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Social Choice and Welfare

Provided in Cooperation with:
Springer Nature

Suggested Citation: Gürer, Eren (2021) : Equity-efficiency implications of a European tax and transfer system, Social Choice and Welfare, ISSN 1432-217X, Springer, Berlin, Heidelberg, Vol. 57, Iss. 2, pp. 301-346,
https://doi.org/10.1007/s00355-021-01314-1

This Version is available at:
https://hdl.handle.net/10419/286748

Social Choice and Welfare (2021) 57:301–346
https://doi.org/10.1007/s00355-021-01314-1

ORIGINAL PAPER

Equity-efficiency implications of a European tax and transfer system

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Received: 16 December 2019 / Accepted: 4 February 2021 / Published online: 19 March 2021

Abstract

This study simulates three income tax scenarios in a Mirrleesian setting for 24 EU countries using data from the 2014 Structure of Earnings Survey. In scenario 1, each country individually maximizes its own welfare (benchmark). In scenarios 2 and 3, total welfare in the EU is maximized over a common budget constraint. Unlike scenario 2, the social planner of scenario 3 differentiates taxes by country of residence. If a common tax and transfer system were implemented in the EU, countries with a relatively higher mean wage rate—particularly those in Western and some of the Northern European countries—would transfer resources to the others. Scenario 2 implies increased labor distortions for almost all countries and, hence, leads to a contraction in total output. Scenario 3 produces higher (lower) marginal taxes for high- (low-) mean countries compared to the benchmark. The change in total output depends on the income effects on labor supply. Overall, total welfare is higher for the scenarios involving a European tax and transfer system despite more than two thirds of all the agents becoming worse off relative to the benchmark. A politically more feasible integrated tax system improves the well-being of almost half of all the EU but considerably reduces the aggregate welfare benefits.

JEL Classification H21 · H24 · F55

I am grateful to Alfons J. Weichenrieder for his supervision and continuous support. I thank Eurostat for granting access to the microdata on the Structure of Earnings Survey, the participants of 6th Mannheim Annual Tax Conference, seminar participants at Goethe University Frankfurt and Istanbul Technical University, Ariana Gilbert-Mongelli, Osman Kucuksen, Selen Yildirim and two anonymous referees for providing valuable comments. None of the conclusions of this paper may be attributed to Eurostat, the European Comission or to any of the national statistical authorities whose data have been used.

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1 Introduction

Reducing economic disparities across the region and assisting vulnerable states have long been on the policy agenda of the European Union.[1] The debt crisis of 2008 highlighted the importance of this goal and provided the impetus for deeper fiscal integration in the EU. An ambitious interpretation of deeper fiscal integration involves implementing a common tax and transfer system (see, e.g, Casella 2005; Fuest and Peichl 2012). Nevertheless, shifting tax and transfer authorities to the EU level is not free of classical equity-efficiency considerations. To the best of my knowledge, a normative treatment of the issue in a Mirrleesian framework does not yet exist in the literature.

This study simulates three optimal income tax scenarios in a Mirrleesian framework for 24 EU countries and quantifies the implications of implementing these tax scenarios. I use gross hourly earnings data from 2014 wave of the EU Structure of Earnings Survey (SES) in order to calibrate the model. In the benchmark scenario (scenario 1, S1), every country maximizes its own welfare over separate budget constraints. In the case of a European tax and transfer system (scenarios 2 and 3), the social planner maximizes the total welfare in the EU with respect to a common budget constraint. For this scenario, two different possibilities are considered. In scenario 2 (S2), the EU is treated as a single country and, hence, the same tax scheme is applied everywhere. In scenario 3 (S3), the social planner is able to condition the taxes to the country of residence ("tagging").[2]

The analysis begins by investigating the outcomes at the EU level. I find that both scenarios involving a common tax and transfer system yields welfare improvement compared to the benchmark. On the other hand, more than two-thirds of the agents become worse off. Whereas S2 leads to a contraction in total output up to 2.65%, efficiency implications of S3 are sensitive to the assumption regarding the income effects on labor supply. Specifications with and without income effects produce an expansion by 1.53% and a contraction by 0.62% respectively.

As a next step, the implications of three scenarios on the economic outcomes by country are explored. In both S2 and S3, countries exhibiting relatively higher mean in the wage rate distribution (all of the Western and some of the Northern European countries) transfer resources to the other countries and become worse off. Transfers are higher in an S3 scenario. In relative terms, Denmark transfers the most resources in both S2 and S3 (around 13% and 24% of its total gross income respectively). S2 implies higher labor distortions for almost every country, explaining the aggregate decline in total output. In S3, compared to the benchmark, high-mean countries are distorted more and low-mean countries are distorted less. Yet, the social planner is able to extract higher labor effort from high-mean countries when the utility function incorporates income effects. When the utility function does not allow

[1] See Atkinson (2002) or Article 158 of the Treaty of Amsterdam that reads "The Community shall aim at reducing disparities between the level of development of the various regions and the backwardness of the least favored regions or islands."

[2] In what follows, S1, S2 and S3 respectively stands for scenarios 1, 2 and 3.

for income effects, higher distortion in high-mean countries directly translates into lower total output. As a result, implication of S3 on aggregate output is dependent on the specific form of the utility function.

The national tax schedules are analyzed in order to understand the changes in welfare distributions within individual countries. In low-mean countries, those with the lowest income benefit the most from cross-country transfers of S2 and S3. In countries with a high mean and low standard deviation (e.g., Sweden), distortion and average taxes on the rich rise sharply in S2 compared to the benchmark, making them the worst off in terms of indirect utility. On the other hand, countries with high mean and high standard deviation (e.g., Germany) exhibit higher overall marginal taxes in the benchmark. Therefore, S2 does not lead to a significant shift in the marginal tax rate schedule. In such countries, the poor are the worst off in S2 because they must share the tax revenues with the poor in low-mean countries. In S3, the latter effect dominates and leads to a disproportional decline in the indirect utility of the poor in all high-mean countries.

S2 and S3 demonstrates the significant losses that high mean countries have to bear for a European tax and transfer system. In order the limit the extent of the direct losses, I investigate a more restrictive scenario. Social planners of S2 and S3 solve their problem with an additional constraint, that is, linearly aggregated social welfare must not be lower than the benchmark in any country. Together with the new constraint, the social planners ensure that a certain fraction of the individuals in transferring countries is better off as a result of the integrated European tax system. In this scenario, S2 does not yield an improvement in social welfare and, hence, it is not investigated in detail. S3, different than the full optimum, implies lower optimal marginal income taxes for every country. While about half of all Europe is better off and there is sizable output expansion in S3 compared to benchmark, increase in total welfare is restricted to 1%.

The remainder of this paper is organized as follows. Section 2 briefly discusses the related studies and the contribution of this study. Section 3 formalizes the social planner's problems in the three scenarios. Section 4 introduces the two specifications used for the utility function. Subsequently, the calibration procedure is explained. The EU-level, country-level and within-country results are presented. Finally, Sect. 5 concludes.

2 Related literature

A vast literature explores and analyzes the different possibilities of deeper fiscal integration in Europe.[3] This study is the first to estimate optimal Mirrleesian schemes for a European tax and transfer system. The analysis of "tagging" (S3), which considers 24 EU countries as subgroups, and the "linear country welfare improving scenario" have not yet been pursued within the discussion on a European

[3] See Fuest and Peichl (2012), Auerbach (2013), Hebous and Weichenrieder (2016) and Dolls et al. (2017) for some of the recent discussions.

tax and transfer system. A number of studies that investigate the implications of a potential EU-wide labor income taxation system, albeit via different methodologies, are discussed in detail below.

Recently, a growing literature evaluates the distributional outcomes of different policies across the EU via micro-simulation approach using EUROMOD. Paulus et al. (2017), for example, analyzes the consequences of fiscal consolidation measures implemented following the financial crisis of 2008. See Figari et al. (2015) for a detailed discussion of the micro-simulation approach for policy analysis.[4]

Closest to the purpose of this paper among the micro-simulation literature, Bargain et al. (2013b) and Dolls et al. (2013) study the redistributive and stabilizing effects of implementing a common tax and transfer scheme in the euro area. By using household level data from EUROMOD, the authors construct a European tax and transfer system as the weighted average of the observed national tax and transfer systems. In a next step, they compare the results of the hypothetical scenario to the observed scenario. In this study, I abstract from the stabilizing effects and take a normative approach to evaluate equity-efficiency implications of different scenarios at the optimum. Conceptually, S2 of this study is equivalent to the European Tax and Transfer System discussed in Bargain et al. (2013b) and Dolls et al. (2013). I find that the optimal tax scheme of S2 is more distortive than almost every nationally optimal tax scheme. Thus, resulting implications on (in particular) efficiency for individual countries are different than Bargain et al. (2013b) and Dolls et al. (2013), where a centralized tax system is assumed to be the weighted average of existing national tax schemes. In S2 of this study, for example, labor supply falls in most of the countries, both with and without income effects.

Kopczuk et al. (2005) studies optimal world redistribution. For a Cobb–Douglas utility function with given parameters and an average flat tax rate, they estimate the ability distributions of 118 countries that matches empirical Gini coefficients and mean incomes. In a next step, they adjust the parameters of the utility function to minimize the squared errors between empirical PPPs and to match the average labor supply. Finally, they estimate a flat tax rate and a constant demogrant to approximate the optimal world redistribution.

More relatedly, Seelkopf and Yang (2018), relying on the methodology in Kopczuk et al. (2005), constructs an optimal EU-wide income taxation system. I estimate fully non-parametric optimal European tax schemes, contrary to the flat tax rate combined with a demogrant in Seelkopf and Yang (2018), whose EU-wide tax system corresponds to S2 with income effects in this study. Solving for non-parametric schemes allows me to thoroughly investigate the changes in the within-country

[4] Note that EU tax and benefit simulation model, EUROMOD, is based on the data from European Union Statistics on Income and Living Conditions (EU-SILC). EU-SILC collects individual information on many dimensions other than labor income, such as health, education, social exclusion. Thus, sample size in EU-SILC is restricted (e.g., 2017 wave has approximately 270,000 persons). On the other hand, SES, the data set used in this study, focuses on collecting harmonized and accurate information on earnings. 2014 wave of SES incorporates over 9 million observations. Because hourly gross labor income is the crucial piece of information to estimate hourly earnings distributions and simulate a structural Mirrlees model, I rely on SES.

distributions of welfare (see Sect. 4.3.3). Notable insights are as follows. In S2, richer are the worst off in high-productivity countries with low standard deviation (e.g., Sweden), whereas poorer are the worst off in high-productivity countries with high standard deviation (e.g., Germany). Redistributive benefits of an integrated tax system for poor countries, however, always come at the expense of the poor in high-productivity countries in S3. Moreover, in Seelkopf and Yang (2018), poorer countries experience a decline in labor distortions and EU-level labor supply remains the same. With the non-parametric tax schemes, I find that marginal income taxes increase especially for the lower part of the distribution in poorer countries, where a high fraction of the population is located, as a result of S2. Consequently, income weighted marginal taxes increase for majority of the countries in S2, including the poorer ones, and there is a sizable contraction in total output.

