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# Marginal Taxes: A Good or a Bad for Wages?

## The Incidence of the Structure of Income and Labor Taxes on Wages

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IMPRESSUM



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# Marginal taxes: a good or a bad for wages?

## The incidence of the structure of income and labor taxes on wages[†]

Pia Rattenhuber[⋆]

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**Abstract**

Empirical evidence so far found ambiguous results for the direction of effect of marginal income tax rates on employee remuneration. Based on the GSOEP data from 2002 through 2008 this study analyzes the impact of the marginal tax load on the employee side on the wage rate also allowing average tax rates and employer payroll taxes to play a role. Instrumental variable estimation based on counterfactual tax rates simulated in a highly detailed microsimulation model (STSM) heals the endogeneity problem of the tax variables with regard to wages. Estimations in first differences show that marginal taxes overall have a negative impact on wages. But this effect is not uniform along the wage distribution; while the negative effect of marginal tax rates prevails in the lower part of the distribution, observations beyond the median benefit from higher tax rates at the margin.

KEYWORDS: Marginal tax rates, tax structure, simulated instrumental variables.
JEL classification: H22, H24, C26.

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# 1 Introduction

During the 1990s many European and other industrialized economies experienced high unemployment rates while tax rates decreased in some countries and increased in others. In 1995 the OECD jobs study (OECD, 1995) set the spot light on taxation and (un)employment. The linkages between different kinds of taxes on labor (payroll and income tax), the structure of taxes (average rates versus marginal rates) and labor market outcomes were discussed. At the time it was debated how to design tax systems in a way that wages would be pushed down, aiming at an employment boost. The so-called "public finance solutions for the European unemployment problem" (Scœrensen et al., 1997) included proposals to reduce social security contributions or average taxes and alter the tax system's degree of progressivity.

Under common assumptions supporters of labor market theories based on perfect competition as much as economists in favor of imperfect labor market models agreed on the wage-increasing effects of average income tax rates. While predictions about payroll tax incidence already gave cause of debate, the main bone of contention was the role of marginal income tax rates. Changes to progressivity through adjustments of the marginal tax rate entail appealing features. Ex ante it is possible to change marginal tax rates holding tax payments per employees constant. If wages change in response to the marginal tax rate, the desired labor market outcome could be reached at low costs. Changes to tax progressivity were thus regarded as the closest realization of a budget neutral labor market policy, so to say a free lunch for labor market policy, and therefore politically a way more feasible scenario than changing the level of average tax rates.

What made the topic so contended is the fact that particularly with regard to marginal tax rates, perfect and imperfect labor market theories yield exactly opposing predictions about the effects of progressivity on wages. Imperfect labor market theories like wage bargaining and efficiency models find a "wage moderating effect of progressivity". Tra-

ditional models of perfectly competitive labor markets lead to the opposite recommendation predicting wage-increasing effects of marginal tax rates, also referred to as the "labor supply effect of progressivity".

Several empirical studies set out to test the effect of the different taxes and their structure on wages. While earlier empirical evidence found support for the predictions of wage bargaining theories, this has been contested by more recent studies. Despite the de-unionization observed in Germany in the past several years, collective agreements still play an important role in wage setting and particularly the right-to-manage model has been considered a fairly close description of the wage regime in place (Nickell and Wadhwani, 1991; Bach and Wiegard, 2002; Ochel, 2005). So far there is little evidence on the effect of tax progressivity and the structure of taxes on wages in Germany in recent years; yet for the second half of the 1980s Schneider (2005) finds support for the wage moderating effect of marginal income taxes with stronger effects in the lower part of the pre-tax wage distribution in West Germany.

Between 2001 and 2006 considerable changes to the income tax schedule and some alterations to the payroll tax system have taken place. I estimate the effect of payroll tax and the income tax structure on wages using these variations in statutory rates. Based on a highly detailed microsimulation model (STSM) that considers the actual household context and income types other than labor, average and marginal tax rates are computed for each employed individual. This approach thus goes beyond standard tax functions or simplified tax calculations for certain socioeconomic types of employees. In contrast to the income tax rates commonly employed in the literature I also consider the overall tax load on the employee accounting for the total tax load. This constitutes a more complete measure of the tax burden on labor income and avoids omitting an essential part of the tax load that may be correlated with other tax variables and wages.

I tackle the well-known endogeneity problem in the tax variables following the approach developed by Gruber and Saez (2002). Aging all income relevant variables a

year ahead and applying the tax code of that year to the inflated tax base, counterfactual tax rates are computed and implemented as instruments. The instrument variable thus captures the tax load an individual would have faced in a particular year had he or she not responded to changes in the tax schedule. Estimation in first differences factors out any observed or unobserved time-constant individual effects. Wage bargaining theories attribute an influence to the level of income received in case of unemployment on the wage outcome of bargaining. Instead of using some aggregate or indexed measure of unemployment benefit I simulate for each employee the counterfactual unemployment assistance he or she would receive in case of unemployment.

Estimation results support the wage-decreasing effect of marginal tax rates in line with the predictions of imperfect labor market models. While the average tax load on employees has a positive impact on hourly wages, part of the employer payroll tax is shifted onto wages. Marginal (income) tax rates on average exert a negative effect on employees' remuneration yet this effect is heterogeneous. When the effect of marginal tax rates is allowed to vary between high and low-wage employees higher marginal rates have a wage-reducing effect in the lower part of the distribution. In the upper part of the wage distribution the effect is positive.

The next section reviews the theoretical and empirical literature in the field. Section 3 explains the estimation strategy, the variations in tax rates used for identification and the instrumental variables (IV) strategy employed. The data, the tax-benefit microsimulation model STSM and descriptive statistics are presented in Section 4 followed by estimation results (Section 5) and the conclusion.

# 2 Literature

Labor market models capable of explaining involuntary employment as an equilibrium phenomenon, such as union wage bargaining, search, and efficiency wage models, claim

that progressivity and thus marginal tax rates have a negative effect on wages (Scœrensen et al., 1997). This is in stark contrast to the predictions of the competitive labor market model (Bovenberg and van der Ploeg, 1994).

In a right-to-manage model unions consider the trade-off between higher after-tax wages for the employed and lower overall employment levels, while working hours are given exogenously. If benefits and the marginal tax rate are kept constant, a rise in the average tax implies a rise in the net replacement ratio and unions push for higher pre-tax wages because net income loss from employment is reduced. With constant average tax, a higher marginal tax rate makes it less costly for the union to "buy" additional jobs through wage moderation; the marginal tax increase leads to lower after-tax wages and the purchase of higher employment leads to a slighter decrease in after-tax wages compared to the initial situation. This even holds for the particular case of a union whose utility only depends on the wage rate and not on the employment level of its members (seniority model of union preferences). While the firm's payoff is not altered by higher marginal tax rates, a given wage increase is less desirable for the union compared to the initial situation with lower marginal taxes. This mechanism is referred to as the *wage moderating effect of progressivity* in imperfect labor market models (see Holm et al. (1994); Koskela and Vilmunen (1996); Koskela (2001); Goerke (2002b)). One of the theoretical models most commonly referred to in the empirical literature was mainly developed by Holmlund and Kolm (1995) and Lockwood and Manning (1993).

