The first three rows refer to the *unconditional* wages. According to all models, on average, potential wages in the private sector exceed those in the public sector. For the private sector wage, predictions for models 1, 3, and particularly 7 are lower than for the other models. For the public sector wage, the models in which selectivity is not accounted for (models 1 and 3) yield higher public sector wage predictions than the other models, with differences of more than 20%.

The other rows refer to *conditional* wage predictions. Row 4 is the average wage in the private sector of people who choose to work in the private sector. All these predictions are very similar: each model reproduces the average wage rate in the private sector rather well. Similarly, row 8 reproduces public sector wages of public sector workers.

The predictions in rows 5 and 7 have no observed sample equivalent. Row 5 refers to the wages that private sector workers could have received if they had worked in the public sector. Similarly, row 7 presents potential private sector wages of public sector workers. These rows reveal much larger differences between the models than rows 4 and 8. In row 5, the main differences again

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[15] These differentials are conceptually similar to those in Hartog and Oosterbeek (1993). Due to endogeneity of some of the explanatory variables, however, we cannot use their formulas and have to rely on simulations. These are straightforward: we compute the systematic part using the parameter estimates, and add error terms drawn from the estimated error term distributions for all individuals. To compute the corresponding standard errors, we repeat this procedure for 100 draws of the complete parameter vector from the estimated asymptotic distribution of the estimator. Fortran programmes are available upon request.

[16] Since the model is in logs, we work with geometric averages throughout.

Table 7
Simulated wages and wage differentials; total sample

	Model	M 1	M 2	M 3	M 4	M 5	M 6	M 7
	All workers:							
1	Private wage	18.39	18.66	18.55	18.77	19.06	18.95	17.29
		0.14	0.94	0.17	0.84	0.62	0.53	0.31
2	Public wage	16.93	12.93	16.49	12.93	12.82	12.82	12.84
		0.25	0.67	0.22	0.45	0.55	0.50	0.49
3	Diff. in %	− 7.93	− 30.56	− 11.06	− 30.98	− 32.69	− 32.30	− 25.69
		1.56	4.86	1.48	4.01	3.29	3.07	3.25
	Conditional wages, private sector workers:							
4	Private wage	17.83	17.86	17.96	17.95	17.78	17.82	17.98
		0.16	0.24	0.18	0.23	0.19	0.20	0.17
5	Public wage	16.35	11.13	15.91	11.24	11.00	10.99	11.10
		0.26	0.84	0.21	0.56	0.70	0.61	0.58
6	Diff. in %	− 8.25	− 37.65	− 11.40	− 37.38	− 38.15	− 38.33	− 38.26
		1.71	4.77	1.51	3.34	3.86	3.43	3.31
	Conditional wages, public sector workers:							
7	Private wage	19.72	20.75	19.95	20.86	22.39	21.82	15.84
		0.24	2.97	0.26	2.65	2.21	1.75	0.75
8	Public wage	18.31	18.15	17.89	17.78	18.15	18.18	17.89
		0.32	0.43	0.32	0.28	0.33	0.34	0.33
9	Diff. in %	− 7.18	− 10.73	− 10.30	− 13.40	− 18.12	− 16.14	13.15
		1.66	13.08	1.72	10.99	8.39	7.10	5.74

Note: First line: estimate; second line: standard error. See Section 5 for definitions of wage differentials and explanation of simulation procedures. Reference individual: 35 years old, male, education level 2.

concern models 1 and 3 versus all others. Row 7 shows that model 7 predicts much smaller private sector wages of public sector workers than all other models. This relates to the large negative estimate of $\rho(u_S, u_0)$ for this model.

Those who selected themselves into the private sector (rows 3 and 4) are those with lower potential wages in both sectors. This is due to both observed and unobserved characteristics: from Tables 3 and 4, e.g., we conclude that age is negatively correlated with selection into the private sector, but positively with wages in both sectors. Accordingly, those who work in the public sector do better in both sectors than the average individual.

There are some remarkable differences between the various specifications. The numbers in row 6 show that private sector workers would be worse off in the public sector. This difference is much smaller in models 1 and 3 than in the other models. For those who actually work in the public sector, the average wage differential is smaller than for those who work in the private sector (row 9). Again, differentials are smaller if selection effects are not incorporated. The

largest negative differential is found for the most general model (model 5) and amounts to about 18 percent. More importantly, the differential changes sign for model 7. This is due to the low predictions for potential private sector earnings of public sector workers (row 7).

If gross wages were the only criterion for sector choice, then the negative average differentials for the public sector workers would indicate that the choice of many public sector workers is not rational. Choosing the public sector, however, is also based on tax rules, job security, social security premiums and entitlements to unemployment benefits, pension rights, and many other non-monetary job characteristics.[17]

Wage advantages between sectors are often found to vary across educational categories or age groups. Van der Gaag and Vijverberg (1988), for instance, find that unconditional wage predictions in the private sector are high for those with low education, but low for those with high education. Hartog and Oosterbeek (1993) find that public sector occupations have higher wage prospects for all educational groups, while van Ophem (1993) reports that the unconditional wage advantage of the public sector is a decreasing function of age. We have looked at conditional and unconditional wage differentials for different educational and age groups. The results are in line with those in Tables 6 and 7.[18] Differentials decrease with age and education level, but remain negative for all models allowing for selectivity. Conditional wage disadvantages for public sector workers are always smaller than those for private sector workers.

