Evaluating the move to a linear tax system in Germany and other European countries

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Abstract   This paper proposes a comparison of the results of tax policy analysis obtained on the basis of unitary and collective representations of the household. We first generate labour supplies consistent with the collective rationality, by use of a model calibrated on microdata as described in Vermeulen et al. [Collective Models of Household Labor Supply with Nonconvex Budget Sets and Nonparticipation: A Calibration Approach (2006)]. A unitary model is then estimated on these collective data and unitary and collective responses to a tax reform are compared. We focus on the introduction of linear taxation in Germany. The exercise is replicated for other European countries and other topical reforms. Distortions due to the use of a unitary model turn out to be important in predicting labour supply adjustments, in the design of tax revenue neutral reforms, and in predicting a reform's welfare implications.

Keywords   Household labour supply · Intrahousehold allocations · Tax reform

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1. Introduction

In the unitary model, household behavior is considered as resulting from the decisions of a single unit, concealing the fact that most households consist of several members. Since flexible and easily identifiable, this representation of household decision processes is very popular when estimating household preferences, particularly in the presence of a complex budget constraint (see for instance van Soest, 1995). In this respect, it is a convenient model when studying the impact of a real or topical tax reform on household behavior (see e.g., Blundell, Duncan, McCrae, & Meghir, 2000). Yet, the unitary model treats the family as a black box and consequently the within family income redistribution resulting from a policy reform cannot be identified. Alternatively, the collective approach specifies the individual preferences of family members and simply assumes that the household decision making process leads to Pareto efficient allocations.

The present paper proposes a quantification of the distortions in tax reform analysis entailed by the use of a unitary model when the data are collective. The evaluation of tax reforms based on both unitary and collective models has been suggested by Beninger and Laisney (2002). Using purely synthetic data, they find important discrepancies in the incentive and distribution effects of revenue neutral reforms based on unitary estimates rather than on the collective parameters. The aim of the present paper is to check the robustness of these results when the collective baseline situation is generated using real world data. This is done by means of a collective model calibrated on real data as described in Frederic Vermeulen et al. (2006), and by estimating a unitary model on this 'collective data set'. We focus on German data, and a revenue neutral tax reform that consists of replacing the smooth progressive tax schedule and the current means tested social benefits by a simple two parameter linear taxation system involving a basic income and a flat tax. The same exercise is replicated for other European countries and other topical reforms.

The outline of the paper is as follows. The second section briefly introduces the baseline German tax and benefit system (corresponding to the year 1998). Section 3 gives statistical evidence on the data used, the 1998 wave of the GSOEP. Estimation results for the unitary model are given in Section 4. Section 5 compares normative and positive analyses of the tax reform on the basis of the two models. Section 6 concludes.

2. The 1998 German tax-benefit system

The German tax system is characterized by comprehensive taxation of various income sources through a smooth nonlinear tax schedule, and by joint taxation of couples. After deduction of income related expenses, child allowances and maintenance payments to ex partners, the individual marginal tax rate starts off at 25.9% (applicable from an annual personal allowance of 6,322 euro). The top rate is 53% for yearly earnings in excess of 61,376 euro. The tax schedule is the same for singles and for couples, but for couples, the 'splitting' system is applied: the tax liability per person is assessed on the basis of half of the joint taxable income, and the outcome is doubled to obtain the total income tax liability of the spouses. Employees are also subject to social security contributions on earnings at a more or less constant rate of about 20%. As these contributions are related to claims toward the social security system, they are treated here as consumption expenses that do not

reduce disposable income, and are thus excluded from our narrow definition of the tax benefit system.[1]

We consider means tested social benefits of a maximum of 511 euro per individual per month plus age depent supplementary payments for children.[2] In addition, there is a universal child benefit, but parents may opt instead for an alternative tax deduction. Dis posable income is defined in the study as net income minus net maintenance payments to or from parents, children and ex partners.

The German tax benefit system results in nonconvex budget sets for a large proportion of households (this concerns more than half of the couples in the sample used). A detailed description of the tax benefit system and an illustration of the potential nonconvexity of the budget constraint are provided in Appendix A.

3. Data

Our exercise consists in estimating a unitary model on the basis of realistically simulated collective data. For this purpose, we use data from the 1998 wave of the German Socio Economic Panel (GSOEP) and then simulate individual behavior according to collective rationality. This section briefly describes the basic data selection, and recalls the two step construction of the collective data base. More detailed information on the sample chosen and some descriptive statistics are given in Appendix B.

The GSOEP is a representative panel data sample of households and individuals living in Germany. It started in 1984 with annual interviews in the Federal Republic of Germany and was extended to the former German Democratic Republic from 1990 on. The panel gives a wealth of information on the labour market status of individuals and on the various income sources of families.

We selected German nationals aged between 25 and 55 years. All are employees with a contractual labour supply of at least 10 h per week or individuals who are voluntarily out of employment. The restriction on hours is introduced to avoid extraordinary high wage rates as the ratio of earnings over hours due to measurement error for people with less than 10 h. As usual in labour supply studies, we exclude the self employed, students, indi viduals on parental leave, and the (registered) unemployed.

The sample of singles consists of 488 individuals: 208 women and 280 men. Here a 'single' is a one person household. He or she may have dependent children living outside the household. We also selected 1,332 families living in a one or two generation households composed of a married couple and dependent (possibly working) children. The children may live inside or outside the household.

Married women have a significantly lower participation rate than married men or sin gles. The distribution of labour supply is more evenly spread for wives than for husbands: they work more often in part time jobs. In particular the wives' weekly working time distribution has a mode at 20 h.

To obtain a data set representing the collective world for Germany, we use the following two step procedure (details are given in Vermeulen et al., 2006). In the first step, we estimate preference parameters for single men and women and then predict their labour

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[1] Admittedly, the different types of social security contributions paid in Germany have different con sumptive aspects, and our assumption is probably more appropriate for payments to the pension system than for health insurance contributions.

[2] Social benefits are 10% lower in the East: this difference is justified by the lower costs of living in the East.

supply and the corresponding consumption level under the 1998 German tax benefit sys
tem. This also involves the estimation of wage equations. In the second step, for families
composed of a married couple (and children), we determine the partners' relative weights
in the household (''male power index''). We suppose that the preferences of married
individuals differ from those of singles by an additional cross leisure term, different for
females and males (δ_f and δ_m hereafter). Therefore, apart from the latter, we assume that
married individuals basically retain the same preferences as before marriage.

The predicted labour supplies, that almost perfectly fit the observed hours of work, are
taken as the baseline situation for the estimation of the unitary model (see Beninger,
Laisney, & Beblo, 2003, for details on the German collective data).

4. Unitary model: estimation

We now describe the estimation procedure for the unitary model, and the estimation
results.