Additionally, different from Seelkopf and Yang (2018), this study recovers the ability distributions over the micro data (SES) and applies empirical PPPs directly to the observed wage rates. Because the construction of PPP-adjusted wage rates in this study does not require any prior assumptions, results can be obtained via different preference specifications. Section 4.3.2 showcases that there are considerable differences between results for utility specifications with and without income effects for S3.

In the optimal income tax literature initiated by Mirrlees (1971) and Akerlof (1978) was the first to argue that conditioning taxes on observable characteristics (tags) that are correlated with earnings ability would improve the performance of taxation.[5] As emphasized above, this study is the first to consider "tagging" for the discussion of a centralized European tax and transfer system. The common practice in the literature of "tagging" is to compare the outcome of the tagged scenario (S3) to the pooled scenario (S2). See, for example, Cremer et al. (2010) and Bastani et al. (2013) among others. Evaluating an EU-wide tax system with tagging by country of residence provides a natural framework to compare the tagged scenario (S3) to the separate maximization (S1). I find that the optimal marginal income taxes increase with "tagging" compared to separate maximization for the groups with higher mean.

Relatedly, Kessing et al. (2020) split the districts of the US into two groups (large metropolitan and other regions) in order to study the trade-off between enhanced redistribution and efficiency enhancing migration. Their model incorporates an extensive margin migration decision and, therefore, the region of residence functions as an endogenous tag. This study assumes immobile workers and considers country of residence as an exogenous tag.[6]

A longstanding argument in the theory of fiscal federalism is that redistributive taxation should be carried out at the central level due to the mobility of the

[5] Since then, "tagging" has received considerable attention both in theoretical [see, e.g., Immonen et al. (1998), Boadway and Pestieau (2006), Cremer et al. (2010) and Kanbur and Tuomala (2016)] and applied literature [see, e.g., Mankiw and Weinzierl (2010), Weinzierl (2011), Alesina et al. (2011), Best and Kleven (2013), Bastani et al. (2013) and Kessing et al. (2020)].

[6] Because the costs that are associated with moving from one country to another are higher compared to migrating between the regions of a single country, I do not primarily consider mobility of the workers and leave that extension for future research.

taxpayers (see, e.g., Oates 1999). On the other hand, a connected body of the literature embeds multiple layers of governments into the Mirrleesian optimal income tax model and, more relevant for the EU, analyzes optimal tax policies and public goods provision when workers are immobile.[7] See Boadway and Keen (1993), Aronsson and Blomquist (2008) and Aronsson (2010). The analysis in this paper does not consider public goods provision, but adds to this literature by quantifying the welfare and equity-efficiency implications of centralized vs. decentralized solutions in an applied example.

3 Conceptual framework

There is a set K of N countries in the economy. Each country k constitutes a fraction s_k, that satisfies $\sum_{k\in K} s_k = 1$, of the total population. Countries are populated by an immobile unit continuum of agents who differ with respect to their wage rates (abilities), w. In each country k, wage rates are distributed with density $f_k(w)$ over the same support $[\underline{w}, \overline{w}]$.[8]

Agents derive utility over the same separable preferences that are a function of consumption, $c(w)$, and labor supply, $l(w) = \frac{z(w)}{w}$, where $z(w)$ corresponds to gross income:

$$U(w) = u(c(w)) - v\left(\frac{z(w)}{w}\right) \tag{1}$$

Disutility of labor supply satisfies usual convexity conditions, that is $v'(.) > 0$, $v''(.) > 0$. Properties of $u(.)$ differ across specifications.

In each of the three tax scenarios, the social planners employ a social welfare function $G(.)$. Note that specific form of $G(.)$ varies according to the choice of $u(.)$ in order to satisfy the diminishing marginal utility of consumption principle. The social planners have access to a non-linear income tax instrument, $T(z(w))$, that satisfies: $z(w) - c(w) = T(z(w))$. The information structure of the model is standard. When choosing the optimal tax schedule, the social planners are able to observe $z(w)$ but not w. Hence, incentive compatibility constraints must be employed in order to ensure that each agent reveals his or her true ability type. In what follows, by using the first-order approach, incentive compatibility constraints are replaced by a law-of-motion that describes how the utilities of different ability types change at the optimum.[9]

[7] Lipatov and Weichenrieder (2016), abstracting from the asymmetric information between the taxpayers and the government, explicitly investigate the case of an EU tax that might be collected to finance the central budget. They find that decentralized but coordinated taxation is superior to a central tax.

[8] Note that there are heterogeneities in two dimensions. Agents differ with respect to their wage rates, w, within a country; whereas, probability distributions of the agents, $f_k(w)$, differ across countries.

[9] Because both specifications of the utility function introduced in Section 3.1 respect Spence-Mirrlees single-crossing condition, the second-order conditions required to use the first-order approach hold.

Scenario 1 (Benchmark) *Social planner's problem* $\forall k \in K$:

$$\max_{\{c(w),z(w)\}_{w\in W}} \int_{w\in W} G(U(w)) f_k(w) dw \tag{2}$$

subject to government budget constraint

$$\int_{w\in W} (z(w) - c(w)) f_k(w) dw = 0 \tag{3}$$

and incentive compatibility constraint

$$\frac{dU(w)}{dw} = \frac{z(w)}{w^2} v'\left(\frac{z(w)}{w}\right) \tag{4}$$

In S1, the social planner solves a standard Mirrlees problem for each country separately according to its individual budget constraint. Therefore, this benchmark scenario excludes the possibility of cross-border transfers. At the same time, the social planner observes the differences in the probability distributions of the agents in each k ($f_k(w)$) and can differentiate the tax schemes across countries.[10]

Scenario 2 (Pooled) *Social planner's problem:*

$$\max_{\{c(w),z(w)\}_{w\in W}} \int_{w\in W} G(U(w)) f_P(w) dw \tag{5}$$

subject to government budget constraint

$$\int_{w\in W} (z(w) - c(w)) f_P(w) dw = 0 \tag{6}$$

and incentive compatibility constraint

$$\frac{dU(w)}{dw} = \frac{z(w)}{w^2} v'\left(\frac{z(w)}{w}\right)$$

where

$$f_P(w) = \sum_{k\in K} s_k f_k(w) \tag{7}$$

The problem of the social planner in S2 is technically identical to S1. The only difference is that the probability distribution function used in S2 ($f_P(w)$) is obtained by pooling the populations of different countries. In other words, the social planner treats the entire population as a single country in S2. Note that, by construction

[10] Note that, in S1, I suppress the country subscript k except for the probability distribution functions $f_k(w)$. This is to emphasize that the only changing aspect across the problems of different countries is the probability distribution of the agents.

of the problem, budget constraints of the countries are also pooled. Hence, transfers between countries are possible. However, the social planner does not exploit the information on differing probability distributions across countries and, therefore, applies the same tax scheme to every country.

In order to construct the probability distribution of the pooled population, the individual probability distributions of various countries are scaled by their population shares and then the resulting probability distributions across countries is summed (see Eq. (7)). As a result, a single wage rate distribution (that integrates to one) is obtained in which any wage bin represents the probability interval of the pooled population.[11]

Scenario 3 (Tagging) *Social planner's problem:*

$$\max_{\{c(w),z(w)\}_{w\in W}} \sum_{k\in K} \int_{w\in W} G(U_k(w)) f_{k'}(w) dw \tag{8}$$

subject to government budget constraint

$$\sum_{k\in K} \int_{w\in W} (z_k(w) - c_k(w)) f_{k'}(w) dw = 0 \tag{9}$$

and incentive compatibility constraint

$$\frac{dU_k(w)}{dw} = \frac{z_k(w)}{w^2} v'\left(\frac{z_k(w)}{w}\right) \tag{10}$$

where

$$f_{k'}(w) = s_k f_k(w) \tag{11}$$

S3 is conceptually similar to S2. The social planner maximizes the weighted sum of the welfares of all countries over a common budget constraint. This implies that cross-border transfers are possible. The difference in the notations of S2 and S3 stems from the notion that the social planner recognizes the differences in the probability distributions of the agents across countries while optimally choosing the tax schedules.[12] Therefore, the social planner is able to condition the law-of-motion between indirect utilities of the agents to an observable tag: the country of residence (see Eq. (10)). As a result, the final optimal tax schemes may differ across countries.

The countries' individual probability distributions in S3 ($f'_k(w)$) are different than those of S1 ($f_k(w)$). This reflects the social planner's need of taking the population

[11] To see this, consider a wage bin, e.g., $[w', w'']$ in two imaginary countries A and B. Suppose probabilities of drawing the considered wage bins, in countries A and B, are 5% and 10% respectively. Furthermore, assume that the population shares of these countries are 40% and 60%. Scaling with the population shares and summing across two countries, probability (or population share in the context of this study) of the interval $[w', w'']$ becomes 8% in the pooled wage rate distribution.

[12] Due to the differences in the probability distributions of the agents, the social planner must first integrate the utilites [or net taxes/subsidies in Eq. (9)] within a country and then sum it across countries.

shares into account while optimally designing the country-specific tax schedules. To construct $f'_k(w)$, it suffices to scale countries' probability distributions by their population shares. Note that, integration of the resulting probability distributions yields countries' population shares, that is $\int_{w \in W} f'_k(w) = s_k$. Hence, the new probability of any wage bin in a given country incorporates both the probability of drawing that particular country and wage bin.[13] Probabilities of wage bins with the densities of S1 ($f_k(w)$), on the other hand, represents only the conditional probabilities (e.g., conditional on being in a country).

4 Calibration and simulations

In this section, I simulate the three scenarios introduced in Sect. 3 for 24 EU member states. The difficulty of obtaining analytical results for Mirrleesian optimal income tax problems is repeatedly mentioned in the literature. However, interpreting the results of simulations for a large set of countries would be challenging without a basic understanding of the role played by the wage rate distributions. Therefore, Appendix B.1 provides examples for two imaginary countries which are intended to build intuition by utilizing a simple applied framework. Main lessons are as follows. If a country, ceteris paribus, exhibits higher mean or standard deviation, this results in higher nationally optimal marginal income taxes. As a result of "tagging", S3, social planner finds it optimal to increase marginal income taxes of such countries in order to raise tax revenue that can be redistributed to the other countries. Even when the two countries' taxes are nationally optimal, pooling the two countries may not necessarily lead the population weighted average of the national tax schemes.

In the rest of this section, first, the specifications used in the simulations are presented. Second, the calibration procedure for the main simulations is introduced. Third, EU-level, country-level and within-country results are respectively presented. Finally, following a brief discussion on political feasibility, a more restrictive centralized taxation scenario is pursued.