In the perfectly competitive labor market model workers can vary hours and aggregate employment is typically measured as overall hours worked. An increase in the marginal tax rate holding the average rate constant reduces labor supply at a given pre-tax wage as individuals substitute work for leisure. In consequence the market-clearing wage has to be increased. This has become known as the *labour supply effect of progressivity*.

Hansen et al. (2000) pick up on the role of the intensive margin in a union bargaining

model. They show that when wage bargaining is not only on wages but also on hours, the traditional union-wage bargaining result with regard to average wages still holds; but the effect of a change in marginal tax rates is theoretically undetermined and depends on the magnitudes of the union's bargaining power, the elasticity of labor supply, and the employment cost of higher wages.

The wage bargaining literature predicts effects of payroll tax levied on the employer's side just as analogous to those of the income tax. In competitive models the incidence of the payroll tax depends on the elasticities of labor supply and demand, the tax-benefit link (valuation of future benefits by employees) and the true firm cost of the tax.

Goerke (2002a) shows how different tax levels and changes to the tax structure behave in different types of imperfect labor markets and emphasizes the role of different assumptions with regard to, inter alia, the nature of the union and the indexation of benefits. Koskela and Schöb (1999) and Goerke (2002a) have shown theoretically that in the scope of a revenue-neutral shift from payroll tax to income tax the structure of taxation should not be neglected. They challenge empirical work to better account for different types of taxes and more complete measures of tax load.

Empirical literature on payroll incidence is based on evaluation type studies (difference estimator, differences-in-differences(-in-differences) estimation, regression discontinuity design) except for the very early macro studies and focuses solely on average payroll taxes. Most of the studies based on micro data find full or partial shifting to wages. Studies that also look at employment normally find nearly no effects on employment and full shifting onto wages (see i.e. Anderson and Meyer (1998); Gruber (1997); Gruber and Krueger (1990); Kugler and Kugler (2009); Mitrusi and Poterba (2000); Ooghe et al. (2003)). In a recent study Saez et al. (2011) analyze for Greece based on a regression discontinuity design a large increase in payroll taxes for employees that entered the labor market in 1993 or later. They find that employers compensate employees

for extra employer payroll taxes, but not for the employee side taxes. They detect no evidence for labour supply responses along the extensive or intensive margins.

The empirical literature on progressivity sometimes also includes estimates of the effects of the average payroll tax rate alongside the progressivity analysis. The studies including payroll taxes alongside income tax variables find with the exception of Brunello et al. (2002) a negative effect of payroll taxes on gross wages. Average tax rates are found to have a positive albeit not always significant impact across all studies.

Studies based on macro/time series data are mostly supportive of the wage moderating effect of tax progression brought forward by theories of imperfectly competitive labor markets. Tax rates are typically instrumented with their own lag and time trends. For the UK Lockwood and Manning (1993) confirm the wage moderation hypothesis of imperfect labor market models; Holmlund and Kolm (1995) find support for the wage bargaining model at different earnings levels for the case of Sweden (for a survey see Sœrensen et al. (1997)). Approaching the issue from a different angle and emphasizing the role of work effort Blomquist and Selin (2008) find for a similar period the same qualitative results when looking at the net-of-tax rate (1 minus the marginal tax rate).

Other studies contest these results. Lockwood et al. (2000) confirm a heterogeneous effect of wage progressivity across the income distribution; while middle-income workers see a wage decrease due to higher progressivity, high-income earners benefit from increased pre-tax earnings. Brunello et al. (2002) derive individual average and marginal tax rates and find wage-increasing effects of progressivity for estimation of a panel in changes as much as with grouped data for Italy. Tranæs et al. (2006) broach the issue of endogeneity and argue that progressivity in aggregate time series is positively correlated with income by construction. Under the assumption that marginal tax rates exhibit very little variation but that productivity increases over time, the productivity driven rise in labor income translates into higher average tax rates while marginal tax rates remain constant. Progressivity thus is positively correlated with income not neces-

sarily due to behavioral response as predicted by non-competitive labor market theories but by construction according to the authors point out.

Tranæs et al. (2006) propose estimated tax functions as an alternative instrument instead of lagged tax rates or simple computations of individual marginal tax rates for certain socioeconomic types of workers. They emphasize that estimated tax functions also allow to better account for subsidies. Based on data for Copenhagen their results estimated in first differences or differences-in-differences in general support the competitive labor market hypothesis. Yet the wage-increasing effect is not significant for all sub-groups, particularly not for the lower occupational groups. They furthermore stress the role of business cycles and put into perspective their main result; during recession when the risk of unemployment is high, unions moderate wages relative to outside wages in view of greater tax progression.

For Germany, Schneider (2005) builds on a monopoly union model that differentiates between high and low-skilled workers and estimates the empirical relationship based on individual-level data from the GSOEP. She finds a wage-reducing effect of progressivity in the 1980s which turns out stronger for employees in the lower part of the wage distribution.

Magnitudes of estimates vary considerably between studies even within those either supporting the competitive or the imperfectly competitive labor market hypothesis. Schneider (2005) finds the average tax rate elasticity of wages to equal 0.31, and a marginal tax rate elasticity of -0.18. Brunello et al. (2002) estimate the elasticity of wages with regard to the average (marginal) tax rate to be between 0.17 (0.92) and 0.52 (1.13) depending on their sample design. Lockwood et al. (2000) find that a 1 percentage point increase in the marginal tax rate increases the wage by 0.7 percent for the socioeconomic group of male white collar workers in the upper earnings quartile. For middle-income earners (defined as unskilled workers, high-wage women and low-wage white-collar men) such an increase in marginal tax would in contrast decrease wages by

3.9%, a magnitude the authors themselves deem as "quite substantial".

The majority of studies and particularly the more recent studies use individual level data. Some authors consider only marginal income tax rates, other also consider average tax rate and (employer) payroll tax. The studies use yearly labor income or the hourly wage rate as the left hand side variable raising the question how comparable results based on these distinctly different measures of wage income are given the potential role of adjustments on the intensive margin of labor supply. Yet in the empirical literature hours worked has been found to be quite inelastic with regard to marginal tax rates for those already working (see i.e. Heckman (1993); Flood and MaCurdy (1992); Blundell et al. (1998); Blomquist et al. (2001)) reassuring these doubts.