6. Summary and conclusion

In the previous sections we have estimated different models to analyse public–private sector wage differentials, and sector selection. Our main findings are as follows. We reject the common assumption that education is exogenous in the sector choice equation. Allowing for endogeneity improves the model significantly, and the effect on the sector choice drops to zero in terms of size and significance level. Accordingly, the positive correlation between education and sector choice, which is found and emphasized in most other studies, seems to be driven by unobserved characteristics that affect both in the same direction.

Not allowing for endogeneity of the education level results in a downward bias of the impact of education level on wages in the private sector. We also reject exogeneity of both hours worked and labour market experience in the

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[17] Note that we can only consider the average differential and not the individual variation in the differentials. For example, we cannot predict the fraction of workers for whom the differential is positive, since $\text{Cov}(u_0, u_1)$ and thus also the variance of $u_0 - u_1$ are unidentified.

[18] Details are available upon request from the authors.

wage equation. Measurement error in the hours variable is likely to induce a spurious negative correlation between hours and wages. The effect of hours worked in the wage equation is negative if hours worked are assumed to be exogenous, as in other studies (see Hartog and Oosterbeek, 1993). This effect changes sign when endogeneity of hours worked is allowed for.

We compute average conditional and unconditional wage differentials for a number of model specifications. For all educational groups, we find that potential wages are on average higher in the private sector than in the public sector, but this advantage falls with age and with education level. Predicted public sector wages are lower for all education and age groups than predicted private sector wages. On average, potential wages of public sector employees are higher in the private sector than in the public sector. For private sector workers, the wage differential between private and public sector wage would be even larger. Selection therefore works in the right direction: on average, the public sector workers have a comparative advantage in the public sector.

Results on conditional and unconditional wage differentials are found to be remarkably stable across specifications, as long as the way in which selection is taken into account remains the same. On the other hand, we obtain very different results for models which do not account for selectivity due to endogeneity of the choice between public and private sector, and for models with a weakly identified selection equation. This suggests that some differences in the results of the many studies on public–private sector pay differentials are due to differences in assumptions used to identify the effect of non-random sector selection. Appropriate instruments and exclusion restrictions are crucial to obtain reliable estimates of the wage differentials, which are generally the main focus of interest. Our results imply that this is more important than generalizing the switching regression model to account for endogeneity of right-hand side variables.

Acknowledgements

Appendix A: Likelihood of Model 5

We discuss the likelihood contribution for a public sector worker with education level 2. Contributions of other individuals can be derived analogously. For given parameter values, observed hours of work, experience, and log

wage rate, let e_H, e_X, and e_1 denote the residuals in hours, experience, and public sector wage equation, respectively. The likelihood contribution is then given by[19]

$$L = f_{H,X,1}(e_H, e_X, e_1)P[E = 2, S = 1|e_H, e_X, e_1], \tag{A.1}$$

where $f_{H,X,1}$ is the trivariate normal density of $(u_H, u_X, u_1)'$. This can also be written as

$$L = f_{H,X}(e_H, e_X)f_{1|H,X}(e_1|e_H, e_X)P[E = 2, S = 1|e_H, e_X, e_1], \tag{A.2}$$

where $f_{H,X}$ is the density of (u_H, u_X) and $f_{1|H,X}$ is the conditional density of u_1 given $(u_H, u_X) = (e_H, e_X)$. We assume joint normality of $(u_H, u_X, u_E, u_S, u_0, u_1)$. This implies that the conditional distribution of (u_E, u_S, u_1) given $(u_H, u_X) = (e_H, e_X)$ is normal with, say, mean μ and covariance matrix Σ.[20]

Under the additional assumption that u_H and u_X are independent, we have $\mu = Ce^*$, with $e^* = (e_H/\sigma_H, e_X/\sigma_X)'$, the vector of normalized residuals. C is then the covariance matrix of $(u_E, u_S, u_1)'$ and $(u_H/\sigma_H, u_X/\sigma_X)'$. We parameterize the error distribution with Σ, σ_H, σ_X, and C (see Table 2).

$f_{H,X}$ is a bivariate normal density which reduces to the product of two univariate densities if u_H and u_X are independent. $f_{1|H,X}$ can immediately be expressed in μ (i.e. C and e^*) and Σ. Using Eqs. (1) and (2) in Section 3, the conditional probability $P[E = 2, S = 1|e_H, e_X, e_1]$ can be written as the difference of two conditional bivariate cumulative probabilities in terms of u_E and u_S. These conditional probabilities are again bivariate normal; their mean and covariance matrix can straightforwardly be expressed in terms of Σ, μ and e_1. Thus the likelihood contribution is a simple expression in normal densities and cumulative bivariate normal probabilities, and its computation is straightforward.