4.1 Simulation specifications

All the simulations are performed with two different specifications:

$$U(c, z) = c - \frac{(z/w)^{1+1/\epsilon}}{1 + 1/\epsilon}, \quad G(U) = log(U) \tag{12}$$

[13] Consider the same countries and the wage bins introduced in footnote 11. After completing the described procedure, new probabilities of intervals $[w', w'']$ in countries A and B are 2% and 6% respectively. For example, 2% represents the probability of drawing the wage bin $[w', w'']$ of country A. In other words, within the context of this study, 2% represents the population share of that wage bin in country A within the combined population of A and B.

$$U(c,z) = ln(c) - \frac{(z/w)^{1+1/\epsilon}}{1+1/\epsilon}, \quad G(U) = U \tag{13}$$

Specifications (12) and (13) differ with respect to their assumptions regarding the income effects on labor supply. Unlike in specification (12), labor supply is sensitive to the income effects in (13). As mentioned in Sect. 3, social welfare function is chosen such that the objective functions of the resulting maximization problems are concave on consumption. Hereafter, I consider (12) as the main specification and report the results for (13) only when the qualitative conclusions differ.[14]

Considering a generalized CRRA social welfare function, the logarithmic specification corresponds to the case where inequality aversion (denoted by ρ) equals to one. In Appendix B.6, I consider social planners with different aversions to inequality, that are $\rho = 0.5$ and $\rho = 2$ for the main specification that does not exhibit income effects on the labor supply.

4.2 Calibration to Europe

Simulations require identifying the densities ($f_k(w)$) of the national wage rate distributions. This section recovers the parameters of the distributions of 24 EU countries for which data are available in the 2014 wave of Structure of Earnings Survey (SES).[15]

The universe consists of individuals between 20 and 60 years old who work full-time. I convert earnings of the agents in all countries into a comparable currency unit, purchasing power standard (PPS). See Appendix A.1 for a description and further details about the preparation of the dataset. In Appendix B.4, I consider the case in which the social planners do not take differences in purchasing powers into account and set optimal tax schemes over nominal Euro units.[16]

Next, the hourly wage rate distributions of the four regions of Europe (east, west, north and south) are descriptively characterized in order to gain a rough understanding into the differences in the skill levels across regions. This exercise is also helpful in identifying appropriate supports for the wage rate distributions (more details on this are below). The presentation of those graphs appears in Appendix A.2.

Assuming gross hourly wage rates follow a log-normal distribution in each country, I separately estimate the means and standard deviations of national wage rate distributions.[17] Subsequently, populations of the countries are recovered by summing the frequency weights of the individuals in the survey.[18] Table 1 presents the

[14] There is no general agreement regarding the importance of income effects in the literature. Gruber and Saez (2002) find that income effects of tax changes are insignificant in the case of reported incomes.

[15] Missing countries are Austria, Croatia, Greece and Ireland.

[16] Indeed, governments usually do not consider spatial differences (e.g., across states) in purchasing powers when designing income tax schedules.

[17] "lognfit" command of Stata is utilized to employ the maximum likelihood technique to estimate the model parameters.

[18] It should be kept in mind that the universe only consists of full-time workers between 20 and 60 years old. Therefore, the resulting population shares may differ from the actual population shares of the corresponding EU countries.

Table 1 Parameters of log-normal wage rate distributions and population shares

Country	(μ, σ)	s_k	Country	(μ, σ)	s_k
Belgium (BE)	(2.873, 0.348)	0.017	Lithuania (LT)	(1.704, 0.531)	0.009
Bulgaria (BG)	(1.397, 0.575)	0.018	Luxembourg (LU)	(2.830, 0.474)	0.002
Cyprus (CY)	(2.248, 0.562)	0.003	Latvia (LV)	(1.708, 0.544)	0.005
Czech Republic (CZ)	(1.959, 0.491)	0.036	Malta (MT)	(2.452, 0.426)	0.001
Germany (DE)	(2.777, 0.533)	0.202	Netherlands (NL)	(2.840, 0.441)	0.032
Denmark (DK)	(2.936, 0.387)	0.007	Poland (PL)	(2.095, 0.566)	0.067
Estonia (EE)	(1.946, 0.542)	0.004	Portugal (PT)	(2.063, 0.573)	0.019
Spain (ES)	(2.465, 0.451)	0.078	Romania (RO)	(1.521, 0.607)	0.039
Finland (FI)	(2.719, 0.346)	0.012	Sweden (SE)	(2.753, 0.315)	0.023
France (FR)	(2.665, 0.417)	0.139	Slovenia (SI)	(2.238, 0.460)	0.006
Hungary (HU)	(1.834, 0.535)	0.023	Slovakia (SK)	(1.953, 0.491)	0.015
Italy (IT)	(2.618, 0.438)	0.075	United Kingdom (UK)	(2.709, 0.508)	0.168

μ and σ respectively denote the mean and the standard deviation of the estimated log-normal wage rate distributons. s_k denotes the population share of the corresponding country within 24 countries in the sample

resulting parameters of the wage rate distributions and population shares used in the simulations. Note that, in line with the recent literature, I perform a robustness check where underlying ability distributions in each country are assumed log-normal appended with a Pareto tail. See Appendix B.7.

Figure 1 illustrates the parameters of countries' log-normal wage rate distributions and population shares in a bubble chart. Given the two-country examples, this visual representation is helpful to gain insights into the outcomes of the simulations. In S1, optimal marginal taxes (and redistribution) increases for the countries higher up and more to the right in the graph. Therefore, the countries in the upper right corner (e.g., the United Kingdom and Germany) are likely to be the least affected ones by an increase in distortion that can be brought about by S2. In S3, on the other hand, countries in the upper part of the graph are expected to be more distorted; whereas those in the lower portion would be expected to be less distorted. In the scenarios involving a common tax and transfer system (S2 and S3), we may presume that countries at the top of the graph lose the most due to the transfers to the countries with low mean wage rates.

The supports of the wage rate distributions are chosen as [1, 50]. The right panel in Fig. 8 is helpful for the discussion of this choice. Setting lower support to one is essential to capture the poor households residing mostly in Eastern Europe. On the other hand, only a small portion of individuals earn more than 50 PPS per hour compared to the rest of the population, irrespective of the region of residence. Hence, 50 was selected as the upper support and only very high wages earned by a miniscule portion of the population are excluded.

Wage rate distributions have to be discretized for the simulations. I split the interval [1, 50] into 20 equal-sized wage bins and follow Mankiw et al. (2009) to compute the probabilities of the bins. See Appendix B.2 for a brief description of the

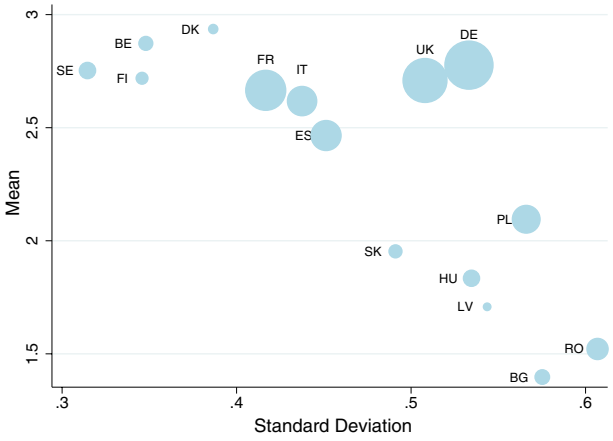

Fig. 1 Bubble chart of wage rate distribution parameters. See Table 1 for a guide to country abbreviations. Axes x and y respectively correspond to the means (μ) and the standard deviations (σ) of the estimated log-normal wage rate distributions. Bubble sizes represent population shares (s_k) of the the corresponding countries within the 24 countries in the sample

discretization procedure utilized. Finally, I set the elasticity of labor supply (ϵ) to 0.5, a commonly employed value in the literature. Appendix B.5 provides robustness checks for the main results by using two different values for ϵ, 0.33 and 0.75. Employing the elasticity estimates for different countries, provided in Bargain et al. (2014), Appendix B.9 discusses the potential implications of accounting for (potentially) heterogeneous labor supply elasticities.

4.3 Results

Results are presented in three layers. First, the implications of the three scenarios for overall Europe are investigated. Next, changes in economic outcomes are examined by country. Finally, national tax schemes are explored in order to analyze the effect of three scenarios on within country distributions of welfare. Note that interpretation of most results require a point of comparison. In what follows, S1 is considered as the benchmark for the purpose of comparing the scenarios involving a common tax and transfer system to the discrete maximization.

While calculating the aggregate welfares in the EU or country level (in Sects. 4.3.1 and 4.3.2 respectively), final measures of the numerical values should be comparable across scenarios. For clarity, I compute the EU and country level welfares respectively as of measure N (that equals 24, the number of countries in the database) and one in all three scenarios. In order to calculate welfare by country, it suffices to integrate the utilities of the agents within countries with the densities used in the problem of S1, that is $SWF_k^i = \int_{w \in W} U(w) f_k(w) dw$ where $i = S1, S2, S3$. After computing welfare levels of each country as of measure one, total welfare in the EU

can be calculated as $SWF^i_{EU} = N \sum_{k \in K} s_k SWF^i_k$, $i = S1, S2, S3$. Notice that, due to scaling by N, SWF^i_{EU} is of measure 24.

4.3.1 EU-Level

When assessing the welfare implications of three scenarios, it is useful to recall the discussions found in Sect. 3. Two aspects are of particular importance: cross-border transfers and the possibility of conditioning tax schemes to the country of residence. In S1, the social planner can differentiate the tax schemes across countries but cross-border transfers are not possible. In S2, the picture is reversed: there can be transfers across borders but the social planner applies the same tax scheme to every country. In S3, both cross-border transfers and differentiating the tax schemes across countries are possible. Note that the instruments of the social planners in S1 and S2 are a subset of the third social planner's instruments. As a result, S3 is welfare improving compared to S1 and S2.

The relationship between the total welfare of S2 and S1 is ambiguous. The possibility of cross-border transfers in S2 undoubtedly generates redistributive benefits and contributes to an improvement in social welfare. At the same time, inability of tailoring tax schemes for different ability distributions in different countries has efficiency costs. For example, a country with low level of inequality would not require high labor distortions in order to meet its redistributive requirements. However, if an integrated tax system requires high labor distortions, that country would also have to bear the burden of high marginal income taxes.

The EU-level results with the main specification (given in Eq. (12)) are presented in Table 2. The second row shows the percentage changes in total welfare compared to the benchmark. Improvement of welfare in S2 suggests that benefits of cross-border transfers outweighs the losses arising from inability of differentiating the tax schemes across countries. As expected, S3 exhibits the highest level of social welfare.

In spite of the increase in total welfare, the third row of Table 2 indicates that approximately 68% of all the agents in the EU are worse off in the scenarios of EU-wide tax and transfer system. This is due to the fact that some of high-mean countries, such as Germany, France and the UK, exhibit very large population shares (see Fig. 1). Because these countries transfer resources in S2 and S3, they become worse off. As a result, a large fraction of the agents within Europe lose in terms of indirect utility.[19]

As shown in the last row of Table 2, S2 and S3 lead to a contraction in total output respectively by 2.65% and 0.62% compared to S1. The next section provides the discussion of the underlying reasons for this outcome.

Table 3 presents the same set of results for the specification with the income effects (given in Eq. (13)). Notice that most of the results are both qualitatively and

[19] While computing the fractions better or worse off, the choice of wage bin numbers might seem to be important. However, both in S2 and S3, most of the countries are entirely worse or better off compared to S1. Hence, the number of wage bins has little impact on the results.