# 3 Identification

## 3.1 Identifying the effects of taxes on wages

In the empirical literature the remuneration variable is either estimated as a function of the retention rate and the progressivity measure or as a function of the retention rate and the net-of-tax rate directly. The second approach is chosen here, and motivated by the bargaining literature, unemployment benefits, the level of unemployment and union density are included as additional variables (see i.e. Bovenberg and van der Ploeg (1994); Holmlund and Kolm (1995); Lockwood et al. (2000); Brunello et al. (2002); Goerke (2002b); Tranæs et al. (2006)):

$$\begin{aligned} ln(W/P) = {} & \alpha_0 + \alpha_1\, ln(1+E(W)/W) + \alpha_3\, ln(1-H(W)/W) + \alpha_4\, ln(1-H'(W)) \\ & + \alpha_5\, lnB + \alpha_6\, ln(u) + \alpha_7\, dens + \varepsilon, \end{aligned} \tag{1}$$

where $H(W)/W$ ($H'(W)$) refers to the employee's average (marginal) tax load and $E(W)/W$ to the employer payroll tax. In the classic wage bargaining model unemploy-

ment ($u$) depresses wages, while unemployment benefits ($B$) and union density ($dens$) exert a positive effect. The coefficient of the average tax rate on the employee ($\alpha_3 < 0$) is expected to be positive while the marginal income tax rate has a wage decreasing effect ($\alpha_4 > 0$). The latter stands in contrast to the competitive model that predicts the opposite sign for the marginal tax rate ($\alpha_4 < 0$).

Equation (1) is estimated in differences and employees' time-constant characteristics drop out. Moreover, error terms may or may not be serially correlated in this framework. Year fixed effects and a constant account for a time trend. Splitting the sample at different points of the distribution further allows to analyze potentially heterogeneous effects of the tax structure along the wage distribution. To ensure that results are not driven by employees switching employer and/or industry, the sample is restricted to observations with at least twelve months of tenure as a robustness check (see Table 3). Based on the description of the data used and simulation of tax rates below, Section 3.3 explains in detail the instrumental variable approach employed in the estimation of the above equation.

## 3.2 The Social Security and income tax system in Germany

The compulsory Social Security in Germany refers to four different branches; (1) the old age pension scheme, (2) the health and long term care insurance, (3) the unemployment insurance.[1] Apart from marginal employment and the so called *midi jobs*, contributions increase proportionally with labor income up to respective assessment ceiling and are shared between the employer and the employee. For the unemployment insurance the old age insurance assessment ceiling is employed. The assessment ceiling for the old age insurance was at, i.e. €63,000 (€54,000) of yearly income in West (East)

[1] The accident insurance also belongs to the Social Security system. Contributions are paid by the firm and depend only in part on the firm's wage bill as employers' risk rating also decides on the amount to be paid. The accident insurance will not be considered here.

Germany in 2008. It is uprated on a yearly basis in view of last year's gross wage development. The assessment ceiling for the health insurance was €43,200 in 2008. In 2008 the statutory contribution rate for employers and employees combined amounted to 19.9% of gross wages towards the old age insurance, roughly 14% towards health insurance, 1.95% towards long term care insurance and 3.3% towards the unemployment insurance.

While contributions for the old age insurance are compulsory for everyone not marginally employed, employees can opt out of the compulsory insurance if they earn beyond the earnings ceiling for the public health system. Up until 2002 this coincided with the assessment ceiling but was split from it since 2003 when it was uprated by 13.3%. In 2005 an additional contribution was levied on top of the health insurance which was to be paid by employees while decreasing the employer's contribution at the same time. Since then the overall statutory contribution is not anymore split evenly between employers and employees anymore.

The employers' contribution for the marginally employed changed frequently in the observed time span. In April 2003 the restriction of no more than 15 working hours per week was lifted and employers had to pay 25% of the gross wage towards social security for employees earning up to €400 per month. At the same time *midi jobs* were introduced to smooth the jump in contributions between marginal employment and normal employment. For employees remunerated between €400 and €800, contributions of employers drop to the common level (20.85%) and employees contributions increase linearly towards 20.85%. Variation between individuals in terms of payroll tax thus arises due to the assessment ceiling and the differential treatment of marginal employment and *midi jobs*.

For assessment of the income tax on the household level, the household's different incomes are summed up and several deductions subtracted from the tax base. Some incomes make part of the taxable income based on which the average tax rate is calculated

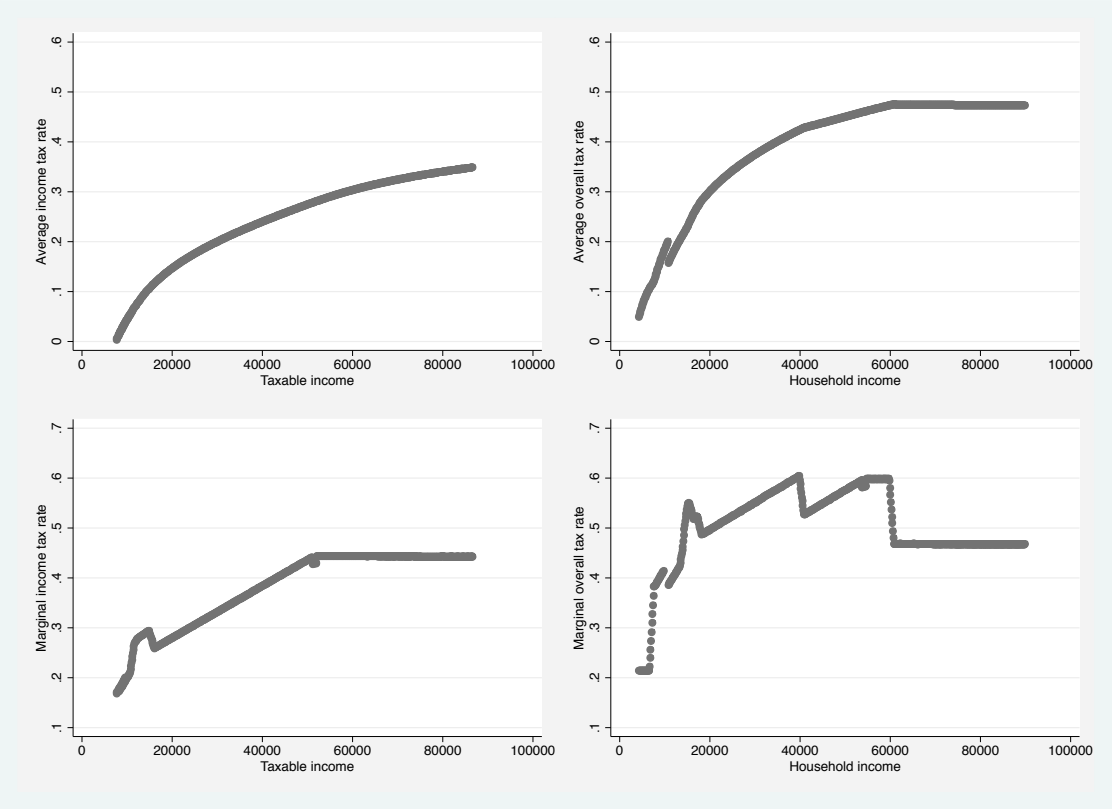
(*zu versteuerndes Einkommen 2 (zvE2)*) but are not considered in the tax base for which the final tax load is assessed (*zu versteuerndes Einkommen 1 (zvE1)*). Moreover, most married couples file for joint taxation where the income tax rate stems from applying the tax function to half the household's taxable income. The resulting amount is then doubled and constitutes the income tax load finally to be paid by the household.