4.1. Estimation procedure for the unitary model

For the specification of the unitary model, we adopt the analogue to the individual utility
functions used in the collective model (see Vermeulen et al., 2006). In order to remain
close to the situation faced by an investigator who only observes aggregate household
consumption, we do not take advantage of the fact that the collective baseline situation
contains each spouse's consumption (see Myck et al., 2006). Thus, we specify:

$$U\left(c, l^f, l^m; \mathbf{d}\right) \quad \beta_c(\mathbf{d})\ln[\mathbf{c} \quad \mathbf{c}(\mathbf{d})]$$
$$+ \beta_l^f(\mathbf{d})\ln\left[\mathbf{l^f} \quad \mathbf{l^f}(\mathbf{d})\right] + \beta_\mathbf{l}^\mathbf{m}(\mathbf{d})\ln[\mathbf{l^m} \quad \mathbf{l^m}(\mathbf{d})]$$
$$+ \delta(\mathbf{d})\ln\left[\mathbf{l^f} \quad \mathbf{l^f}(\mathbf{d})\right]\ln[\mathbf{l^m} \quad \mathbf{l^m}(\mathbf{d})]. \tag{1}$$

Appendix C gives the conditions under which this utility function is increasing in its
arguments and concave. We also experimented with direct translog utility functions along
the lines of van Soest (1995), but with a quadratic form in logs of departures from minimal
requirements, as in Eq. (1). Although several specifications were superior to our preferred
specification in terms of likelihood values, all led to utility functions that were nonin
creasing in at least one argument for a majority of observations. This made them useless
for tax reform analysis.

The β and δ functions are assumed to be linear in $\mathbf{d}$, and the minimum requirements in
consumption and leisure are set to the values chosen for the collective model. Of course,
the budget constraint remains the same as for the collective model.

We suppose that each spouse has K alternative values h_k for his/her weekly labour
supply, leading to leisure choices $l_k = T - h_k$, where T is the total time available: 168 h a
week. We choose $K = 7$, and the following set of possible values for h^k: 0, 10, 20, 30, 40, 50,
60. Hence, the couple has $K^2 = 49$ possible combinations. If $\hat{U}_j \quad \hat{U}\left(c_j, l_j^f, l_j^m; \mathbf{d}\right)$ denotes
the utility generated by combination j of the set of combinations { $(c_j, l_j^f, l_j^m)_j^{K^{\wedge}2}$}, adding an
error term ε_j to the utility derived from combination j, we have:

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$$\hat{U}_j \quad \hat{U}\left(c_j, l_j^f, l_j^m; \mathbf{d}\right) + \varepsilon_j \qquad \forall j \quad 1, \ldots, K^2. \tag{2}$$

The distribution of ε_j is assumed to be the extreme value distribution defined by:

$$\Pr\left[\varepsilon_j < \varepsilon\right] \quad \exp(\quad \exp(\quad \varepsilon)), \qquad \varepsilon \in \mathbb{R}, \tag{3}$$

and the ε are assumed independent. If combination j is chosen by a household, its contribution to the likelihood is

$$\Pr\left[\hat{U}_j > \hat{U}_k, \forall k \; / \; j\right] \quad \frac{\exp\left[\hat{U}\left(c_j, l_j^f, l_j^m; \mathbf{d}\right)\right]}{\sum_k^{K^2} {}_1 \exp\left[\hat{U}\left(c_k, l_k^f, l_k^m; \mathbf{d}\right)\right]}. \tag{4}$$

This corresponds to the likelihood of the multinomial logit model. In order to account for unobservable heterogeneity in consumption, we also estimate a discrete mixture of such models (see Heckman & Singer, 1984; Hoynes, 1996) with two to three mass points on the coefficient of $\ln[c \quad c(\mathbf{d})]$ (mixed multinomial logit model, MMNL; details are given in Vermeulen et al., 2006, Appendix A.2).

4.2. Estimation results

Table 1 presents estimation results for a model with three mass points. Although the coefficient of the third mass point is poorly determined (β_3^c), and the estimated regime probabilities are extremely unequal (.990, .008, and .002, computed from the logits e_1 and e_2, see Eq. (20) in Vermeulen et al., 2006), an LR test rejects the specification with two mass points, which itself rejects the MNL specification. We conducted a descending specification search, starting with a full set of household and personal characteristics for $\mathbf{d}$ in β_c and δ and with only own characteristics plus characteristics of children in β_f and β_m. For instance, an indicator to distinguish between households in East and West Germany, included to account for potential heterogeneity of the two populations, turns out to have a significant effect only on the δ coefficient. Among the variables $\mathbf{d}$ we also include information concerning the regimes (i.e. mass points) 'chosen' in the calibration of the collective model (see Vermeulen et al., 2006, line below Eq. (20)). The inclusion of this kind of 'observed unobservable heterogeneity' aims at maximum fairness towards the unitary model. The corresponding variables turn out to be highly significant in several places (variables $reg3_f$ and $reg1_m$).

Given these parameter estimates, all couples present a positive marginal utility of the female's leisure. The concavity condition is satisfied for all couples (at least for the 'chosen' regime, see the next section). The presence of children has a negative effect on the consumption coefficient. This effect increases if the household has children less than 6 years old. Living in Eastern Germany has a negative effect on the unitary estimate of the interaction term δ. Table 2 gives statistics on the cross leisure terms for both models and depending on the number of children. In the unitary estimates, δ is positive on average, and is negative for 3 couples only. In the collective model the calibrated δ_m (for males) is also positive on average, but much smaller, and the calibrated δ_f (for females) is negative on average for all household types, a puzzling result that warrants further research. At this stage our conjecture is that this may be connected to our insufficient treatment of time devoted to household production activities.

Table 1 MMNL estimates of preferences for couples: 3 mass points

		Coef.	s.e.	t Value
β_K^f	$\ln(l^f \quad l^f) \times kid$	5.27	1.15	4.6
β_{K6}^f	$\ln(l^f \quad l^f) \times kid6$	1.01	.30	3.4
β_{sr}^f	$\ln(l^f \quad l^f) \times sch\_real_f$	.55	.25	2.2
β_{ju}^f	$\ln(l^f \quad l^f) \times job\_uni_f$	.92	.40	2.4
$\beta_{r_3^f}^f$	$\ln(l^f \quad l^f) \times reg3_f$	5.02	.52	9.6
$\beta_0^{r_3}$	$\ln(l^f \quad l^f)$	.80	.70	1.1
β_K^m	$\ln(l^m \quad l^m) \times kid$	3.15	1.21	2.6
β_{ju}^m	$\ln(l^m \quad l^m) \times kid6$	1.12	.31	3.7
β_0^m	$\ln(l^m \quad l^m)$	1.40	.76	1.9
$\delta_{a\_f}^2$	$\ln(l^f \quad l^f) \times \ln(l^m \quad l^m) \times (\ln age_f)^2$	.12	.01	9.5
δ_K	$\ln(l^f \quad l^f) \times \ln(l^m \quad l^m) \times kid$	1.38	.31	4.5
δ_{K6}	$\ln(l^f \quad l^f) \times \ln(l^m \quad l^m) \times kid6$	.34	.11	3.0
δ_{sr_f}	$\ln(l^f \quad l^f) \times \ln(l^m \quad l^m) \times sch\_real_f$	.56	.11	5.0
δ_{sa_f}	$\ln(l^f \quad l^f) \times \ln(l^m \quad l^m) \times sch\_abi_f$	.49	.14	3.5
δ_{sa_m}	$\ln(l^f \quad l^f) \times \ln(l^m \quad l^m) \times sch\_abi_m$	.15	.06	2.6
δ_{jn_m}	$\ln(l^f \quad l^f) \times \ln(l^m \quad l^m) \times job\_noap_m$	.18	.07	2.6
δ_E	$\ln(l^f \quad l^f) \times \ln(l^m \quad l^m) \times East$	.56	.04	12.4
$\delta_{r_3^f}$	$\ln(l^f \quad l^f) \times \ln(l^m \quad l^m) \times reg3_f$	1.49	.13	11.7
β_K^c	$\ln(c \quad c) \times kid$	10.82	1.92	5.6
β_{K6}^c	$\ln(c \quad c) \times kid6$	3.77	1.19	3.2
$\beta_{sr_f}^c$	$\ln(c \quad c) \times sch\_real_f$	5.56	1.20	4.6
$\beta_{sa_f}^c$	$\ln(c \quad c) \times sch\_abi_f$	5.28	1.46	3.6
$\beta_{r_3^f}^c$	$\ln(c \quad c) \times reg3_f$	16.94	1.25	13.5
$\beta_{r_1^m}^c$	$\ln(c \quad c) \times reg1_m$	4.21	.97	4.3
β_1^c	$\ln(c \quad c)$, regime 1	26.94	1.92	14.0
β_2^c	$\ln(c \quad c)$, regime 2	10.81	3.01	3.6
β_3^c	$\ln(c \quad c)$, regime 3	22.39	44.67	0.5
e_1	''logit'', regime 1	6.36	.85	7.5
e_2	''logit'', regime 2	1.58	1.05	1.5
log likelihood mp 3		4218.75		
log likelihood mp 2		4224.75		
log lik. multinomial logit		4245.56		