Table 2 Results at the EU-level (without Income Effects)

	Scenario 1	Scenario 2	Scenario 3
EU welfare (utils)	83.372	85.506	85.893
% change	–	+ 2.56%	+ 3.02%
Fraction better off	–	32.4%	32.3%
Total gross income (% change)	–	− 2.65%	− 0.62%

% change in welfare, fraction better off and % change in gross income in S2 and S3 are in comparison to the benchmark, S1

Table 3 Results at the EU-level (with income effects)

	Scenario 1	Scenario 2	Scenario 3
EU welfare (utils)	52.875	54.001	54.607
% change	–	+ 2.13%	+ 3.28%
Fraction better off	–	30.3%	32.3%
Total gross income (% change)	–	− 2.28%	1.53%

% change in welfare, fraction better off and % change in gross income in S2 and S3 are in comparison to the benchmark, S1

quantitatively similar, except for the efficiency implications of S3. In this case, S3 yields an expansion in total output by 1.53% due to the social planner's ability to exploit the income effects on labor supply. More is written on this topic in the next section.

4.3.2 Country-level

For the purpose of general illustration, Fig. 2 depicts transfers by country in S2 and S3. The left panel consists of countries that transfer resources after the implementation of a common tax and transfer system; countries on the right panel are receivers of those transfers. Note that sorting countries according to the percentage welfare loss (compared to benchmark) yields exactly the same ranking. Hence, it is not reported here.

Ranking of the countries in Fig. 2 is almost entirely consistent with the ranking of the means of national wage rate distributions. Therefore, it can be concluded that mean is the most important parameter in determining the winners versus the losers as well as their respective rankings. Two exceptions, however, are the UK and Estonia. Recall from the two-country examples that countries with a higher standard deviation transfer resources. Although the UK has a lower mean compared to Sweden and Finland (see Table 1), it transfers more resources because it has a much higher standard deviation. Analogous reasoning holds for Estonia.

In Fig. 2, it is interesting to observe that results of S3 is only an amplified version of those in S2. Countries that win (lose) in S2 continue winning (losing), but to a greater extent. In essence, ability of conditioning tax schemes to the country of residence allows the social planner to exploit the tax base of high-mean countries more effectively in order to increase redistribution to the low-mean countries.

Fig. 2 Transfers (as a fraction of total gross income) in European tax and transfer systems. See Table 1 for a guide to country abbreviations. Notice the difference between x-axis scales of left and right panels. The left panel and the right panel respectively incorporate the countries that transfer resources and the receivers of the transfers in S2 (blue) and S3 (red) (colour figure online)

Overall, ex-ante losers of fiscal integration are mostly located in northern (Denmark, Finland, Sweden and the UK) and western (Belgium, Denmark, France, the Netherlands and Luxembourg) Europe. Outwards transfers relative to total gross income are highest in Denmark, around 13% and 24% respectively in S2 and S3. Southern countries (Cyprus, Spain, Malta, Portugal and Slovenia) would receive transfers; however Italy would become a provider of transfers by a small margin. All of eastern Europe wins with Bulgaria and Romania being at the top of the list.[20]

Hereafter, results are presented for four countries that represent different segments of Fig. 1. Sweden represents the high mean-low standard deviation segment; Germany represents the high mean-high standard deviation segment; Slovakia represents the low mean-(relatively) low standard deviation segment; and Poland represents the low mean-high standard deviation segment. Table 4 shows more detailed results with the main specification for these four countries. Results of all 24 countries are provided in Appendix B.3.

The first panel in Table 4 presents welfare and transfer levels by country in the three scenarios. Consistent with the size of transfers in S2 and S3, the welfare levels of the four diverse countries progressively approach each other. Germany transfers more resources because it exhibits a higher mean wage rate than Sweden and, therefore, loses a greater fraction of its welfare. Analogously, the welfare gain of Slovakia is higher compared to Poland.[21]

Panel 2 of Table 4 showcases the income weighted marginal tax rates and percent changes in total output compared to S1. Among the four countries of interest, income weighted average marginal tax rates increase for all in S2 compared to the benchmark, except for Germany. Table 8 further suggests that Germany is the only

[20] The M49 standard of the United Nations is utilized in classifying countries into the regions (see Appendix A.2). See Table 1 for a guide to country abbreviations.

[21] Note that, in S2, agents in the same wage bin enjoy the same utility levels irrespective of their country of residence. Yet, total welfare differs across countries due to differing national wage rate densities.

Table 4 Results by country (without income effects) for the three scenarios

Panel 1	Welfare			Transfers (% gross income)		
Country	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2 (%)	Scenario 3 (%)
DE	3.88	3.72	3.61	–	− 9.68	−16.32
PL	2.95	3.34	3.55	–	33.69	53.32
SE	3.77	3.66	3.58	–	− 6.35	−11.63
SK	2.68	3.27	3.54	–	61.05	87.95
Panel 2	Total gross income (% change)			Income weighted MTR %		
Country	Scenario 1	Scenario 2 (%)	Scenario 3 (%)	Scenario 1 (%)	Scenario 2 (%)	Scenario 3 (%)
DE	–	0.13	− 2.05	29.57	29.36	32.27
PL	–	−3.04	4.25	33.01	36.81	27.33
SE	–	−8.46	− 1.19	19.95	32.93	21.79
SK	–	−8.12	5.61	29.05	39.96	21.06

See Table 1 for a guide to country abbreviations. S1, by construction, excludes the possibility of cross-border transfers. Percent changes in total gross income use S1 as the benchmark. Income weighted marginal tax rates (MTR) are calculated by weighting the MTR of an agent by the share of the agent's gross income in the total gross income of its country

country with an, albeit very slight, declining distortion among all 24 countries. The reasons for Germany's uniqueness is discussed in the next section. The rise in marginal tax rates for almost all countries is consistent with the intuition built with the example of a pooled tax scheme demonstrated in Fig. 11. Pooling countries leads to a highly dispersed gross earnings distribution which requires higher marginal tax rates at the optimum compared optimal marginal taxes of S1. As a result, total output declines in all of the countries except for Germany, explaining the overall contraction presented in Tables 2 and 3.

Finally, in line with the two-country examples, income weighted average distortions increase for the high-mean countries in S3, and decrease for the low-mean countries. As a result, high-mean countries contract and low-mean countries expand. Because total income generated in the high-mean countries is greater, S3 still leads to a contraction in total output (see the last column of the last row in Table 2).

Simulation results with specification (13) are shown in Table 5. Because the qualitative nature of the results for S1 and S2 do not change, they are not discussed further. On the other hand, there are notable differences in the results for S3. The rest of this section therefore focuses on the results for S3 in Table 5. Note that transfer receiving countries enjoy higher utility levels than countries providing transfers. This is consistent with the previous findings in the literature of tagging (see, e.g., Mankiw and Weinzierl 2010). The main motive to implement tagging is the assumption of wage rates being correlated with the tagged groups. Hence, tagging is a motion from no information end to the perfect information end. In this case, the social planner finds it optimal to extract higher labor effort from more productive agents because marginal disutility of an extra unit of output is lower for them. This causes total welfare of high-mean countries to be lower at the optimum. Moreover,

Table 5 Results by country (with income effects) for the three scenarios

Panel 1	Welfare			Transfers (% gross income)		
Country	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2 (%)	Scenario 3 (%)
DE	2.48	2.38	2.21	–	− 9.31	−22.56
PL	1.83	2.07	2.39	–	30.16	80.72
SE	2.43	2.34	2.17	–	− 8.36	−21.79
SK	1.67	2.02	2.42	–	52.11	125.08
Panel 2	Total gross income (% change)			Income weighted MTR %		
Country	Scenario 1	Scenario 2 (%)	Scenario 3 (%)	Scenario 1 (%)	Scenario 2 (%)	Scenario 3 (%)
DE	–	3.04	6.14	34.95	34.92	38.69
PL	–	− 10.45	− 12.61	40.56	45.97	31.83
SE	–	− 4.92	6.87	22.02	38.75	25.17
SK	–	− 18.59	− 17.74	36.28	50.27	24.66

See Table 1 for a guide to country abbreviations. S1, by construction, excludes the possibility of cross-border transfers. Percent changes in total gross income use S1 as the benchmark. Income weighted marginal tax rates (MTR) are calculated by weighting the MTR of an agent by the share of the agent's gross income in the total gross income of its country

it reverses the sign of the change in total outputs across countries. In contrast to the main specification, high-mean countries expand whereas low-mean countries contract.

The social planner is only able to accomplish this when the utility function incorporates the income effects on labor effort. Equations (14) and (15) are the first-order-conditions of the agents with respect to labor supply respectively for specifications (12) and (13).

$$T'(z) = 1 - \left(\frac{1}{w}\right)\left(\frac{z}{w}\right)^{1/\epsilon} \tag{14}$$

$$T'(z) = 1 - \left(\frac{1}{w}\right)\left(\frac{z}{w}\right)^{1/\epsilon} c \tag{15}$$

Because income effects are assumed away in (14), higher marginal tax rates directly translate into a lower labor supply. On the other hand, in (15), an increase in the marginal tax rate together with an increase in the labor supply can be justified if net income (c) declines sufficiently. Hence, the social planner is able to extract higher labor effort from high mean countries such as Germany and Sweden in spite of increasing income weighted marginal tax rates compared to the benchmark S1. The analogous holds for Poland and Slovakia. In contrast to the total output implications of S3 with specification (12), specification (13) yields an expansion due to the higher labor supply from more productive countries (see the last column of the last row in Table 3).

For the convenience of interpersonal utility comparisons, heterogeneities in preferences are assumed away in the simulations, similar to the bulk of the normative policy analysis literature.[22] On the other hand, Bargain et al. (2013a), using the data for married women, shows that there are considerable differences over preference for work across 11 European countries and the US. They show that the ranking of individuals in welfare distribution across countries can be altered by the choice of welfare metric, once heterogeneities in preferences are accounted for. Thus, there might be ramifications for cross-country redistribution.

According to the findings of Bargain et al. (2013a), Nordic countries together with Portugal and Belgium exhibit higher willingness to work, whereas Austria, Germany, Ireland and Netherlands are more work averse. A welfare metric that evaluates individuals with higher willingness to work as better off, e.g., "rent metric" of Bargain et al. (2013a), would favor work averse countries in terms of redistribution. Hence, in such a scenario, one might expect that part of the outwards transfers from countries such as Germany and Netherlands might be taken over by, for example, Nordic countries and Belgium. Furthermore, if low-productivity countries exhibit higher willingness to work on average compared to the high-productivity countries, the overall extent of cross-country transfers might decline.[23] Analogous of the interpretations would hold for a welfare metric that considers work averse countries as better off.

4.3.3 Within-country

In this section, I examine national tax schedules in order to gain insights into the changes in distributions of welfare within countries. Note that the tax schedules in this section are presented over PPS units of income. But, it would suffice to multiply PPS units with PPPs presented in Table 7 in order to translate the schedules into national currency units.