While the income tax function is smooth, the marginal income tax rate when referring to a marginal increase in labor income and not taxable income takes some unexpected turns. E.g. as social security and other kinds of provident expenses (*Vorsorgeaufwendungen*) can be offset only up to a certain amount, it is even possible for the marginal tax rate to turn negative at certain levels of initial taxable income.

The largest reform of income and corporate taxation in Germany since WWII was passed in 2000 (*Steuerreform 2000*). The objective was to reduce the tax burden for both, companies and private households to boost growth and employment of the economy. Beginning in 2001 the top (lowest) marginal personal income tax was reduced from from 51% (22.9%) to 42% (15%) in 2005, and the tax allowance increased from €6,902 to €7,664. In 2007 an additional top tax bracket was introduced (*Steueränderungsgesetz 2007*) that applies a tax rate of 45% to taxable incomes beyond €250,000.

Apart from the variation in income taxes across time, marital status, the number of children in the household, other household members' income and non-labour income lead to variation in taxable income and thus income tax rates between individuals. The overall financial situation of households is characterized by social security and income tax payments on the one hand, and by a variety of transfers such as child and parental leave benefits, home-owner subsidy, commuter tax allowance. Figure 1 captures graphically the differences between considering the structure of the income tax alone or focusing on the overall tax load on the employee that accounts for all kinds of taxes on labor on the employee's side. It shows at different levels of taxable income, the structure of income taxes as opposed to the the structure of the overall tax load for a hypothetical

Figure 1: Differences in tax structure between income tax and overall tax load




*Notes*: Tax rates and progressivity for different levels of labor income of a hypothetical person when keeping everything else constant. For convenience negative marginal tax rates are excluded in the schematic plot.
*Source*: Own calculations.

single man. Under the assumption that he only has labor income and is not eligible for any subsidies, tax rates for different levels of labor income were simulated. While the average overall load exhibits a smooth shape similar to average income tax (top row), the path of marginal tax rates (middle row) is less steady for the overall tax load.

The peculiar twists and turns of the marginal tax rates are amongst other things connected to critical points in the level of labor income for the assessment of social security or the level of taxable income. As the overall tax load combines all kinds of tax payments levied on labor income, it mirrors the interaction of the different institutional rules that make up the German tax and transfer system. I.e. in the second row the decrease in

the marginal income tax rate between taxable income of roughly € 15,000 and € 16,000 is due to the fact that coming from this level of taxable income the marginal increase in income actually leads to a decrease in the amount of deductible provident expenses. This reduction in the marginal tax rate also carries over to the overall marginal tax load in the lower right panel of Figure 1. The steep increase in the marginal tax rate to the left captures when the increase in labor income entails that the person would have to pay income taxes by passing the tax allowance threshold. Just beyond € 40,000 (€ 60,000) the assessment ceiling for the health (old age) insurance is reached. Marginal overall tax rates again increase between roughly € 40,000 up till € 52,000, the end of the progression zone where the tax schedule levels out. Beyond € 60,000 the marginal social security tax rates are zero and the marginal overall tax rate is driven by the income tax schedule.

## 3.3 Instrumental variable estimation

Labor income constitutes a large part of the income tax base and is equivalent to the payroll tax base up to the assessment ceiling. Income and payroll tax rates are calculated as a function of the respective tax base. Therefore they are clearly prone to endogeneity problems as tax rates can be influenced by employers' as much as individuals' behavioral responses to the tax code. Moreover tax rates correlate not only with individual effects but also contemporaneous macroeconomic shocks as they may introduce correlated deviations between wage rates and taxable income. Valid instruments are thus needed for the different tax variables.

Appropriate instrument variables as proposed by Gruber and Saez (2002) are implemented to solve the endogeneity problem. Each individual's marginal and average tax rates in year $t$ are instrumented with the simulated tax rates he would have encountered if his tax base had not endogenously changed between $t-1$ and $t$. This is achieved by aging all income-relevant variables from year $t$ one year ahead with the

overall economic growth rate exogenous to the individual's decision and applying the tax code actually in place in year $t+1$ based on STSM. Only variation in the tax laws and economic developments exogenous to the individual is thus used for identification. A couple's decision, e.g., to marry just before a tax code change makes marriage even more attractive, is instrumented by predicting their individual tax rates if they had not married.

Apart from instrumenting the potentially endogenous tax rates, the equation of interest is estimated in first differences to take care of person fixed effects. This also takes out most of the variation on the individual level connected to wages, like experience, age, tenure, occupation. If a person did not switch employer, person fixed effects also account for any peculiarities to the sector or firm that are constant across time. Firm size, industry affiliation, the firm's pay scheme may amongst other characteristics be linked to wages and are taken out by first-differencing.

# 4 Data and the Tax-Benefit-Simulation Model

## 4.1 The German Socio Economic Panel

The analysis is based on the German Socio Economic Panel (GSOEP), a representative sample of over 11,000 private households in Germany (Haisken-DeNew and Frick, 2005). The panel supplies detailed information on labor income as much as other sources of household income. Labor market information, i.e. the type of job, working hours, tenure, and employer characteristics like industry affiliation and firm size is available. The sample is restricted to individuals that make part of the compulsory Social Security system, therefore excluding other groups that are subject to the income tax like the self-employed, civil servants, and retired people. The analysis is furthermore based on data of continually employed people as payroll and income taxes are

both assessed on a yearly basis and people receiving unemployment benefits or assistance during unemployment spells shall not be considered in the analysis. Individuals on vocational training are excluded. Gross monthly earnings in the month before the interview together with the information on hours worked is used to calculate the hourly wage rate and finally together with the tax variables the consumer wage.

The GSOEP does not contain information about the pay scheme for a particular worker (collective, firm, plant level agreement or none of the above). As a proxy variable the degree of coverage by collective agreements on the industry level is added using data from IAB's establishment panel. Furthermore unemployment rates on a regional level (*Raumordnungsregionen*) are introduced as a measure of unemployment probability.