Notes: *kid* and *kid6* are dummies with value 1 if the couple has at least one child and one child less than 6 years old. *sch real_f*, *sch real_m*, *sch abi_f* and *sch abi_m* are dummies with value 1 if the wife (*f*) or the husband (*m*) have short and long secondary schooling. *job uni_f* and *job noap_m* are dummies with value 1 if the wife has university or college degree and if the husband has no training, respectively. *East* is a dummy with value 1 if the couple lives in East Germany. *reg3_f* and *reg1_m* are dummies with value 1 if the third consumption regime was the best one for the wife and the first consumption regime was the best one for the husband in the calibration procedure, respectively. $(ln\ age_f)^2$ is the square of the wife's log age in years. *mp* is the number of mass points. e_1 and e_2 allow the computation of the regime probabilities (see Eq. (20) in Vermeulen et al., 2006)

5. Predictions with the unitary model

We assume that the regime corresponding to a couple is the one which gives the best labour supply predictions under the condition that it leads to an increasing utility function. The frequencies of the regimes are more or less in accordance with the estimated probabilities, although regime 2 is chosen more often than it should (.053 predicted versus .008

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Table 2 $\delta(\mathbf{d})$ coefficients in unitary and collective model by number of children

	no ch.	1 ch.	2 ch.	≥3 ch.	Total			
	Mean	Mean	Mean	Mean	Mean	s.d.	Min.	Max.
δ	4.12	1.47	1.23	1.07	1.93	1.43	.23	6.42
δ_f	4.17	3.34	3.63	3.43	3.63	3.22	12	6
δ_m	.21	.02	.21	.62	.19	2.23	8	6
no.	296	410	478	148	1,332			

Note: δ corresponds to the cross leisure term estimate for the unitary model. δ_f and δ_m are calibrated values from the collective model, for female and male, respectively

Table 3 Collective versus unitary female labour supply, baseline tax scheme

	0	10	20	30	40	50	60	Total
0	**15.99**	6.98	3.30	2.10	.30			28.68
10	4.13	**.90**	1.28	.90				7.21
20	6.76	3.75	**3.45**	2.48	.75			17.19
30	2.63	1.88	2.78	**2.93**	2.70	.23		13.14
40	3.30	2.63	3.90	9.23	**11.49**	2.70		**33.26**
50	.23			.08	.08	**.00**		.38
60	.08			.08			**.00**	.15
Total	**33.11**	16.14	14.71	17.79	15.32	2.93	.00	1,332

Note: rows: wives' collective labour supply, columns: unitary. Entries in the body of the table and in the margins give frequencies (in %), except the last cell which gives the number of observations. Bold entries in the body of the table: diagonal (their sum gives the percentage of correct predictions). Bold entries in the margins: modes

Table 4 Collective versus unitary male labour supply, baseline tax scheme

	0	10	20	30	40	50	60	Total
0	**.45**	.60	.30	.23	1.35	.23		3.15
10		**.08**		.08	.23	.08		.45
20			**.00**	.15	.30			.45
30	.30	.83	.45	**1.20**	4.58	2.70	.08	10.14
40	1.35	8.93	3.30	8.71	**40.47**	16.14	.60	**79.50**
50		.23	.08	.15	1.73	**3.68**	.30	6.16
60						.15	**.00**	.15
Total	2.10	10.66	4.13	10.51	**48.65**	22.97	.98	1,332

Note: see note to Table 3

estimated probability). The third regime is never chosen, as it never satisfies the positivity restrictions on the marginal utility of consumption.

As reported in Tables 3 and 4, the unitary model performs moderately well in predicting labour supply. Predictions are correct for only a third of the wives and for 45% of the husbands. The margins of the tables are not very well predicted, except for the participation rate. The results for cells within the tables are bad, as some large discrepancies occur. For instance, more than 44% of nonparticipating wives are predicted to work.[3] The unitary model tends to smooth the hours distribution. The mode is significantly lower for the

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[3] This conditional frequency is obtained from the first row of Table 3: 1 (15.99/28.68) .443.

unitary model, both for women and men: 80% of the husbands actually work full time in the collective baseline situation, but only 49% are predicted to work 40 h with the unitary model. Labor supply of both spouses is underpredicted on average. This points to the misspecification of the unitary model. However, the predictions from this particular model are in line with those found in the literature.

5.1. Linear tax reform

A linear tax schedule is applied with joint taxation for couples. It consists of a basic income plus a flat tax rate, replacing the current means tested social benefits and the smooth progressive tax rate. The tax reform applied linearizes the budget constraint, which is a rather large departure from the present design of the German tax benefit system. Approximate revenue neutrality is achieved by setting the negative income tax for zero income at −6,000 euro for singles and −9,600 euro for couples and computing the constant marginal tax rate for both singles and couples as residual tax rate. It is important to note that the definition of a revenue neutral reform will differ if it is based on the unitary rather than on the collective model, because predicted behavioral adjustments will differ between the two models. In fact the unitary model leads to a flat tax rate of $t=.403$, the collective model to $t=.428$. This lets the reform appear much more favorable for singles (relatively) with the unitary than with the collective model.