The upper panel of Fig. 3 depicts the marginal and average tax rate schedules of Germany implied by the three scenarios. As emphasized in the previous section, the difference in the optimal marginal tax rate schemes in S1 and S2 is hardly noticeable. This is because Germany exhibits both a high mean and a high standard deviation in the wage rate distribution and hence, requires a higher marginal tax rate schedule in S1 compared to other countries.[24] As a result, Germany is one of the

[22] Recently, Lockwood and Weinzierl (2015) demonstrates that if preferences for leisure are responsible for part of the earnings inequality within a country, optimal income tax scheme is less redistributive. Given that the emphasis of this study is on cross-border transfers, however, within country preference heterogeneity would not have major implications on the main findings.

[23] Portugal is the only country in Bargain et al. (2013a) that receives transfers according the results of this study.

[24] Income weighted average marginal tax rates presented in Tables 4 and 5 should not be confused with overall marginal tax rate schedules of the countries. Poland and Slovakia exhibit higher income weighted marginal tax rates compared to Germany. This is because a high fraction of the populations in Poland and Slovakia are located in the bottom of the interval [1, 50] where optimal marginal taxes are higher (when wage rate distributions are assumed log-normal). Thus, the overall marginal tax rate schedule of Germany can still be above the schedules of Poland and Slovakia.

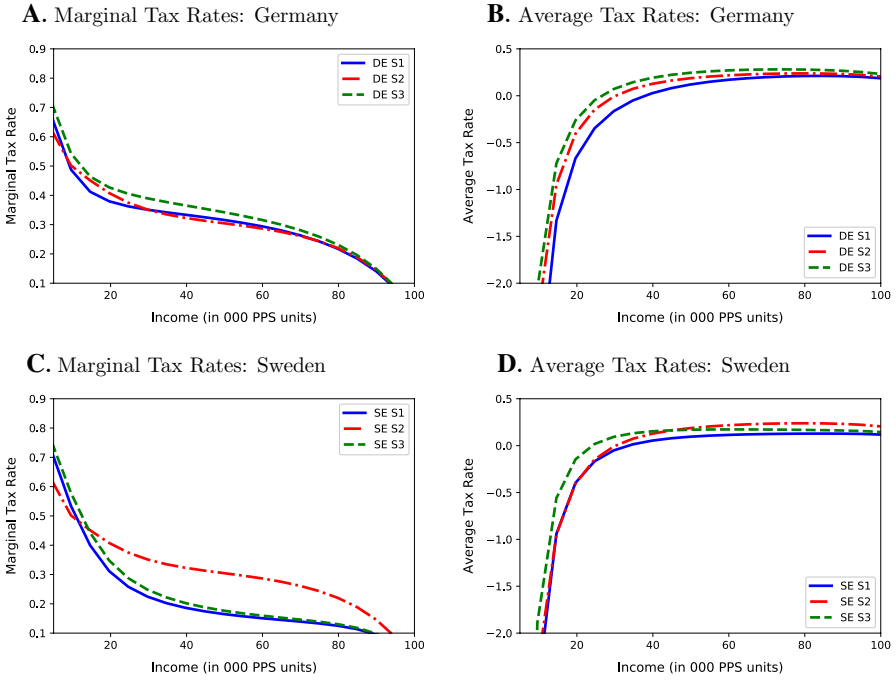

Fig. 3 Resulting tax schedules of the three scenarios (Germany and Sweden). Marginal tax rates are calculated according to Eq. (14). Average tax rates are given by $(z(w) - c(w))/z(w)$ where $z(w)$ and $c(w)$ respectively denote the gross and net income for an agent of type w.

least affected countries from the increase in distortion brought about by S2. Consistent with the two-country examples, marginal tax rate scheme shifts upwards in S3. Average tax rate schemes, on the other hand, gradually shift upwards and to the left, indicating that redistribution to the poor declines despite increasing taxes on the rich.

Results for Sweden are demonstrated in the lower panels of Fig. 3. Because of exhibiting a low standard deviation, optimal marginal tax rates decline sharply after low incomes in S1. Therefore, in contrast with Germany, middle and high incomes are exposed to increasing marginal taxes in S2. In S3, the marginal tax rate schedule shifts upwards, just as in all other countries with a relatively higher mean. Movement in the average tax rate scheme across scenarios is similar to Germany. The main difference is that taxes paid by the rich are the highest in S2 due to the sharp increase in marginal taxes compared to the benchmark.

Figure 4 illustrates the percentage of changes in the indirect utilities of 20 wage bins in Germany and Sweden for S2 and S3 compared to benchmark. In the countries that transfer resources, the poor might be the worst off because of sharing the benefits of redistribution with other countries. Moreover, the rich might be the worst off due to the increased average taxes. Figure 4 suggests that the former dominates in both countries in S3. In S2, the poorest are the worst off in Germany, whereas the richest lose more, on average, in Sweden. The different result in Sweden is caused

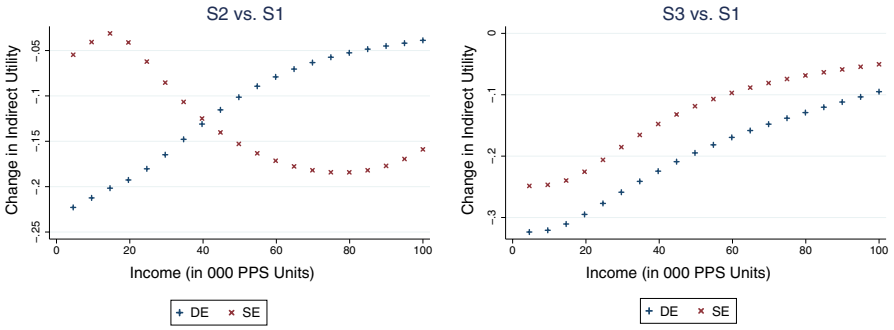

Fig. 4 Changes in indirect utilites relative to S1 (Germany and Sweden). Left (right) panel depicts the changes in the indirect utilites of the agents in S2 (S3) compared to S1

by the sharp increase in the average taxes paid by the rich in S2. Although not presented here, this result holds for all high-mean countries that exhibit relatively low standard deviation. As explained above, due to having a low standard deviation, high incomes are exposed to a sharp increase in distortion and average taxes in S2.

Figure 5 presents the tax schemes for the low-mean countries, Poland and Slovakia. Similar to the case of Sweden, the increase in distortion brought about by S2 is higher for Slovakia which exhibits relatively low standard deviation. In S3, consistent with two-country examples, marginal tax rate scheme shifts downwards for both of the countries. In contrast to high-mean countries, the average tax rate schedule gradually moves downwards and to the right suggesting an increased redistribution towards the poor and lower taxes for the rich. Only exception is the very high incomes of SK who pays the highest taxes in S2 as is the case in Sweden.

Analogous to the case of high-mean countries, poorer households in low-mean countries are better off due to the increased transfers (flowing from the high-mean countries), whereas a reduction in average taxes leads to utility gains for richer households. Figure 6 indicates that transfers to the bottom of the distribution dominates the latter, leading poorer in both Poland and Slovakia to gain the most in the scenarios involving a European tax and transfer system.

Overall, it can be concluded from this section that the biggest winners of implementing a common tax and transfer scheme are the poor in low-mean countries. In S2, relative changes in indirect utilities within high mean countries are dependent on the standard deviation. If the wage rate distribution of a country exhibits relatively low standard deviation, richer households in that country lose the most in S2 as a result of sharply increased distortion and average taxes. Otherwise, the poor lose the most because they have to share the tax revenues of their country with the low-mean countries. In S3, on the other hand, utility gains of the poor in low-mean countries come at the expense of the poor in high-mean countries irrespective of the standard deviation.

Finally, it is worth noting that changes in income taxes might trigger imperfect movement of labor and capital. This is less concerning for S2 in which the tax schemes are the same across countries. On the other hand, implementing S3

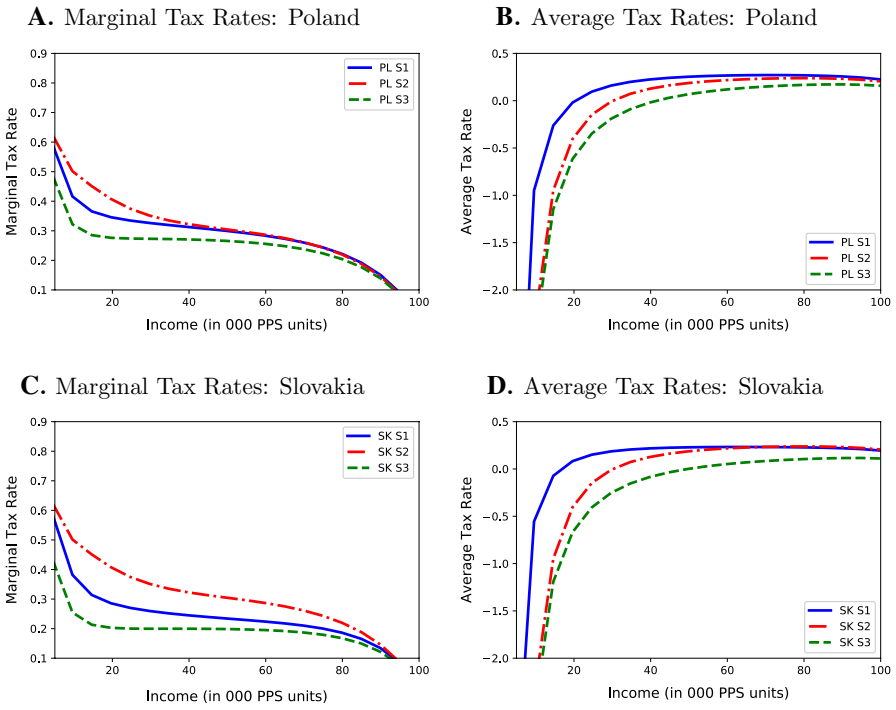

Fig. 5 Resulting tax schedules of the three scenarios (Poland and Slovakia). Marginal tax rates are calculated according to Eq. (14). Average tax rates are given by $(z(w) - c(w))/z(w)$ where $z(w)$ and $c(w)$ respectively denote the gross and net income for an agent of type w

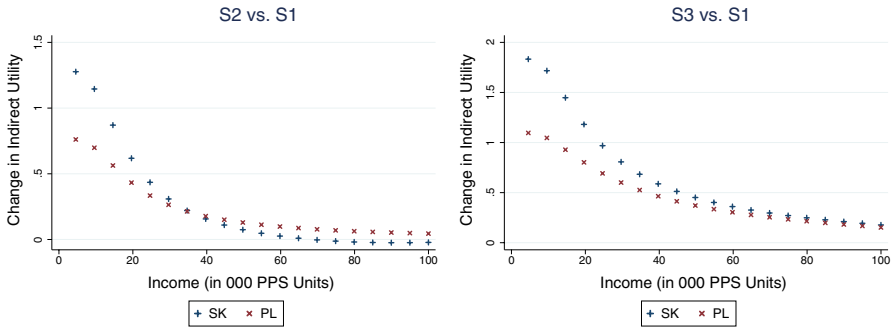

Fig. 6 Changes in indirect utilites relative to S1 (Poland and Slovakia). Left (right) panel depicts the changes in the indirect utilites of the agents in S2 (S3) compared to S1

might lead labor and capital to move from transferring countries, which experience increased labor distortions compared to the benchmark, towards transfer receiving countries. Movement of (productive) labor would likely contribute to the

redistribution of tax revenues from high-tax to low-tax countries.[25] Furthermore, if labor and capital are complements in the production function, capital mobility might induce productivity redistribution in favor of low-tax countries. As a result, the optimal cross-country transfers of S3 might be achieved via smaller increases in the marginal income taxes of high-productivity countries compared to the findings of this section.