## 4.2 The tax-benefit simulation model (STSM)

The micro-simulation model STSM depicts in great detail the German tax and transfer system. For the study at hand different measures of tax rate are calculated, namely employer payroll tax rates, income tax rates and the overall tax load on the employee's side.

Payroll tax loads are calculated given the employed's yearly labor income and job type (marginal employment, *midi job* or common employment). The income tax payments are assessed in the household context. After adding up all income components of household members certain expenses are deducted and benefits relevant for the income tax are accounted for the calculation of taxable income. The income tax function is then applied directly to taxable income for singles and unmarried couples; for married couples joint taxation is implemented.

Net income is derived as gross income (including social transfers) less income tax and the employee's social security contributions. Social transfers considered on the

household level are child benefits, child-rearing benefits, housing benefits, social assistance, education benefits for students, and unemployment compensation. The average income and overall tax rate is the same for a married couple in this framework. But note that the marginal tax rates may differ between husband and wife. Keeping i.e. the husband's income and all other household characteristics stable, a marginal increase in the wife's labor income may be subject to a quite different degree of tax load than in the opposed scenario (increasing the husband's labor income by the exact same marginal amount), given different initial levels of labor income.

For the currently employed in the data each individual's counterfactual UE assistance is simulated in case that he or she would loose their job. The simulation again takes into account each person's household context.

## 4.3 Descriptive Evidence

Table 1 shows the main characteristics of the estimation sample. The majority of observations works full-time and is employed in West Germany. Table 2 depicts the main variables of interest and their development over time. Real wages declined over time, a well-known development in Germany for that time span.

Average employer payroll taxes remained on average quite stable across time; the decrease between 2005 and 2006 by nearly one percentage point picks up the decrease in the employer's contributions to the health insurance.

The income tax reform of 2000 changed the tax tariff in steps with the first half of adjustments taking place between 2000 and 2002. The reduction of the average tax rates by about two percentage points in the middle of the distribution of taxable income between 2002 and 2005 also shows up in the empirical tax rates calculated here. The subsequent introduction of a top tax bracket shows for the last years. The starting tax rate saw the greatest change in the tax schedule decreasing by roughly a third between

Table 1: General characteristics of the data set

| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|
| Age (in years) | 43.79 | 43.61 | 43.92 | 44.08 | 44.28 | 44.44 | 44.67 |
| *sd* | 9.46 | 9.68 | 9.39 | 9.39 | 9.53 | 9.60 | 9.73 |
| Female (in %) | 47.45 | 48.31 | 48.33 | 48.53 | 46.29 | 47.16 | 47.53 |
| *sd* | 49.94 | 49.98 | 49.98 | 49.99 | 49.87 | 49.93 | 49.95 |
| Full-time (in %) | 81.54 | 80.80 | 79.34 | 80.61 | 80.74 | 81.22 | 80.24 |
| *sd* | 38.80 | 39.39 | 40.49 | 39.54 | 39.44 | 39.06 | 39.83 |
| Vocational training (in %) | 69.79 | 68.80 | 68.20 | 68.02 | 68.60 | 66.82 | 65.83 |
| *sd* | 45.92 | 46.34 | 46.58 | 46.65 | 46.42 | 47.09 | 47.44 |
| East Germany (in %) | 18.08 | 18.02 | 17.70 | 17.71 | 17.92 | 19.17 | 18.96 |
| *sd* | 38.49 | 38.44 | 38.17 | 38.18 | 38.36 | 39.37 | 39.20 |

*Notes*: Sample restricted to employed people with positive income tax payment.
*Source*: Own calculations based on GSOEP 2002 through 2008.

2002 and 2005; empirically this carries over to a decrease in average income tax from 7.56% to 5.36% for taxable incomes below €20,000. In the tax tariff marginal tax rates with regard to taxable income were reduced across the board. On a smaller scale this feeds through to a decrease in marginal tax rates when considering a marginal increase in labor income. The overall average tax rate that measures all taxes raised on labor income through social security and the income tax is considerably higher at a level of around 38%. It picks up the increase in payroll tax loads on employees during those times with assessment ceilings and contribution rates consistently on the rise except for the last two years where contributions to the unemployment insurance and health insurance were slightly reduced. The marginal overall tax rate shows that on average about 50% of extra labor income are taken away by taxes. The income tax system is clearly progressive with a measure of residual income progression of 0.84 across time.

For the hypothetical income in case of unemployment different scenarios are conceivable as a lower threat point. If the employee was entirely certain to be reemployed within the next months his income expectations in case of unemployment would be cap-

Table 2: Descriptive statistics

| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|
| Real hourly wage rate | 14.92 | 14.93 | 14.82 | 14.58 | 14.39 | 14.39 | 14.12 |
| *sd* | 5.27 | 5.32 | 5.22 | 4.91 | 4.66 | 4.87 | 4.77 |
| Average employer payroll tax rate (in %) | 20.38 | 20.65 | 21.13 | 21.10 | 21.17 | 20.15 | 19.79 |
| *sd* | 1.21 | 0.90 | 1.04 | 1.40 | 0.94 | 1.10 | 0.83 |
| Average income tax rate (in %) | 18.27 | 18.25 | 17.02 | 16.57 | 16.58 | 17.05 | 17.15 |
| *sd* | 5.69 | 5.75 | 5.72 | 5.62 | 5.50 | 5.60 | 5.64 |
| Average overall tax load (in %) | 38.65 | 38.89 | 38.12 | 38.15 | 38.60 | 38.06 | 37.83 |
| *sd* | 5.41 | 5.53 | 5.57 | 5.47 | 5.36 | 5.37 | 5.36 |
| Marginal income tax rate (in %) | 30.87 | 30.86 | 30.35 | 29.18 | 29.35 | 29.79 | 29.86 |
| *sd* | 15.28 | 13.11 | 12.54 | 8.31 | 8.25 | 11.98 | 10.99 |
| Marginal overall tax load (in %) | 49.94 | 50.37 | 50.35 | 49.64 | 50.21 | 49.46 | 49.02 |
| *sd* | 15.13 | 13.10 | 12.73 | 8.67 | 8.80 | 12.67 | 11.26 |
| Income tax progressivity (in %) | 84.63 | 84.54 | 83.91 | 84.93 | 84.77 | 84.63 | 84.71 |
| *sd* | 18.23 | 14.53 | 13.95 | 8.19 | 8.87 | 14.25 | 12.37 |
| Monthly UE assistance | 651 | 657 | 657 | 498 | 487 | 474 | 459 |
| *sd* | 400 | 402 | 404 | 232 | 223 | 218 | 214 |
| Regional unemployment rate (in %) | 10.78 | 11.65 | 11.60 | 13.01 | 11.99 | 10.21 | 8.59 |
| *sd* | 4.85 | 4.84 | 4.73 | 4.65 | 4.40 | 4.16 | 3.62 |
| Collective contract (in %) | 50.07 | 48.47 | 48.26 | 44.44 | 45.01 | 44.16 | 45.37 |
| *sd* | 20.15 | 19.45 | 21.13 | 20.24 | 20.44 | 20.60 | 21.44 |
| Collective contract, incl. orientation (in %) | 72.77 | 71.74 | 69.74 | 65.56 | 69.12 | 68.21 | 69.59 |
| *sd* | 16.00 | 14.79 | 16.18 | 16.14 | 15.61 | 15.98 | 16.04 |