In Fig. 1, we consider for the sake of illustration the changes in disposable income following the reform, for a particular individual, in euro per week. This is a single woman with the mean gross hourly wage rate of single women (about 13 euro), and no capital income.[4] This woman is thus a potential recipient of social benefits. The move to a linear
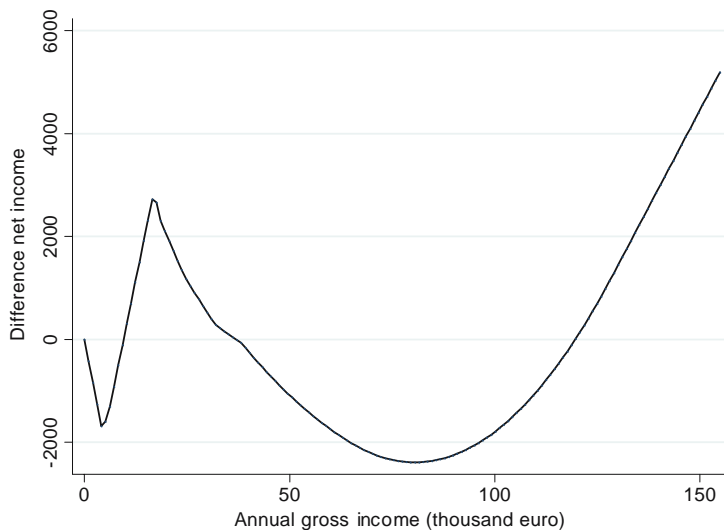

Fig. 1 Change in disposable income, single woman, w 13 euro, no capital income

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[4] We discuss the situation for a single rather than for a couple, because for couples the budget constraint is more difficult to represent graphically.

Table 5 Tax revenues

	Collective model		Unitary model	
	Baseline	Linear tax.	Baseline	Linear tax.
Single women	8.91	8.88	8.91	7.80
Single men	15.58	17.91	15.58	16.34
Couples	44.10	41.84	44.72	45.09
Total	68.59	68.63	69.21	69.23
Flat tax rate		.428		.403

Note: total tax revenues in billion euro per year, using the sampling weights

tax system is beneficial for her only over a narrow range of hours corresponding to the progressive withdrawal of social benefits in the 1998 system. A first decrease (in post compared to pre reform disposable income) at very low hours is due to the fact that the flat tax rate applies from the first hour of work. A second one is due to the fact that under the 1998 system that person faces lower marginal tax rates. Wealthy households will gain from the reform.

5.2. Positive aspects of the reform

The unitary model introduces distortions in the prediction of tax revenues: Table 5 reveals that the unitary setting overpredicts total tax revenue by .6 billion euro. Unlike the collective model, the unitary model predicts couples to have higher tax liabilities under linear taxation.

We predict labour supply in the case of the baseline tax benefit system and the linear tax reform (recall that the baseline situation used for each model consists of the predictions from that model), and compare predicted participation rates and working hours for the different tax systems, obtained with the collective and with the unitary models. The largest discrepancies between collective and unitary predictions are obtained for wives. Under linear taxation these discrepancies are partly due to differences in the reform definition (regarding the tax rate), but for the 1998 tax system they are due only to the misspecification of the unitary model.

Table 6 compares the collective and unitary labour supply of wives after the reform for wives.[5] The quality of unitary predictions proves to be better for the reform than for the baseline situation. However, labour supply is well predicted for only about a third of the wives, and it is badly predicted (prediction error ≥20 h) for another third of them.

Tables 7 and 8 compare variations in unitary and collective labour supply for females and males. The adjustment of labour supply following the tax reform is poorly predicted by the unitary model, which predicts well the change in labour supply for only half of the wives and half of the husbands well. Beninger et al. (2003) show that this is in general verified for radical reforms, such as a linear tax reform. The reaction   mostly a reduction   in hours worked is underestimated for wives but overpredicted for husbands. Indeed, in the collective model wives' labour supply is much more affected than husbands' by changes in the tax system. The unitary model predicts that more men than women change their labour supply: nearly 72% of wives and 66% of husbands do not react to the reform for the unitary model. This contradicts the results obtained with the collective model, according to which the corresponding values are 61% and 73%.

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[5] The corresponding table for men is omitted to save on space.

Table 6 Collective versus unitary female labour supply, linear taxation

	0	10	20	30	40	50	60	Total
0	**17.87**	9.16	5.03	2.63				**34.68**
10	5.18	**2.63**	1.58	2.10	.60			12.09
20	3.83	3.30	**4.88**	3.00	2.10	.15		17.27
30	1.95	2.40	3.08	**3.98**	4.95	.45		16.82
40	1.05	.98	2.78	5.48	**6.31**	.75		17.34
50	.30		.45	.23	.45	**.00**		1.43
60	.15		.08	.15			**.00**	.38
Total	**30.33**	18.47	17.87	17.57	14.41	1.35	.00	1,332

Note: see note to Table 3

Table 7 Variation in female labour supply, collective versus unitary

	≤ 10	0	10	20	30	Total
≤ 30	.53	1.28	.23			2.03
20	2.78	5.78	.45	.08		9.08
10	**4.96**	16.59	.60	.75		23.35
0	9.91	**44.67**	2.55	3.23		**60.59**
≥10	.83	3.00	**.68**	.38		4.96
Total	18.99	**71.32**	4.50	4.43	.00	1332

Note: rows: collective, columns: unitary. For example, for 5.78% of women the collective model predicts a drop in labour supply by 20 h, while the unitary model predicts no change. Also see note to Table 3

Table 8 Variation in male labour supply, collective versus unitary

	10	0	10	20	≥30	Total
≤ 30						.00
20						.00
10	**5.33**	18.32	.45	.83	1.95	26.88
0	12.76	**47.45**	2.03	4.65	5.86	**72.75**
≥10		.15	**.00**		.23	.38
Total	18.09	**65.92**	2.48	5.48	8.04	1332

Note: see note to Table 7

Interestingly, wives and husbands react more similarly to the reform in the unitary than in the collective setting. Indeed, Table 9 shows that for almost 60% of couples (sum of the diagonal elements), both spouses have the same labour supply change. The collective model predicts the spouses to react differently to the tax reform (see Beninger et al., 2003).

5.3. Normative aspects of the reform

We describe the welfare effects of the reform measured at the household level by the unitary model by showing the distribution of percentage changes in *household utility* for

Table 9 Variation in unitary labour supply, female versus male

	10	0	10	20	≥30	Total
≤ 10	**4.06**	14.87	.08			18.99
0	*14.04*	**50.38**	1.28	1.35	4.28	**71.32**
10		.68	**.83**	1.28	1.73	4.50
20			.30	**2.33**	1.80	4.43
30				.53	**.23**	.75
Total	18.09	**65.92**	2.48	5.48	8.04	1,332

Note: rows: female, columns: male. For example, in 14.04% of households the wife does not change her labour supply after the reform, while her husband reduces his by 10 h. Bold entries in the body of the table: households where both spouses adapt their hours of work in the same way

every decile of the pre reform distribution of the household equivalent disposable income.[6] These graphs require cautious interpretation. Considering percentage changes does not by itself permit interpersonal or interhousehold welfare comparisons. But given that the composition of deciles in corresponding graphs will remain identical across reforms, the graphs may be expected to convey a feel for the importance of welfare effects. What is well defined in the graphs is the information on proportions of winners and losers by decile. The graphs show the quartiles of the distribution (box). The lines emerging from the box extend upwards to the largest utility change smaller than $Q_{75}+1.5(Q_{75}-Q_{25})$ and downwards to the smallest utility change larger than $Q_{25}-1.5(Q_{75}-Q_{25})$. Observations outside this range are plotted individually.