4.3.4 Political feasibility and a more restrictive tax and transfer system

A centralized tax and transfer scheme in Europe clearly has major redistributive benefits. This is consistent with the long-standing agenda of Europe that aims at mitigating economic disparities in the region and maintaining a reasonable standard of living for all of its citizens. Additionally, while it is not the focus of this study, Bargain et al. (2013b) argues that a European tax and transfer system would help providing macroeconomic stability for credit-constrained countries. They find that, after replacing one-third of national tax systems with an EU-wide tax scheme, 10–15% of a macroeconomic income shock would be absorbed. On the other hand, for a given ability pool in Europe, an integrated taxation system must generate direct costs that are needed to be borne by high-productivity countries. This study can also be seen as an attempt to clarify the extent of such costs at the optimum.

It is highly probable that high-productivity countries would not volunteer for a centralized taxation system in order to avoid such costs. Indeed, both in S2 and S3, almost every individual in high-productivity countries become worse off compared to the benchmark. Is there a possible scenario where a European tax and transfer system is still beneficial but extreme costs to the highly productive countries are avoided? As an attempt to address this question, I investigate a more restrictive case of a European tax and transfer system in the rest of this section.

Social planners of S2 and S3 solve their optimization problem by considering an additional constraint. That is weighted sum of utilities should not be less than S1 in any country. Formally, I add the following constraint to S2 and S3:

$$\int_{w\in W} U_k^r(w) f_k(w) \geq \int_{w\in W} U_k^{S1}(w) f_k(w) \quad \forall k \in K \quad where \quad r \in \{S2, S3\} \tag{16}$$

In this scenario, the social planners still have concavity in their objective function and, hence, concerned about redistribution. On the other hand, they impose the restriction that linearly aggregated social well-being should improve in every country. This still does not guarantee that countries that transfer resources to the others would voluntarily enter to a centralized tax system. If a country aggregates individual well-being with a concave social welfare function, it might still be worse off compared to the benchmark under the new scenario.[26] Nevertheless, with the new

[25] I would like to thank to the anonymous referee who pointed this out.

[26] Obviously, there would not be a feasible solution to the optimization problem if individual indirect utilities in the constraints are aggregated with a logarithmic social welfare function.

restriction, the social planners of S2 and S3 ensure that a certain fraction of the workers become better off in the countries that transfer resources.

EU-level results are presented in Table 6. With the new restriction, Europe becomes worse off as a whole in S2. When the government cannot differentiate taxes by country of residence, the social planner prioritizes efficiency and it is optimal to set marginal income taxes very low (not reported here) to ensure that at least richer households are going to be better off in a centralized tax system. As a result there is substantial expansion in the total output but very little redistribution to the needy. Hence, social welfare in the EU, which is aggregated by a logarithmic function, declines. Thus, I do not pursue S2 in the rest of this section.

S3 still improves social welfare, albeit by a lower magnitude compared to the fully optimal taxation system. Under this scenario, there is still a sizable expansion in total output while almost half of the population in Europe is better off. Indirect utility of every individual in transfer receiving countries improve. In addition, a considerable fraction of the individuals residing in the transferring countries, from 27% in Cyprus to almost 50% in Sweden, do not experience a decline in their well-being. By country fractions of individuals that are better of in S3 are reported in Appendix B.8 (Fig. 19).

Figure 7 presents the country-level transfers for S3. In order to enable an easy comparison to the full optimum, placement of countries across the panels are the same as Fig. 2. Notice that Portugal, Malta, Cyprus, Slovenia, Poland and Portugal, if anything, becomes slight losers of the new system. While outwards transfers do not exceed 2% of the total output of the transferring countries, these transfers still correspond to a sizable fraction of the total output of the transfer receiving countries. Finally, in contrast to the full optimum case, optimal marginal taxes decrease under the new scenario for transferring countries compared to the benchmark. By lowering the tax marginal tax rates, the social planner is still able to extract resources from high productivity countries without making the rich worse off. Country specific tax schemes and distribution of within-country welfare implied by S3 can be found in Appendix B.8 (respectively Figs. 20, 21).

Finally, in order to structure the discussion of political feasibility further, I implement the test proposed by Bierbrauer et al. (2020). According to Bierbrauer et al. (2020), the following statements are equivalent—as long as the tax reforms are

Table 6 Results at the EU-level with linear country welfare improving system (without income effects)

	Scenario 1	Scenario 2	Scenario 3
EU welfare (utils)	83.372	82.163	84,207
% change	–	− 1.45%	+ 1.00%
Fraction better off	–	51.16%	47.38%
Total gross income (% change)	–	+ 16.95%	+ 6.81%

% change in welfare, fraction better off and % change in gross income in S2 and S3 are in comparison to the benchmark, S1

Fig. 7 Transfers (as a fraction of total gross income) with linear country welfare improving system in S3. See Table 1 for a guide to country abbreviations. Notice the difference between x-axis scales of left and right panels. The left panel and the right panel respectively incorporate the countries that transfer resources and the receivers of the transfers at the full optimum (see Fig. 2)

monotonic[27]: "The median voter benefits from a reform", "There is a majority of voters who benefit from a reform". In the setting of this study, the single-crossing condition is satisfied in all scenarios and, thus, the tax reforms are monotonic. It is more convenient to explore whether the latter statement holds within each country. I find that if a country transfers (receives) resources, majority of that country is worse (better) off compared to the benchmark scenario. Thus, departing from Fig. 2, it can be concluded the median voter of 14 out of 24 countries is better off with S2 or S3 studied in the previous section. S3 of this section, on the other hand, performs worse based on the criteria of Bierbrauer et al. (2020). In this scenario, only 8 out of 24 countries receive transfers for the sake of avoiding high costs to highly productive countries (see Fig. 7). Thus, the median voter benefits from the reform in 8 countries.

5 Conclusion

This study analyzes the equity-efficiency implications of a European tax and transfer system in a Mirrleesian setting. Using the Structure of Earnings Survey 2014 wave, three different income taxation scenarios are calibrated and simulated for 24 member states of the EU. In S1, every state discretely solves its own maximization problem. In S2 and S3, welfare in the EU is maximized with respect to a common budget constraint. In S3, the social planner can condition taxes to the country of residence whereas the social planner of S2 is restricted to apply the same tax scheme to every country. For the purpose of comparing the common tax and transfer systems to discrete maximization, S1 is considered as the benchmark while discussing the numerical results.

In spite of the increase in total welfare, more than two-thirds of the households become worse off in S2 and S3 compared to the benchmark. When the social planner

[27] There is a single cutoff that separates the proponents of the reform from its opponents.

is unable to differentiate the tax schemes across countries (S2), total output contracts by 2.65%. Implications of S3 on the total output is sensitive to the assumption regarding the income effects on labor supply. When the income effects are assumed away, S3 leads to a contraction by 0.62% while the specification with the income effects yields an expansion of 1.53%.

Countries with high mean transfer resources to low-mean countries. Because the size of the transfers are higher in S3 compared to S2, total welfare decreases (increases) gradually in high- (low-) mean countries when moving from S1 to S3. Pooling the populations in S2 results in a highly dispersed gross earnings distribution, leading to increased distortion (and reduced output) in almost all of the countries. In S3, on the other hand, high-mean countries contract, whereas low-mean countries expand when the income effects are assumed away. When the utility function allows for the income effects, the conclusion is reversed, explaining the contrast in the total output implications of S3.

Poorer households in low-mean countries gain the most from both scenarios involving a common tax and transfer system. Within high-mean countries, standard deviation of the wage rate distribution determines the segment of the population that experiences the highest decline in indirect utility. In countries with a low standard deviation (e.g., Sweden), the richest lose the most due to much higher taxes and distortion compared to the benchmark scenario. The poorest lose the most in countries with a high standard deviation (e.g., Germany) because of sharing the redistributive taxes with the poorest in low-mean countries. In S3, the latter effect dominates in all high-mean countries, rendering the problem as a trade-off between the poor in high- and low-mean countries.

The outcomes of S2 and S3 lays out the potential costs of an integrated tax system to the high productivity countries. It is possible to limit the costs by imposing the restriction that linearly aggregated social welfare must not decline in any country compared to the benchmark. Inferring from the size of the transfers and the fractions of individuals that become better off in every country, such a scenario seems more politically feasible compared to the full optimum case. On the other hand, with the new constraint, S2 yields a reduction in aggregated well-being, whereas S3 improves social welfare by about 1%.

The analysis in this study can be extended in multiple directions. First, it would be interesting to examine the effect of cross-country heterogeneities in redistributive preferences and labor supply elasticities on the model outcomes. Second, the assumption of immobile workers can be removed to investigate the optimal tax schedules under the trade-off between enhanced redistribution and productivity-enhancing migration as in Kessing et al. (2020). Finally, incorporating extensive margin labor supply decision to the model seems promising for future research.

Appendix A: Data

A.1 Description and preparation

The purpose of the Structure of Earning Survey, conducted once every four years since 2002 by Eurostat, is to collect harmonized data on the demographics and

remunerations of individuals in Europe (see Eurostat (2014)). The 2014 wave incorporates data for 24 member states of the EU (plus Norway which is excluded from the analysis). See Table 1 for a list of these 24 countries. I focus on full-time workers that are between 20 and 60 years old. The size of the selected sample is over 7.6 million.

Monetary values in the survey are in national currency units. However, for the purposes of this study, earnings should be comparable across countries. Therefore, I convert all the monetary values into an artificial currency unit introduced by Eurostat: purchasing power standard (PPS). PPS, which can be recovered by dividing national currency units by Purchasing Power Parities (PPPs), is a common currency unit that eliminates price level differences across borders (see Eurostat (2008)). I use Eurostat (2019) to extract PPPs in 2014 for 24 countries in the data set and convert national currency units into PPS. See Table 7 for the PPPs of 24 countries.

The variable "average gross hourly earnings" is readily available in the survey. It is constructed by dividing "gross hourly earnings in the reference month" by "number of hours paid during the reference month" (see Eurostat (2014)). The reference month is October. According to Eurostat (2014), October is the month least affected by annual leaves and public holidays.

When the aforementioned division is performed to compute a new gross hourly earnings variable, there are, albeit small, inconsistencies with the readily available variable.[28] For precision, I proceed with the computed variable. Finally, I exclude those earning less than 1 PPS per hour.

A.2 Regional wage rate distributions

In order to demonstrate the hourly wage rate distribution in the EU, the 24 countries are classified into four regional categories according to the M49 standard of the United Nations.[29] The categories are Western Europe (Belgium, Germany, France, Luxembourg, the Netherlands), Northern Europe (Denmark, Estonia, Finland, Latvia, Lithuania, Sweden, the United Kingdom), Eastern Europe (Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia) and Southern Europe (Cyprus, Spain, Italy, Malta, Portugal, Slovenia). Figure 8 illustrates the distribution of hourly wage rates for the four regions.