Appendix B

The variables used for the analysis are described in Table 8 and Table 9 provides summary statistics. Experience for Model 5 is provided in Table 10.

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[19] Since the model is recursive, the Jacobian term is equal to 1.

[20] See, e.g., Greene (1997, p. 90).

Table 8
Explanation of variables

Code	Description
public	Dummy; 1 if employed in public sector, 0 if in private sector
wage	Hourly earnings
log wage	Log of Hourly earnings
ed level	Ordered variable on education:
ed level 1	Basic or intermediate schooling (Haupt/Realschule)
ed level 2	Basic schooling and apprenticeship
ed level 3	Intermediate schooling and apprenticeship
ed level 4	High school (Gymnasium, Fachhochschule)/high school and apprenticeship
ed level 5	Engineering school or higher specific school
ed level 6	University
hours	Hours worked per week for pay[a]
exp	Actual labour market experience (constructed from a biographical scheme; after the age of 15).
age	Age
married	Dummy; 1 if married
blue	Dummy; 1 if blue collar
white	Dummy; 1 if white collar
civil	Dummy; 1 if civil servant
head	Dummy; 1 if head of household
mortg	Mortgage payments per month
intinc	Interest income per month
child	Number of children younger than 16 in household
fs2	Dummy; 1 if father intermediate schooling
fs3	Dummy; 1 if father high school
ft1	Dummy; 1 if father apprenticeship
ft2	Dummy; 1 if father engineering school
ft3	Dummy; 1 if father university
ms2	Dummy; 1 if mother intermediate schooling
ms3	Dummy; 1 if mother high school
mt1	Dummy; 1 if mother apprenticeship
mt2	Dummy; 1 if mother engineering school
mt3	Dummy; 1 if mother university
f blue	Dummy; 1 if father blue collar
f white	Dummy; 1 if father white collar
f civil	Dummy; 1 if father civil servant
f self	Dummy; 1 if father self employed
l2par	Dummy; 1 if grown up with father or mother only
m worked	Dummy; 1 if mother employed when individual was 15
m no work	Dummy; 1 if mother was not employed when individual was 15

[a] Two variables on hours worked are available: normal hours worked, and actual hours worked including overtime. Furthermore, the individual was asked whether working overtime was paid for. The variable on hours worked used here measures *earnings-effective* hours worked: if the individual reported overtime hours and overtime work is paid for, hours is constructed on the basis of this measure. In other cases, hours is constructed on the basis of normal hours worked.

Table 9
Descriptive statistics

Variable	Private sector		Public sector	
	Mean	Std. dev.	Mean	Std. dev.
public	0		1	
wage	18.745	7.866	19.741	7.499
log wage	2.865	0.351	2.920	0.350
hours	43.148	6.843	41.328	6.101
exp	23.085	11.689	23.463	11.296
age	39.545	11.096	41.570	10.605
mortg	259.109	515.379	300.931	521.497
intinc	24.913	186.956	26.826	141.844
ed level 1	12.4		6.1	
ed level 2	59.3		41.1	
ed level 3	14.6		23.2	
ed level 4	6.4		10.5	
ed level 5	3.0		2.1	
ed level 6	4.2		17.1	
married	0.778		0.787	
blue	0.579		0.197	
white	0.415		0.273	
civil	0.000		0.528	
head	0.892		0.954	
child	0.793		0.733	
fs2	0.079		0.115	
fs3	0.060		0.079	
ft1	0.725		0.731	
ft2	0.019		0.028	
ft3	0.027		0.043	
ms2	0.064		0.104	
ms3	0.019		0.028	
mt1	0.347		0.418	
mt2	0.002		0.009	
mt3	0.006		0.007	
f blue	0.486		0.349	
f white	0.120		0.150	
f civil	0.064		0.163	
f self	0.124		0.152	
l2par	0.131		0.117	
m worked	0.399		0.395	
m no work	0.513		0.557	
N. obs.	1306		560	

Table 10
Experience, Model 5

	Coefficient	*t*-value
const exp	3.847	2.41
age 15–25	5.732	3.31
age 25–35	9.203	19.31
age 35–45	10.941	32.29
age 45–55	10.213	26.32
age 55–65	2.052	2.08
married	0.818	3.99
child	− 0.333	− 3.57
fs 2	− 0.950	− 3.17
fs 3	− 1.758	− 3.28
ft 1	− 0.302	− 1.26
ft 2	− 1.593	− 2.79
ft 3	− 2.288	− 3.35
ms 2	− 0.841	− 2.51
ms 3	− 1.289	− 1.91
mt 1	− 0.500	− 2.56
mt 2	− 0.861	− 0.75
mt 3	0.622	0.48
m worked	− 1.632	− 8.72
l2par	− 1.064	− 3.66
f blue	0.438	1.56
f self	− 0.581	− 1.76
f white	− 0.642	− 1.89
f civil	− 1.070	− 2.79
$Var(u_X)^{1/2}$	3.429	59.70

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