Individual welfare effects of the reform are measured separately for husbands and wives within the collective model framework. They are described by showing the distribution of percentage changes in *individual utility* for every decile of the pre reform distribution of the wives' or husbands' equivalent disposable income.[7]

A direct comparison of the welfare analysis based on the two models is made on the basis of cross tabulation of the positions of *households* (winner, indifferent, loser) with the pairs of positions of the *spouses*. A ±1% change has been taken to define indifference.

Considering the unitary model, very few couples benefit from the move to linear tax ation (see Fig. 2). The reform also has a negative impact for most of the married women (collective model, see Fig. 3). Only for men does this reform yield positive gains (see Fig. 4). Table 10 compares the effects of a move to linear taxation. About 80% of the couples are predicted to be welfare losers in the unitary framework. However, while over 80% of the wives are losers with the collective model, only 52% of the husbands are predicted to be losers. The percentage of Pareto winning households (columns $f_+ m_0$, $f_0 m_+$ and $f_+ m_+$) is 7.8%, and there are over 60% Pareto losing households (columns $f\ m$, $f\ m_0$ and $f_0 m$). The percentage of households for which the move to linear taxation creates potential conflict amounts to 29% (22.5% where wives gain and husbands lose, plus 6.7% where wives lose and husbands gain). For 16% of the households, the unitary and the collective predictions are contradictory (e.g., decrease in household utility for the unitary model, while the reform is seen as Pareto improving at the household level for the col lective model).

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[6] The equivalence scale for the household disposable income is a modified OECD scale: 1 for the first parent, 0.7 for the second, 0.6 for each child over 16 years old, 0.5 for each child between 7 and 15 years and 0.4 for each child younger than 6 years.

[7] The equivalence scale for the individual disposable income is: 1 for the parent (the wife or the husband), the same as above for the children.
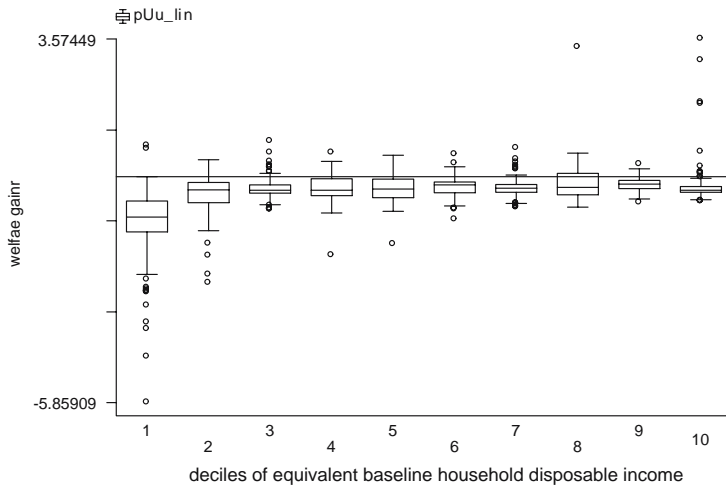
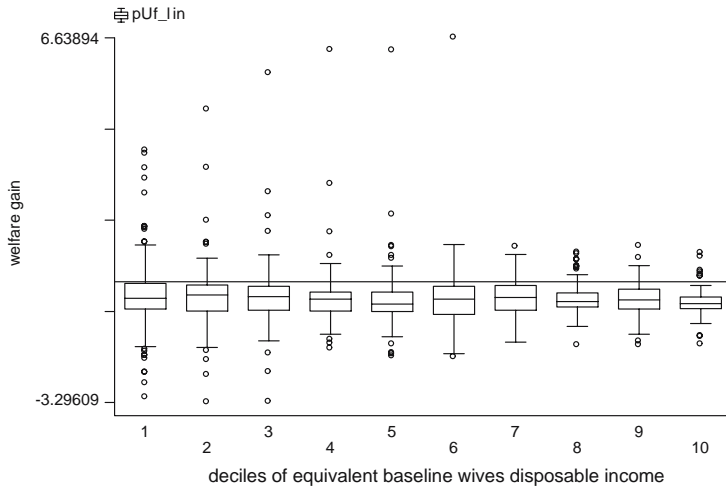**Fig. 2** Relative welfare gains from a switch to linear taxation for households, unitary model

Fig. 3 Relative welfare gains from a switch to linear taxation for married women, collective model

6. Summary of comparable results for other European countries or other reforms

Similar work was conducted for Belgium, France, Italy, and the UK.[8] For Germany we also summarize results obtained for other reforms than the move to linear taxation described above (Beninger et al., 2003). All the reform definitions can be found in Section 6 in Myck et al. (2006).

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[8] See the references given in Vermeulen et al. (2006).
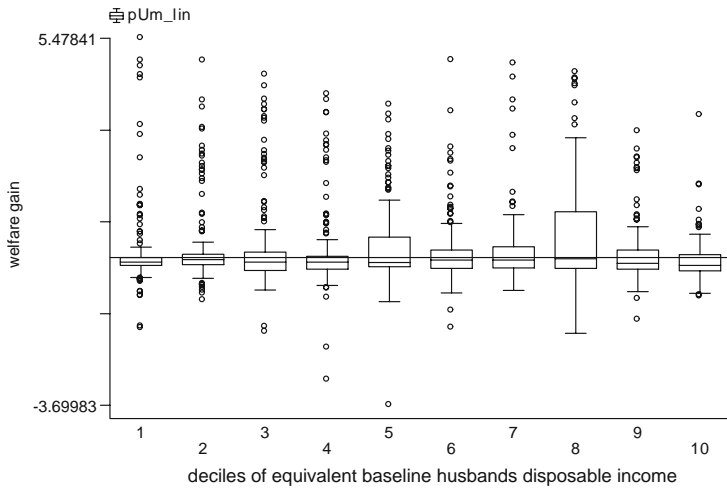
Fig. 4 Relative welfare gains from a switch to linear taxation for married men, collective model

Table 10 Winners and losers: collective versus unitary model, linear taxation

	f m	f m_0	f m_+	f_0 m	f_0 m_0	f_0 m_+	f_+ m	f_+ m_0	f_+ m_+	Total
hous	39.6	10.8	18.4	1.6	1.4	1.4	4.3	.7	1.4	79.6
hous$_0$	2.3	3.2	2.8	.4	.6	.5	1.1	.8	.6	12.2
hous$_+$	.8	1.4	1.3	.3	.8	.5	1.3	.8	1.1	8.2
Total	42.7	15.3	22.5	2.3	2.9	2.4	6.7	2.3	3.1	1,332
Total f	(f)	80.5		(f_0)	7.5		(f_+)	12.0		1,332
Total m	(m)	51.7		(m_0)	20.4		(m_+)	27.9		1,332

Note: move from the 1998 to the linear tax scheme. Rows correspond to winning (hous$_+$), indifferent (hous$_0$) and losing (hous) couples, on the basis of the estimated coefficients of the unitary model. Households are considered indifferent if their post reform utility level is within ±.1% of the pre reform level. Columns correspond to the winning, indifferent or losing wives and husbands on the basis of the simulated ''col lective'' data. Spouses are considered indifferent if their post reform utility level reform is within ±.1% of the pre reform level

6.1. Belgium

Two baseline situations are considered. The first situation corresponds to predictions ob tained from the collective model with the estimated power index and estimated coefficients of leisure interaction. The second situation starts from the calibrated values of these variables (to allow shifts in bargaining power following a reform, the constant in the power index regression is adjusted so that the estimated index corresponds to the calibrated one). Unitary models, including a leisure interaction term, are estimated on both of these data sets. Regular preferences are obtained for only 38% and 24% of the observations, respectively, and adjustments to the marginal propensity to consume are performed in order to correct for this. The fit is poor, with strong under estimation of labour force participation of females in couples. Qualitative results obtained for the reforms with the two different baselines do not differ much.