The left panel of Fig. 8 illustrates the hourly wage rates at which the number of individuals peak and phase out in each region. Eastern Europe clearly distinguishes itself with an early peak followed by a sharp decline, suggesting that most individuals earn low salaries compared to individuals in other EU regions. In terms of the wage rate that the population peaks, Eastern Europe is followed respectively by Southern and Northern Europe which, however, exhibit thicker right tails. Western Europe, on the other hand, appears to be the other extreme with a late peak and more gradual phase out, suggesting that wages are significantly higher than in other EU regions.

[28] Less than 1% of the readily available variable exceed or stay below of the computed variable by one PPS unit.

[29] The United Nations classifies Cyprus as part of Western Asia. However, for the purposes of this study, because Cyprus is an EU country, it is assigned to the Southern Europe group.

Table 7 Purchasing power parities (PPP) . Source: Eurostat (2019)

Country	PPP	Country	PPP
Belgium (BE)	1.086	Lithuania (LT)	0.601
Bulgaria (BG)	0.897	Luxembourg (LU)	1.199
Cyprus (CY)	0.922	Latvia (LV)	0.675
Czech Republic (CZ)	17.233	Malta (MT)	0.796
Germany (DE)	1.043	Netherlands (NL)	1.097
Denmark (DK)	9.942	Poland (PL)	2.397
Estonia (EE)	0.715	Portugal (PT)	0.785
Spain (ES)	0.899	Romania (RO)	2.209
Finland (FI)	1.231	Sweden (SE)	11.839
France (FR)	1.096	Slovenia (SI)	0.802
Hungary (HU)	175.567	Slovakia (SK)	0.658
Italy (IT)	1.003	United Kingdom (UK)	0.948

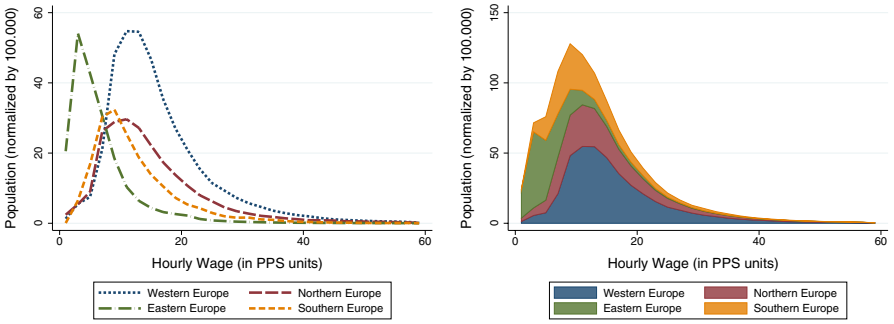

Fig. 8 Distribution of Hourly Wage Rates by Region. Western Europe: BE, DE, FR, LU, NL; Northern Europe: DK, EE, FI, LV, LT, SE, UK; Eastern Europe: BG, CZ, HU, PL, RO, SK; Southern Europe: CY, ES, IT, MT, PT, SI. See Table 1 for a guide to country abbreviations

For a unified picture of Europe, the area chart in the right panel stacks the regional distributions presented in the left panel. Redistribution in the case of a common tax and transfer system implies transfers from the right end to the left end of the picture. The graph suggests that, while Eastern Europe brings about a high mass to the lower end of the wage rate distribution, its contribution to the higher end is almost non-existent. On the contrary, Western Europe has a relatively small number of low wage earners, whereas it constitutes a big fraction of high wage earners. Southern and Northern Europe appear to be dispersed to the both ends of the graph with Northern Europe exhibiting slightly more high wage earners. In conclusion, the graph suggests that, in absolute terms, much of the burden of redistribution would be borne by Western Europe and the biggest benefitor is likely to be Eastern Europe.

Appendix B: Simulations

B.1 Two-country examples

In order to simulate the examples in this section, I follow the calibration procedure described in Section 4.2 by using arbitrary wage rate distributions for two imaginary countries. Furthermore, with one exception, the results of S2 are not discussed separately. This is because, as noted in Section 3, structures of the problems of S1 and S2 are basically identical. Therefore, any mechanism described for S1 applies also to S2.

Consider countries A and B. Suppose, in both countries, wage rates follow a log-normal distribution. In example 1, means and standard deviations of log-normal wage rate distributions are $(\mu^A, \sigma^A) = (2.5, 0.5)$ and $(\mu^B, \sigma^B) = (2, 0.5)$. In essence, every aspect of these countries is the same except for the mean of their wage rate distributions. The resulting marginal and average tax schemes of the two countries for S1 and S3 are presented in Fig. 9.

Upper panel of Fig. 9 suggests that marginal taxes are higher for the high-mean country (A) in S1.[30] This is because, everything else equal, higher mean implies that country A has a higher fraction of richer households. This provides the social planner with a larger tax base to exploit in order to meet the redistribution requirements of country A.

In S3, compared to S1, optimal marginal taxes are higher for the high-mean country, lower for the low-mean country. This signals that the social planner finds it optimal to transfer resources from the high-mean country to the low-mean country. The lower panel of Fig. 9 clarifies that notion. In country A, average taxes on the rich are higher in S3, whereas redistribution to the poor declines; the reverse is true for country B.[31]

In example 2, means and standard deviations of log-normal wage rate distributions are $(\mu^A, \sigma^A) = (2, 0.4)$ and $(\mu^B, \sigma^B) = (2, 0.7)$. In this example, only the standard deviation differs between countries A and B. Figure 10 presents the results.

A higher standard deviation in wage rate distribution translates into more inequality and, hence, a greater need for redistribution. Therefore, the optimal marginal tax rates of S1 are higher in country B. In S3, there are transfers from the country with higher standard deviation to the other country. Note that, when the supports of the wage rate distributions are the same, a higher standard deviation translates into greater fraction of high ability agents. As a result of tagging, the social planner exploits this tax base for redistribution purposes.[32] However, numerical simulations

[30] The optimal marginal tax rates decline through high incomes under the assumption of log-normal wage rate distribution (see e.g., Tuomala (1990), Mankiw et al. (2009))

[31] This is consistent with Cremer et al. (2010), who find that, under certain assumptions, if a group's wage rate distribution first-order stochastically dominates the other one, the dominating group transfers resources to the dominated group as a result of tagging.

[32] This result is in line with Boadway and Pestieau (2006) which suggests that tagging leads to transfers from the group with a greater share of high ability individuals to the one with a lesser share.

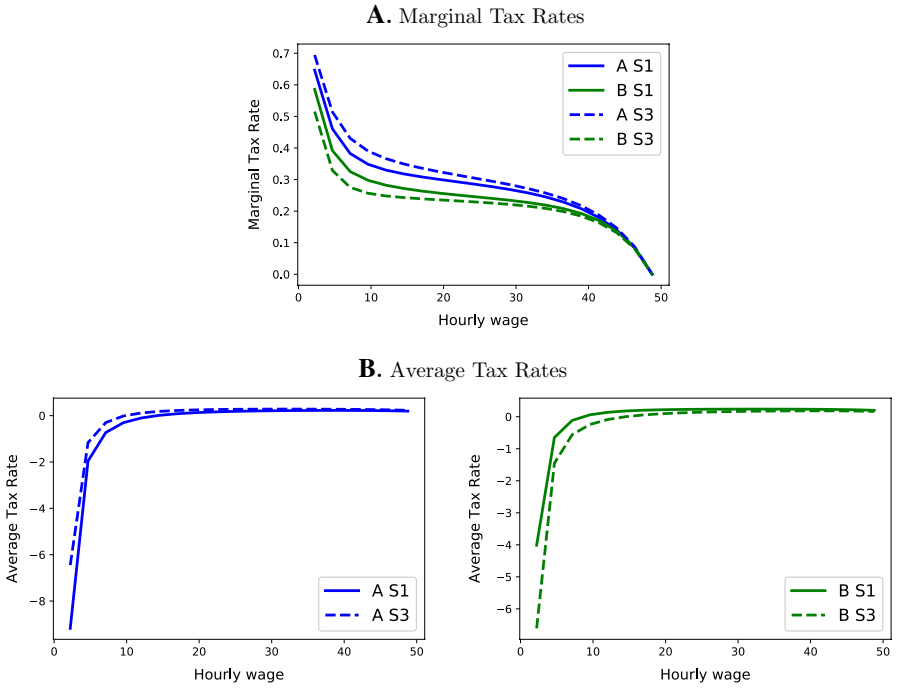

Fig. 9 Resulting tax schemes of Example 1

in the main text with 24 EU countries show that the impact of standard deviation on cross-country transfers is limited.

One finding regarding the pooled tax schemes is worth mentioning: even when the initial tax schemes are optimal, pooling countries does not necessarily lead to the average of initial tax schemes at the optimum. To show this, countries A and B of example 1 are pooled and the resulting marginal tax rate schemes are presented in Fig. 11.

When two countries with different means are pooled, the resulting wage rate distribution exhibits a higher standard deviation than each country's initial distribution, ceteris paribus. Figure 11 shows that, as explained in example 2, this requires resulting marginal tax rates to be higher than each country's optimal marginal tax rates in S1. This intuition is helpful to interpret the results of S2 in the main text.

B.2 Discretization procedure

First, in order to approximate national wage rate distributions, 24 continuous log-normal distributions are constructed in Python with means and standard deviations provided in Table 1.[33] Let $f_k(w)$ and $F_k(w)$ respectively denote the probability density and cumulative distribution functions of each continuous distribution. Next, the

[33] The "scipy.stats" module is used.

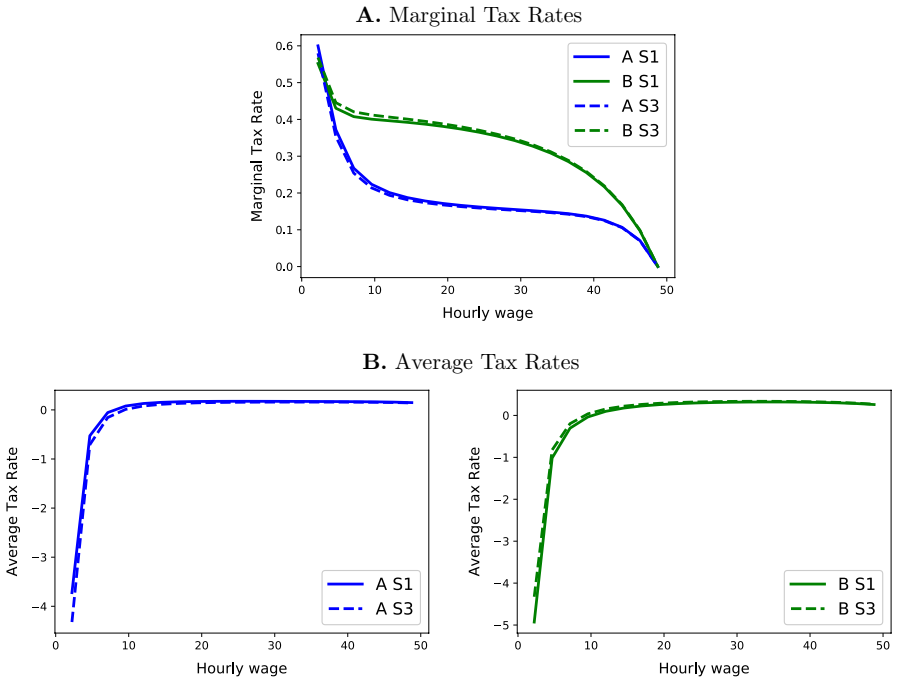

Fig. 10 Resulting tax schemes of Example 2

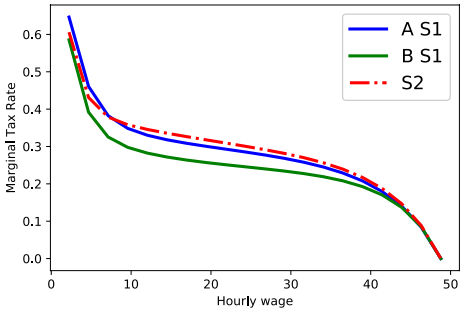

Fig. 11 Pooled marginal tax rates of Example 1

interval [1, 50] is split into 20 equal-sized bins by using 21 nodes. Let w_n, where $n \in \{1, 2, \ldots, 21\}$, be the associated nodes. Each wage bin (that corresponds to an agent) is represented by its midpoint, that is $w_i = (w_n + w_{n+1})/2$. Each node is evaluated at $F_k(w)$ and the probability mass of each agent is calculated as $F_k(w_{n+1}) - F_k(w_n)$ (that also equals $\int_{w_n}^{w_{n+1}} f_k(w)dw$). Finally, the resulting probability masses of each country is separately scaled such that they integrate to one.