*Notes*: Hourly wage rates and UE benefits deflated with CPI to 2002. Sample restricted to employed people with positive income tax payment.
*Source*: Own calculations based on GSOEP 2002 through 2008.

tured by unemployment benefits which can be obtained for a limited number of months only and are a fraction of his last labor income (*Arbeitslosengeld* or respectively *Arbeitslosengeld I*). With greater risk aversion and a less optimistic look at reemployment chances the employee considers long-term unemployment (UE) assistance as his income in case of unemployment.[2] The unemployed are required to rely on their own wealth up to a certain allowance before being entitled to unemployment assistance. If

[2]Before 2005 *Arbeitslosenhilfe* is calculated, from 2005 on *Arbeitlosengeld II*.

one considers wealth in the long run to be used up and neglects partner's (other) income the basic allowance would be non-zero for everyone taking i.e. account of the children in the household. Table 2 shows the level of the hypothetical monthly UE assistance based on these assumptions. On average the *Hartz* reforms reduced the level of UE assistance to be expected in case of unemployment but this reduction did not take place uniformly. Depending on each person's situation the hypothetical income level under the new rules could be higher or lower than before the reforms.

Regional unemployment rates are declining from 2005 on. The industry level indicator for coverage by a collective or firm agreement declines over the years.[3] If establishments whose pay scheme is oriented towards the collective agreement are also considered in a wide definition of wage bargaining indicator, the fraction of coverage hovers around 70%.

# 5 Estimation results

Table 3 summarizes estimation results for equation (1) with the OLS results in first differences in the column (1). The dependent variable is the real hourly wage rate and standard errors are clustered on the industry level in all estimations. In columns (2) through (6) the instrumental variable approach outlined above is employed. The Durbin-Hausman-Wu test assesses whether the tax variables suspected of endogeneity can in fact be treated as exogenous. The test statistic evaluates to 6.876 (p-value = 0.076) and confirms that the tax variables in fact should be treated as endogenous. Endogeneity remains an issue in the further specifications and is accounted for by 2SLS estimation. Beyond the tax variables the strength of bargaining and the level of UE assistance have a positive effect on wages as proposed by wage-bargaining models. The point estimate for regional unemployment is negative as predicted but not significant. Effects for the

[3]The indicator is computed from the IAB establishment panel for each year.

Table 3: Estimation results for income taxes and payroll tax

| *Dependent variable:* | FD-OLS | FD-IV | FD-IV | FD-IV | FD-IV | FD-IV |
|---|---|---|---|---|---|---|
| ln(real hourly wage) | (1) | (2) | (3) | (4) | (5) | (6) |
| ln(1+$(E(W)/W)$) | -2.369 | -2.491 | -2.680 | -3.591 | -4.072 | -4.487 |
| | (0.715) | (1.520) | (1.599) | (1.970) | (1.738) | (1.735) |
| ln(1-$(H(W)/W)$) | -1.569 | -1.805 | -1.779 | -1.703 | -1.423 | -0.844 |
| | (0.090) | (0.276) | (0.247) | (0.266) | (0.221) | (0.102) |
| ln(1-H'(W)) | -0.080 | 0.165 | 0.192 | 0.186 | 0.228 | -0.012 |
| | (0.014) | (0.106) | (0.090) | (0.115) | (0.097) | (0.051) |
| ln(Real UE assistance) | 0.039 | 0.039 | 0.040 | 0.041 | 0.038 | 0.055 |
| | (0.008) | (0.012) | (0.012) | (0.011) | (0.012) | (0.009) |
| ln(Regional unemployment rate) | -0.014 | -0.014 | -0.013 | -0.003 | -0.016 | -0.014 |
| | (0.020) | (0.020) | (0.019) | (0.023) | (0.020) | (0.021) |
| ln(Degree of organization) | 0.015 | 0.016 | 0.015 | 0.013 | 0.016 | 0.014 |
| | (0.005) | (0.005) | (0.005) | (0.005) | (0.006) | (0.005) |
| *Sample size and restrictions:* | | | | | | |
| N | 15,100 | 15,100 | 14,997 | 14,752 | 15,100 | 14,767 |
| Sample restrictions | - | - | marginal > average tax | tenure > one year | - | - |
| H(W) defined on the level of the ... | income tax | income tax | income tax | income tax | overall load | loads and benefits |
| *Identification:* | | | | | | |
| Endogeneity test statistic | | 6.876 | 8.352 | 7.053 | 7.082 | 7.082 |
| ... p-value in $\chi^2_{(3)}$-distribution | | 0.076 | 0.039 | 0.070 | 0.069 | 0.069 |
| Underidentification test statistic | | 10.000 | 9.984 | 13.419 | 13.677 | 13.677 |
| ... p-value in $\chi^2_{(1)}$-distribution | | 0.002 | 0.002 | 0.000 | 0.000 | 0.000 |
| *Implied tax rate elasticities:* | | | | | | |
| Average employer payroll tax | -0.404 | -0.425 | -0.458 | -0.613 | -0.695 | -0.766 |
| | (0.122) | (0.259) | (0.273) | (0.336) | (0.297) | (0.296) |
| Average employee tax load | 0.334 | 0.385 | 0.379 | 0.363 | 0.893 | 0.334 |
| | (0.019) | (0.059) | (0.053) | (0.057) | (0.139) | (0.041) |
| Marginal employee tax load | 0.034 | -0.071 | -0.083 | -0.080 | -0.226 | 0.013 |
| | (0.006) | (0.045) | (0.039) | (0.050) | (0.096) | (0.056) |

*Notes*: Standard errors clustered on industry level are reported in parentheses. Estimates are based on first-differenced data. In all 2SLS estimations the respective tax rates are instrumented by their simulated counterparts (see text). Year fixed effects and constant included. The term "overall tax" refers to H(W) as the overall tax load on the employee's side (income tax and employee side social security contributions) respectively, and "loads and benefits" also considers financial benefits accruing to the household.
*Source*: Own calculations based on GSOEP 2001 through 2008.

non-tax variables are stable across all different specifications to follow.