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The *Belgian reform* improves the bargaining position of a majority of women. Col
lective labour supply reactions to the reform are moderate, and the same result emerges
when using the unitary model instead. But whereas the unitary model predicts that 97% of
the households benefit from the reform, for the collective model there is a Pareto
improvement for only 65.5%, and not all of these are winners according to the unitary
model. Gini coefficients on equivalent incomes and concentration ratios focusing on in
come tax, obtained with both types of models, are in agreement qualitatively, although they
differ in absolute values. The reform slightly reduces inequality, and increases the con
centration of tax payments.

The second reform considered is the introduction of a linear income tax, which replaces
both the current tax system and social security contributions. For each model, the flat tax
rate was first set at a level of 50%. In a second step, a basic income (applicable to both
singles and individuals in couples) was chosen to ensure revenue neutrality. Since labour
supply reactions may differ across models, this basic income may also differ (for the first
baseline situation, e.g., the basic income associated with the collective model is equal to
2,860 euro; whereas it is equal to 2,830 euro for the unitary model).

The *linear taxation* also leads to moderate labour supply reactions when predicted with
the collective model. For the unitary model, the predicted behavior for women is similar,
although more pronounced reactions are obtained, but for men the overall direction of the
change is reversed. According to the collective model, the reform is a Pareto improvement
for about 30% of the households, disadvantages both spouses for some 20%, and has
conflicting impacts for 46%. These ambiguous effects are only very partially captured by
the unitary model, for which 42% of the households win and 57% lose. According to both
models, the reform increases overall inequality, leaving the concentration ratio almost
unchanged.

6.2. France

The effects of the French tax credit reform on labour supplies, as predicted by the col
lective model, are rather small, with only 5% of wives and 1% of husbands altering their
labour supply. Some 10% of these are not recipients of the tax credit after the reform: this
type of reaction is purely ''collective'', and is ruled out by the unitary setting. The esti
mation of a unitary model without leisure interaction term (LES) on the collective baseline
leads to regular preferences for all households in the sample. Predictions are poor: only
41% of the women have correct labour supply predictions (75% for men). For the positive
analysis of the reform, the unitary model under predicts the changes found with the col
lective one, but both models agree in finding that the reform does not fulfil its objective, as
it does not succeed in increasing participation of low wage earners, at least if one restricts
attention to couples. For 19% of the couples, the reform appears indifferent from the
unitary point of view, whereas he wins and she loses for the collective model. For 32% the
reform is preferred (U), whereas she wins and he loses (C). For only 23% total agreement
is found, in that the reform is preferred for (U) and Pareto improving for (C).
Contradictions concern only 1% of households.

6.3. Germany

Beyond the linear tax reform, for which results were reported above, the German Tax
Reform 2000 and a revenue neutral move from joint to individual taxation were also
analyzed.

Taking (C) as reference, (U) yields about 33% correct predictions for reactions to the German tax reform and to individual taxation, and 40% for reactions to linear taxation. Overall, (U) predicts more changes than (C).

The *German tax reform 2000* has negative welfare effects for 23% of individuals in couples, with equal shares of men and women in this percentage. Overall the reform is more beneficial to women (71% win) than to men (53%). For the unitary model 81% of the households benefit from the reform, but the collective model shows only 66% Pareto winners (+ +), less than 1% of Pareto losers, and 22% of conflicting changes (+− and −+). For this reform there are few (3.4%) outright contradictions between the two models ((U+, C− −), (U+, C= =), (U+, C= −), (U+, C= =), etc.).

For *individual taxation*, revenue neutrality is obtained by multiplying the tax liability by a factor of .942 for the collective model, and by a factor of .894 for the unitary model. Thus, the tax burden is predicted to shift from singles to couples in a much more pro nounced way when using the unitary model. The collective model shows that the only decile of the distribution of pre reform equivalent incomes in which a majority of women prefer the reform to the status quo is the highest decile. For men, there are some large gains and losses (measured in relative terms) at all deciles. The unitary model finds the largest percentage of winners in the highest two deciles, but also the largest losses. There are only 3.5% Pareto winners, but 56% Pareto losers, and conflicting effects arise for 32% of the households. Some 8% contradictions arise between the two models.

6.4. Italy

The estimation of a unitary model leads to poor predictions on a sample of Italian households. Working hours predictions are correct for only 34% of men and 57% of women. The estimated unitary model tends to smooth the distribution of labour supply, leading to over prediction for men and under prediction for women. In particular, 13% of wives are predicted to be out of the labour market whereas they are working full time, and more than 50% of men are predicted working 10 h more than actual.

Two tax reforms were evaluated, namely the 2002 tax system and a linear income tax. The first one is not expected to be revenue neutral, due to both a reduction in tax rates and a substantial increase in tax credit for children and for employment income. The hypothetical linear tax system is defined to ensure revenue neutrality. In both reforms the largest discrepancies between the collective and the unitary model are found in the male labour supply, as only 35% (31%) of the cases are on the main diagonal when the 2002 reform (the linear income tax) is introduced in the simulation exercise. Moreover, husbands are expected to react much more to the first reform according to the unitary model than what is predicted by the collective framework. The unitary model also predicts a higher drop in women's participation.

6.5. UK

The unitary model is estimated on the collective baseline as derived in Myck et al. (2006). The household utility function includes a leisure interaction term and the estimated coefficients give rise to regular preferences for the whole sample. The unitary specification does remarkably well in predicting the underlying (collective) distribution of hours. In deed, hours are predicted accurately for 58% of men and 64% of women, and with a 10 h margin of error for 94.5% of men and 96% of women. Relative to the collective model, however, the unitary specification over predicts nonparticipation. While 2.9% of men and

10.2% of women are not employed in the collective baseline, the figures are 7.6% and 13.2%, respectively in the unitary model.

The unitary model does not allow us to model distribution of resources between partners and therefore to distinguish between two variants of the Working Families Tax Credit (WFTC) reform: one where the benefit is paid to the main carer and the other when it is paid to the main earner. Simulation of the WFTC using the unitary model results in smaller labour market response to the reform than either of the variants simulated in the collective world. For 20.4% out of the 2,619 couples with children in our sample the reform leads to a change in the number of working hours (relative to 35.0% for either of the variants of the WFTC simulation using the collective model). As we would expect, all of those who change their hours of work choose a combination of male and female hours at which they can claim the new credit. Most couples who change their labour supply reduce their hours of work and, as expected, there is a significant shift from two and no earner couples to one earner families. The main difference between the unitary and the collective simulations is a much greater effect of the reform on employment of men. While the collective model predicts an increase in male participation from 96.3% to 98.2% (when WFTC is paid to main carer) and 97.7% (when it is paid to main earner) the unitary model predicts an increase from 89.4% to 94.6%. The percentage point increase in female employment rate is similar: while the collective model predicts a reduction from 85.6% to either 79.5% or 80.4%, the simulation using the unitary model results in the reduction of the female employment rate from 82.4% to 76.0%.