For the benchmark specification in column (2) full first stage output is provided in the Appendix. The partial $R^2$ Shea range between 0.04 and 0.07. Angrist and Pischke (2009, p. 217-218) propose to take the partial $R^2$ Shea a step further and to actually test

whether one of the endogenous regressors is under- or weakly identified when there are several endogenous regressors. Their proposed procedure rejects underidentification for every single endogenous regressor thus supporting the chosen design. The Kleibergen-Paap test assesses whether the instruments together are adequate to identify the equation (Kleibergen and Paap, 2006) and underidentification as a whole is rejected too, with the overall underidentification test statistic amounting to 10. Identification tests for the other specifications also confirm the validity of the chosen design.

Results in columns (2) through (4) show that average tax rates exert a positive impact on wages while employer payroll tax is partly shifted onto employees. The implied average income tax rate elasticity of wages is in a similar range to that found by Schneider (2005) for the 1980s. Yet the elasticity of the wage with regard to the marginal tax rate is roughly -0.07. The aforementioned study reports a twice as large elasticity. Clearly different from zero the wage moderating effect of marginal tax rates is stable across different sample restrictions. The evidence thus clearly points towards a wage-decreasing effect of marginal income tax rates.

In the literature it is common to include solely income tax rates on the employee's side alongside the employer side payroll taxes or not considering the latter at all. This approach may have some drawbacks if one suspects correlation between the employee's social security contributions not considered in the estimation and the other tax variables. While the direction, size and consequences for standard errors of the potential bias due to omitting employees' social security contributions cannot be pinned down, there is no means to include employees' social security contributions as an additional variable either due to multicollinearity. In column (5) the overall tax load on the employee's side is therefore considered consisting not only of income taxes but also of employees' social security contributions. Apart from being closer to various theories' definition of the employee's tax load, the overall tax load should also be the economically relevant measure. For many employees the tax load due to social security is substantial and in

many cases larger than the income tax load. The chosen approach along the way also circumvents the multicollinearity problem. The negative effect of the marginal tax rate also prevails in this definition of the employees' tax load. It becomes insignificant and close to zero when considering additionally the benefits that accrue to individuals in the scope of the tax and transfer system (column (6)).

Studies that estimated the impact of (marginal) tax rates on before-tax-wages have found effects to differ along the wage distribution, in size or even direction of effects. In Table 4 this is followed up splitting the sample at different points. While it cannot be rejected that average tax rates act in a similar fashion across the two groups, this hypothesis is clearly rejected for marginal tax rates. I.e. for the sample split at the median the $\chi^2_{(1)}$ test statistic for equality of coefficients on the marginal tax rate terms between the two groups evaluates to 9.06. All specifications confirm the wage-reducing effect of marginal (income) tax rates on wages for the lower half of the distribution. But in the upper half of the distribution the effect becomes positive. This holds for different locations of the sample split while not significantly so when dividing the observations at the 40%-percentile. The differential effect is also confirmed for the alternative overall tax measure proposed above in column (4).

This opposes results by Schneider (2005) who found significant wage-reducing effects of income progressivity across the whole wage distribution for Germany in the late 1980s. Two points may serve as an explanation: For one the sample of observations was limited to a sub-group of employees most prone to union membership; for another a considerably larger part of employees was still bound by collective agreements in that period. In these years 72.2% (56.3%) of employees in West (East) Germany were bound by collective agreements according to Kohaut and Schnabel (2003). Fifteen years later the share of coverage had decreased to 63.1% (44.4%).

The findings above are more closely related to the results by Lockwood et al. (2000) who find effect heterogeneity not only in magnitude but also size and significance along

Table 4: Estimation results along the wage distribution

| *Dependent variable:* | FD-IV | FD-IV | FD-IV | FD-IV |
|---|---|---|---|---|
| ln(real hourly wage) | (1) | (2) | (3) | (4) |
| $\ln(1+E(W)/W)$ | -2.728 | -2.367 | -1.939 | -4.490 |
| | (1.734) | (1.179) | (1.175) | (1.515) |
| $\ln(1-H(W)/W) \times$ low | -1.453 | -1.038 | -1.001 | 0.024 |
| | (0.716) | (0.274) | (0.215) | (0.009) |
| $\ln(1-H(W)/W) \times$ high | -0.770 | -1.073 | -1.190 | -0.026 |
| | (0.798) | (0.403) | (0.317) | (0.016) |
| $\ln(1-H'(W)) \times$ low | 0.491 | 0.172 | 0.136 | 0.015 |
| | (0.359) | (0.108) | (0.077) | (0.005) |
| $\ln(1-H'(W)) \times$ high | -0.638 | -0.491 | -0.425 | -1.038 |
| | (0.466) | (0.226) | (0.156) | (0.261) |
| ln(Real UE assistance) | 0.021 | 0.024 | 0.020 | -0.992 |
| | (0.008) | (0.009) | (0.008) | (0.334) |
| ln(Regional unemployment rate) | -0.022 | 0.002 | -0.023 | 0.281 |
| | (0.016) | (0.019) | (0.016) | (0.102) |
| ln(Degree of organization) | 0.012 | 0.014 | 0.014 | -0.090 |
| | (0.004) | (0.004) | (0.005) | (0.273) |
| *Sample size and restrictions:* | | | | |
| N | 15,100 | 15,100 | 15,100 | 15,100 |
| Sample spit at ...%-percentile of wage distribution | 30 | 40 | 50 | 50 |
| H(W) defined on the level of the ... | income tax | income tax | income tax | overall load |
| *Identification:* | | | | |
| Endogeneity test statistic | 16.700 | 14.335 | 13.155 | 18.955 |
| ... p-value in | 0.005 | 0.014 | 0.022 | 0.002 |
| *Implied tax rate elasticities:* | | | | |
| Average employer payroll tax | -0.466 | -0.404 | -0.331 | -0.767 |
| | (0.296) | (0.201) | (0.201) | (0.259) |
| Average tax $\times$ low | 0.235 | 0.177 | 0.178 | 0.593 |
| | (0.116) | (0.047) | (0.038) | (0.149) |
| Average tax $\times$ high | 0.182 | 0.261 | 0.298 | 0.683 |
| | (0.189) | (0.098) | (0.079) | (0.230) |
| Marginal tax $\times$ low | -0.183 | -0.066 | -0.053 | -0.273 |
| | (0.134) | (0.041) | (0.030) | (0.099) |
| Marginal tax $\times$ high | 0.291 | 0.229 | 0.202 | 0.091 |
| | (0.212) | (0.105) | (0.074) | (0.276) |

*Notes*: Standard errors clustered on industry level are reported in parentheses. In all 2SLS estimations in first differences the respective tax rates are instrumented by their simulated counterparts (see text). Year fixed effects and constant included.
*Source*: Own calculations based on GSOEP 2001 through 2008.

the wage distribution. They point out that for different parts of the wage distribution different labor market models may be a more apt description than others. The study

conducted here can be interpreted in a similar way; if the suspected location of wages paid according to a bargaining model is in the lower half of the distribution (remember that coverage by a collective agreement reaches roughly half the work force in Germany), the model's predictions on the effects of marginal taxes may be relevant only in that realm. If labor contracts in the upper half of the distribution are set individually between the employer and the employee as commonly reported for the more skilled and better-paid, a competitive labor market would then be the better description for this part of the distribution. Altogether results clearly reject the notion of a uniform effect of marginal tax rates across the wage distribution.