6.6. Summary

An important result is that all studies which estimate a unitary model (for Belgium, France, Germany, Italy and the UK) find substantial distortions arising from its use in predicting the positive and normative effects of reforms. The study for Spain (Raquel Carrasco and Javier Ruiz Castillo, 2002) also produces evidence of such distortions, by separating 'unitary effects' of the collective model, that is, effects obtained considering only changes in the budget restriction, and not the changes in the bargaining position of the spouses.

7. Conclusion

The aim of this study has been to illustrate the distortions in policy evaluation entailed by the use of unitary model estimates when the underlying data obey collective rationality. We have addressed this question by estimating a unitary model on realistically simulated micro data for Germany within a collective setup.

A comparison of the collective data and the unitary predictions showed that in the baseline situation, on average, labour supply is underpredicted by the unitary model. In total, only a third of female labour supply decisions are correctly predicted (the corresponding figure for men is 40%). Much more interesting for policy evaluation are the distortions in predicted labour supply adjustments in reaction to a tax reform. For the move to linear taxation, and taking the collective predictions as the reference, the unitary predictions for the labour supply variation are correct for only about half of the wives. In the collective setting, the labour supply of married women is more responsive to this reform than their husbands' is, whereas the unitary model predicts more men to alter their hours of work. Thus, by basing policy evaluation on unitary estimates when the data are generated by the collective model, the changes in hours for wives and for husbands will be

underestimated and overestimated, respectively. Our results also show that the *design* of revenue neutral reforms itself may be heavily distorted by the use of a unitary model on collective data.

Turning to the normative aspects of reform evaluation, we compare changes in household utility predicted by the unitary model and changes in individual utility predicted by the collective model. We find that these predictions are contradictory for more than 16% of the households (e.g., decrease in household utility for the unitary model, while the reform is seen as Pareto improving at the household level for the collective model). An other distinguishing trait of the collective model is that it allows for diverging effects on the welfare of both partners, whereas the unitary model is mute on 2006. It turns out that the move to a linear tax system in Germany creates conflicting welfare effects for 29% of the households.

While these results must still be considered as only illustrative, because there are several shortcomings in our approach (in particular, we do not take into account household pro duction; the calibration approach for the identification of the spouses' weights and the cross leisure term may capture part of the unobservable heterogeneity in the model; also the specification of the income sharing rule may be problematic), they amply document the rewards to be expected from further work on the estimation of multi person household models in realistic settings.

Appendix A: Detailed description of the German tax-benefit system

Germany has a personal income tax system administered at the federal level and regulated by the Personal Income Law (Einkommensteuergesetz). The German tax system is char acterized by a comprehensive tax that covers labour earnings as well as income from other sources, such as capital investment or housing rents, and by joint taxation for married couples. For our exercise we use a simplified form of the 1998 German tax benefit system.[9] Gross income is the sum of income from different sources: income from employment, capital investment, rental and leasing and maintenance payments received from an ex partner. Gross taxable income is equal to gross income minus income related expenses. The standard deductions are listed in Table A.1.

The function applied to the tax base is smoothly progressive. In 1998 the top rate applied was 53% for yearly earnings in excess of DM 120,041.[10] Earnings below the basic personal allowance of DM 12,365 are tax free. The tax schedule used is the same for singles and for couples. However for couples, the 'Ehegattensplitting' method (marital splitting) is used: the tax rate is applied to half of the joint taxable income, and the outcome

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[9] This simplification is an adaptation, to our particular sample and emphasis, of the microsimulation program developed at ZEW (for a description see the documentation by Peter and Steiner 2003).

[10] For convenience, the tax rules and our tax program are written in DM rather than in euro, as the nonlinear 1998 German tax scheme is only available in DM (1 euro 1.95583 DM). All other nominal magnitudes in the paper are given in euro.

Table A.1 Simplified tax benefit system for household taxation, Germany 1998 singles (married couples)

Taxable income

earnings
capital income
income from rental and leasing
maintenance payments from ex partner

Tax reliefs
DM 2,000 (4,000) standard deduction for earnings[a]
DM 6,000 (12,000) standard deduction for capital income
DM 108 (216) standard special expense deduction
child allowance (or child benefit alternatively)
exemption for social security contribution ('Vorsorge')
maintenance payments to ex partner

Tax base: taxable income minus tax reliefs

Tax schedule: tax rate applied to (half) the tax base:

Income (X) bracket	Income tax liability
0 12,365	0
12,366 58,643	$(91.19 \cdot Y + 2{,}590) \cdot Y$
58,644 120,041	$(151.96 \cdot Z + 3{,}343) \cdot Z + 13{,}938$
>120,041	$.53 \cdot X 22{,}843$

X rounded taxable income, Y ($X 12{,}312$)/10,000, Z ($X 58{,}590$)/10,000)
solidarity supplement: tax scaled up by a factor of 1.055 [b]

Net Income: gross income minus (twice) the tax liability

Benefits
child benefit: DM 220 for 1st and 2nd child, DM 300 for 3rd, DM 350 from 4th child on (or child allowance alternatively)
means tested social benefits (incl. housing benefit and special payments):[c] DM 1,000 in the West, DM 900 in the East[d]
means tested social benefits for partner and children, depending on age

Maintenance
maintenance payments to children, ex partners or parents outside the household

Disposable income: net income plus benefits minus maintenance

Notes: [a]The tax scheme is given in DM because of the nonlinearity of the tax function. Since 2000, the tax scheme is given in DM and euro by the Federal Government. 1 euro 1.95583 DM. Time unit is the year. [b]The solidarity supplement for the reconstruction of East Germany ('Solidaritatszuschlag') is based on a measure of taxable income that includes the child allowance whether or not parents opt for it. [c]For lack of information on the stock of savings etc., we assume that couples reporting more than DM 600 capital income or more than DM 4,800 rental income per year are not eligible for social benefit payments. [d]These numbers are based on the average effective maximum social benefit paid in 1998 Statistisches Bundesamt (2001)

is doubled in order to obtain the total income tax liability of the spouses. Tax rate pro gressivity and marital splitting lead to a relative advantage for married couples if spouses have unequal incomes.

Parents can opt for either a child benefit (DM 220 for the first and the second child, DM 300 for the third and DM 350 from the fourth child on) or a child allowance, that is a lump sum deduction of DM 6,912 for each child up to age 27, if still in education or doing military or civil service. Due to the progressive tax scheme the child benefit is less, and the tax deduction is more, favorable for high income households.