# 6 Conclusion

A classic in the public finance literature is the role of the level and structure of taxation in wage formation. Theoretical predictions of the traditional competitive labor market model were challenged by theories based on imperfect labor markets in the 1990s. In view of consistently high unemployment rates in many industrialized countries at the time various proposals were made to influence the wage outcome through public finance reforms with the ultimate goal to reduce unemployment. The issue whether marginal income tax rates have a wage-reducing or increasing effect received particular attention. For one because a policy reform affecting progressivity was considered to come closest to a politically feasible budget neutral reform; for another because the benchmark theories of perfect and imperfect labor markets provided clearly opposing predictions. Various empiricists set out to empirically test which theory and finally which policy recommendation is more apt to describe reality. And while earlier studies found support for wage-reducing effects of progressivity this was challenged by the following generation of empirical studies. Not only the direction of effects varies widely across studies but also the magnitude of effects, even suggesting over-shifting of taxes onto wages.

The study undertaken here extends the literature by stepping away from tax functions or simplified tax computations for certain socioeconomic core groups and instead implements the German tax and transfer system in a very detailed microsimulation model. This allows to consider not only the pure income tax tariff structure but also to assess complete tax load on labor on the employee's side stemming from income tax and employees' social security contributions. Given that the actual tax load in the end of the day is influenced by many more peculiarities of the tax and benefit system than just the income tax function, a more complete measure of household's tax load is developed. As tax rates are endogenous, simulated counterfactual tax rates a household would have faced had it not adapted its behavior to the reforms undertaken in that period, are con-

structed based on the microsimulation model. Individuals' relevant incomes are aged a year ahead using exogenous macroeconomic inflation indicators and the tax legislation in place that year is applied to the resulting hypothetical tax base. Estimation in first differences furthermore purges fixed effects.

Estimation results show that employer payroll taxes are partly shifted onto employees and average (income) tax rates on the employee side act wage-increasing. Evidence on marginal tax rates clearly lends support to the wage moderating effects of progressivity. These results also hold when the overall tax load on the employee side, including income tax and social security contributions alike, are considered.

Along the wage distribution the result on employees' marginal tax load is heterogeneous. A negative effect prevails in the bottom of the wage distribution and positive effects in the upper part. This evidence is suggestive of the prevalence of different wage setting regimes in different parts of the labor market. The lower part of the wage distribution is typically considered as the target audience and member base of unions. The wage-reducing effect of progressivity detected empirically is in line with the commensurate theories of imperfect labor markets. In the upper part of the wage distribution a greater share of employees can be expected to bargain on a one-to-one basis with the respective employer over wages, a description closer to the assumptions of competitive labor markets.

These results caution against broad-brush policy recommendations proposing to cut or increase marginal taxes with the goal of promoting employment. Even provided that there is no adjustment in employment itself in response to such reform, the heterogeneous effects found along the wage distribution in this study pose a true challenge to the design of a well-targeted policy. Considering in addition that the tax load on employees is in part assessed on the household level and in part on the individual level makes the challenge to engineer marginal tax rates even more demanding. A further complication to simple policy recommendations relates to the tax-benefit-link; the valuation of future

benefits tied to taxes or contributions may be stronger for some kinds of taxes and more relevant to some employees depending on their level of wage and other income.

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# 7 Appendix

## 7.1 First stage estimation results for the baseline 2SLS specification, column (2) in Table 3

| | *Instrumented variables*[1] Specification (2) in Table 3: | | |
|---|---|---|---|
| | ln(1+(E(W)/W)) | ln(1-H(W)/W) | ln(1-H'(W)) |
| ln(1+$(E(W)/W)^{sc}$) | -0.140 | -0.139 | -0.397 |
| | (0.024) | (0.031) | (0.149) |
| ln(1-$(H(W)/W)^{sc}$) | -0.010 | -0.275 | -0.077 |
| | (0.002) | (0.019) | (0.069) |
| ln(1-$H'(W)^{sc}$) | -0.002 | 0.003 | -0.204 |
| | (0.001) | (0.003) | (0.073) |
| ln(Real UE assistance) | -0.001 | -0.024 | -0.026 |
| | (0.000) | (0.001) | (0.003) |
| ln(Regional unemployment rate) | -0.001 | 0.001 | 0.002 |
| | (0.001) | (0.006) | (0.011) |
| ln(Degree of organization) | 0.000 | 0.001 | -0.002 |
| | (0.000) | (0.001) | (0.002) |
| 2003 | 0.003 | -0.005 | -0.005 |
| | (0.000) | (0.001) | (0.002) |
| 2004 | 0.009 | 0.018 | 0.013 |
| | (0.000) | (0.002) | (0.002) |
| 2005 | 0.010 | 0.015 | 0.019 |
| | (0.000) | (0.002) | (0.004) |
| 2006 | 0.011 | 0.012 | 0.014 |
| | (0.000) | (0.002) | (0.004) |
| 2007 | 0.003 | 0.007 | 0.010 |
| | (0.000) | (0.001) | (0.002) |
| Constant | -0.001 | -0.001 | 0.002 |
| | (0.000) | (0.000) | (0.001) |
| *Relevance of instruments:* | | | |
| Partial $R^2$ Shea | 0.046 | 0.072 | 0.041 |
| Angrist-Pischke first-stage $\chi^2$ test statistic | 31.317 | 211.606 | 7.984 |
| ... p-value in $\chi^2_{(1)}$-distribution | 0.000 | 0.000 | 0.006 |

[1] "*sc* "refers to the simulated counterfactual values for the respective tax rates.
*Notes*: Standard errors clustered on industry level are reported in parentheses. Estimates are based on first-differenced data. Partial $R^2$ Shea is calculated as proposed by Shea (1997); Godfrey (1999). The related test for the relevance of the instrument variable, the Angrist-Pischke first-stage $\chi^2$ test statistic, is based on the methodology proposed by Angrist and Pischke (2009, p. 217-218).
*Source*: Own calculations based on GSOEP 2001 through 2008.