Social benefits are means tested and depend on the number of people in the house hold.[11] As a simplification, we assume that the maximum social benefit (including housing benefit and special payments) a person can receive is DM 1,000 a month and DM 700 for

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[11] In this static setting we ignore unemployment insurance and unemployment benefits, which are both related to former earnings. Both transfers actually require the search of, and the willingness to take up, a job.
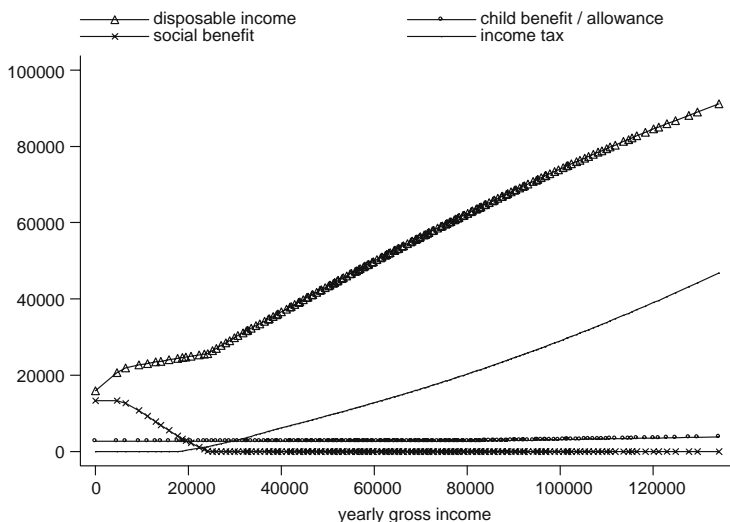
Fig. 5 The 1998 German tax benefit system. Situation of a couple with two children. The wife and the husband earn respectively 18 and 25 euro per hour. They potentially receive means tested social benefit

the partner.[12] In addition there are age dependent supplementary payments for children. The amount of the transfer is decreasing in the level of earned income ('anrechnungsfreies Erwerbseinkommen'). In addition, social benefits are related to the geographical location, since they are paid by the local governments and housing benefits depend on the average rent of the locality. We distinguish only between East and West Germany, and approxi mate that social benefits are 10% lower in the East. The difference between East and West Germany stems from the lower costs of living in the East as a substantial fraction of the social benefit is the housing benefit. Finally, social benefit payments depend on the wealth situation of the household, and child benefits are deducted from social benefit payments.

As a graphical illustration of the tax benefit system described above, Fig. 5 depicts a typical situation for a couple with two children. The husband has an hourly wage rate of 25 euro, the wife earns 18 euro per hour. The household does not have any capital inflows or income from rental or leasing. It is therefore eligible for means tested social benefits at low labour income. The parents receive child benefit for both children. From a yearly gross income of just above 80,000 euro they will opt for child allowance instead, as the tax relief exceeds the lump sum benefit payment. Figure 5 also reveals the nonconvexity of the resulting budget constraint when labour earnings are high enough for social benefit payments to cease.

Appendix B: Sample description

Table B.1 shows descriptive statistics for singles and for couples with various sociode mographic characteristics. On average, women have a lower schooling and vocational

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[12] The maximum social allowances we apply for both parts of Germany are based on the average effective maximum social benefits paid in 1998 (see Statistisches, 2001).

Table B.1 Descriptive statistics on the selected samples

	Single women Mean	s.d.	Single men Mean	s.d.	Mar. women Mean	s.d.	Mar. men Mean	s.d.
Participation	.94	[e]	.96		.71		.97	
Age	37.2	9.44	36.7	7.98	39.5	7.04	41.9	7.34
Schooling[a]								
No degree	.03		.04		.02		.01	
Short secondary	.34		.35		.41		.31	
Long secondary	.23		.21		.12		.19	
Other	.03		.02		.06		.06	
Voc. training[b]								
No training	.13		.06		.10		.05	
Technical training	.21		.18		.24		.25	
Univ. or polytech.	.14		.18		.08		.15	
East Germany	.14		.20		.28		.28	
Separ. or divorced	.27		.32					
Never married	.66		.68					
Widowed	.07		.00					
# Children	0		0		1.40	1.06	1.40	1.06
No children	1		1		.22		.22	
1 Child	0		0		.31		.31	
2 Children	0		0		.36		.36	
≥3 Children (#)[c]					3.39	.28	3.39	.28
Hours work (week)	36.8	5.65	38.9	6.40	30.1	10.4	39.6	5.53
Gross wage (hour)[d]	13.1	4.75	14.6	5.75	11.6	5.17	15.6	6.56
Capital income	40.1	72.1	42.4	74.9	52.1	143.5	52.1	143.5
Child benefit	131.2	45.9	147.6	64.2	206.0	124.8	206.0	124.8
Total unearned inc. (month)[f]	49.5	195.5	30.4	234.2	321.9	459.1	321.9	459.1
Observations	208		280		1,332		1,332	

Notes: [a]reference category: primary school; short and long secondary school correspond to 'Reals chulabschlus' and 'Abitur'; [b]reference category: apprenticeship; technical training and polytechnic cor respond to 'Fachschule' and 'Fachhochschule'; [c]for this and the four subsequent variables, statistics concern only positive values; [d]nominal variables in euro; [e]variables for which only the mean is shown are indicator variables; [f]total unearned income also includes rental and leasing, social benefit, housing benefit, incomes of children and net maintenance payments; highly negative net maintenance may lead to negative total unearned income

education level than men. For example 15% of the husbands in the sample have a poly technic or university degree, but only 8% of the wives. More than half of the couples live with 1 child at most. Only few households receive housing or social benefits. Most couples have capital income.

Appendix C: Concavity condition of the unitary utility function

The utility function is

$$U(c, l^f, l^m) = \beta_c \ln(c - \bar{c}) + \beta_f \ln(l^f - \bar{l}^f) + \beta_m \ln(l^m - \bar{l}^m) + \delta \ln(l^f - \bar{l}^f) \ln(l_m - \bar{l}^m)$$

We assume that all the differences $c - \bar{c}, l^f - \bar{l}^f, l_m - \bar{l}^m$ are strictly positive, as well as the coefficients β_c, β_f and β_m. Since the gradient of U is

$$\partial U \quad \begin{bmatrix} \frac{\beta_c}{c\ c} \\ \frac{1}{l^f\ l^f}\left[\beta_f + \delta\ln\left(l_m \quad l^m\right)\right] \\ \frac{1}{l_m\ l^m}\left[\beta_m + \delta\ln\left(l^f \quad l^f\right)\right] \end{bmatrix},$$

a sufficient condition for U to be increasing in its arguments is

$$\delta > \min\left\{\ \frac{\beta_f}{\ln\left(l_m \quad l^m\right)},\ \frac{\beta_m}{\ln\left(l^f \quad l^f\right)}\right\}. \tag{C.1}$$

We assume that this condition is satisfied. The hessian of U is

$$\partial^2 U \quad \begin{bmatrix} \frac{\beta_c}{(c\ c)^2} & 0 & 0 \\ 0 & \frac{\beta_f + \delta\ln\left(l_m \quad l^m\right)}{\left(l^f \quad l^f\right)^2} & \frac{\delta}{\left(l^f \quad l^f\right)\left(l_m \quad l^m\right)} \\ 0 & \frac{\delta}{\left(l^f \quad l^f\right)\left(l^m \quad l^m\right)} & \frac{\beta_m + \delta\ln\left(l^f \quad l^f\right)}{\left(l^m \quad l^m\right)^2} \end{bmatrix}. \tag{C.2}$$

Calling A the second diagonal block, concavity of U is then equivalent with A negative, thus, given condition 5, with $A>0$. Thus the concavity condition is

$$\left[\beta_f + \delta\ln\left(l^m \quad l^m\right)\right]\left[\beta_m + \delta\ln\left(l^f \quad l^f\right)\right] > \delta^2. \tag{C.3}$$

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