B.3 Results for 24 countries

See Tables 8 and 9.

Table 8 Results by country (without income effects) for the three scenarios

Panel 1	Welfare			Transfers (% gross income)		
Country	Scenario 1	Scenario 2	Scenario 3	Scenario 1 (%)	Scenario 2 (%)	Scenario 3 (%)
BE	3.96	3.77	3.60	–	− 11.49	− 20.39
BG	1.94	3.16	3.53	–	188.46	243.73
CY	3.17	3.41	3.56	–	18.59	31.35
CZ	2.69	3.27	3.54	–	60.05	86.66
DE	3.88	3.72	3.61	–	− 9.68	− 16.32
DK	4.06	3.84	3.61	–	− 13.67	− 24.45
EE	2.71	3.28	3.54	–	56.23	83.59
ES	3.41	3.49	3.57	–	6.63	11.36
FI	3.73	3.64	3.58	–	− 5.29	− 9.39
FR	3.68	3.62	3.58	–	− 4.01	− 6.41
HU	2.54	3.24	3.54	–	76.80	109.79
IT	3.63	3.59	3.58	–	− 2.10	− 2.97
LT	2.35	3.21	3.53	–	105.95	145.45
LU	3.94	3.76	3.61	–	− 11.03	− 18.98
LV	2.36	3.21	3.53	–	102.47	141.95
MT	3.37	3.48	3.56	–	8.45	13.76
NL	3.94	3.76	3.61	–	− 11.15	− 19.28
PL	2.95	3.34	3.55	–	33.69	53.52
PT	2.91	3.33	3.55	–	36.88	58.20
RO	2.16	3.19	3.53	–	137.11	187.08
SE	3.77	3.66	3.58	–	− 6.35	− 11.63
SI	3.08	3.37	3.55	–	25.58	39.52
SK	2.68	3.27	3.54	–	61.05	87.95
UK	3.79	3.67	3.60	–	− 7.19	− 11.59
Panel 2	Total gross income (% change)			Income weighted MTR %		
Country	Scenario 1 (%)	Scenario 2 (%)	Scenario 3 (%)	Scenario 1 (%)	Scenario 2 (%)	Scenario 3
BE	–	− 6.00	− 2.42	22.09	31.13	25.71
BG	–	− 11.29	9.78	31.05	45.44	17.31
CY	–	− 1.82	2.81	32.81	35.05	29.09
CZ	–	− 8.05	5.56	29.07	39.88	21.15
DE	–	0.13	− 2.05	29.57	29.36	32.27
DK	–	− 3.95	− 3.15	23.88	29.70	28.44
EE	–	− 5.74	5.67	31.69	39.10	23.90
ES	–	− 4.66	1.10	27.93	34.39	26.38
FI	–	− 7.28	− 0.98	22.01	32.94	23.49
FR	–	− 4.51	− 0.70	26.11	32.55	27.12
HU	–	− 7.41	6.61	30.98	40.63	21.78
IT	–	− 3.97	− 0.32	27.20	32.78	27.65
LT	–	− 9.25	7.59	30.23	42.34	19.53

Table 8 (continued)

Panel 2	Total gross income (% change)			Income weighted MTR %		
Country	Scenario 1 (%)	Scenario 2 (%)	Scenario 3 (%)	Scenario 1 (%)	Scenario 2 (%)	Scenario 3
LU	–	− 1.40	− 2.41	27.67	29.63	30.97
LV	–	− 8.55	7.59	30.95	42.04	20.34
MT	–	− 5.91	1.28	26.59	34.93	24.75
NL	–	− 2.45	− 2.42	26.54	30.03	29.92
PL	–	− 3.04	4.25	33.01	36.81	27.33
PT	–	− 3.05	4.53	33.27	37.06	27.24
RO	–	− 7.92	9.06	33.32	43.13	20.99
SE	–	− 8.46	− 1.19	19.95	32.93	21.79
SI	–	− 6.43	3.18	28.14	36.97	23.61
SK	–	− 8.12	5.61	29.05	39.96	21.06
UK	–	− 0.82	− 1.39	29.45	30.54	31.31

See Table 1 for a guide to country abbreviations. S1, by construction, excludes the possibility of cross-border transfers. Percent changes in total gross income use S1 as the benchmark. Income weighted marginal tax rates (MTR) are calculated by weighting the MTR of an agent by the share of the agent's gross income in the total gross income of its country

B.4 Results with nominal currency units

In this section, I replicate some of the results reported in the main text without translating the currency units into PPS. It should be emphasized once again that SES reports individual incomes in national currency units. Thus, although the social planners in this section do not consider spatial differences in purchasing power parities, remaining exchange rate differences should still be taken care of. I use ECU/Euro exchange rates table of 2014 provided by Eurostat within the data manual to translate national currency units of Bulgaria, Czech Republic, Denmark, Hungary, Lithuania, Poland, Romania, Sweden and United Kingdom into Euro (Table 10).

Table 10 reports resulting means and standard deviations. Firstly, note that standard deviations of the hourly wage rate distributions usually do not change (compared to Table 1) due to the standard deviation of log-income being scale-independent.[34] On the other hand, high-mean and low-mean countries are more polarized. Mean wage rates appear higher in Northern and Western Europe, but lower in Southern and Eastern Europe. Thus, it would be interesting the compare the welfare consequences and size of the transfers to the case with PPS currency units.

Table 11 and Fig. 12 presents the results that are equivalent to Table 2 and Fig. 2 in the main text.

[34] For Bulgaria and Lithuania, there are notable declines in standard deviations. This is because workers who make less than one Euro per hour have been dropped when estimating the parameters of hourly wage rate distributions. When incomes are not scaled by purchasing power differences, many workers stay below this threshold in those countries, masking some of the variability in hourly wage rates.

Table 9 Results by country (with income effects) for the three scenarios

Panel 1	Welfare			Transfers (% gross income)		
Country	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2 (%)	Scenario 3 (%)
BE	2.55	2.42	2.12	–	− 12.23	− 33.25
BG	1.15	1.93	2.47	–	167.36	347.13
CY	1.98	2.13	2.36	–	16.60	48.64
CZ	1.67	2.02	2.41	–	51.23	123.28
DE	2.48	2.38	2.21	–	− 9.31	− 22.56
DK	2.62	2.47	2.10	–	− 13.78	− 38.09
EE	1.68	2.02	2.42	–	49.42	122.02
ES	2.17	2.20	2.31	–	4.12	15.33
FI	2.40	2.32	2.20	–	− 7.20	− 17.72
FR	2.36	2.30	2.23	–	− 5.40	− 11.24
HU	1.56	1.99	2.43	–	67.27	158.36
IT	2.31	2.28	2.26	–	− 3.54	− 5.61
LT	1.43	1.97	2.45	–	92.75	207.82
LU	2.52	2.40	2.18	–	− 10.94	− 27.95
LV	1.44	1.97	2.45	–	90.17	203.89
MT	2.15	2.19	2.31	–	5.28	17.77
NL	2.53	2.41	2.17	–	− 11.28	− 29.20
PL	1.83	2.07	2.39	–	30.16	80.72
PT	1.81	2.06	2.40	–	33.18	87.77
RO	1.29	1.95	2.46	–	123.34	271.48
SE	2.43	2.34	2.17	–	− 8.36	− 21.79
SI	1.94	2.10	2.36	–	20.58	55.59
SK	1.67	2.02	2.42	–	52.11	125.08
UK	2.41	2.34	2.23	–	− 7.26	− 16.09
Panel 2	Total gross income (change)			Income weighted MTR		
Country	Scenario 1	Scenario 2 ()	Scenario 3 ()	Scenario 1 ()	Scenario 2 ()	Scenario 3 ()
BE	–	− 1.33	11.24	24.39	36.22	29.87
BG	–	− 32.40	− 29.65	41.51	57.73	20.36
CY	–	− 6.46	− 8.62	39.89	43.36	34.02
CZ	–	− 18.40	− 17.57	36.28	50.16	24.76
DE	–	3.04	6.14	34.95	34.92	38.69
DK	–	1.10	13.08	26.70	34.49	33.46
EE	–	− 16.14	− 16.93	39.47	49.19	27.82
ES	–	− 5.69	− 3.42	32.91	41.79	30.84
FI	–	− 4.33	5.28	24.66	38.95	27.28
FR	–	− 2.56	3.02	30.04	38.80	31.75
HU	–	− 20.10	− 19.99	39.12	51.33	25.40
IT	–	− 2.72	1.43	31.58	39.28	32.42
LT	–	− 24.62	− 23.40	38.90	53.66	22.89
LU	–	2.26	8.23	32.11	34.96	36.90

Table 9 (continued)

Panel 2	Total gross income (change)			Income weighted MTR		
Country	Scenario 1	Scenario 2 ()	Scenario 3 ()	Scenario 1 ()	Scenario 2 ()	Scenario 3 ()
LV	–	− 23.76	− 22.99	39.71	53.28	23.77
MT	–	− 7.11	− 3.98	31.25	42.49	28.91
NL	–	1.43	8.87	30.45	35.31	35.46
PL	–	− 10.45	− 12.61	40.56	45.97	31.83
PT	–	− 11.04	− 13.33	41.00	46.36	31.70
RO	–	− 26.40	− 25.89	43.35	54.88	24.37
SE	–	− 4.92	6.87	22.02	38.75	25.17
SI	–	− 11.38	− 10.20	33.96	45.76	27.59
SK	–	− 18.59	− 17.74	36.28	50.27	24.66
UK	–	1.39	4.21	34.67	36.45	37.24

See Table 1 for a guide to country abbreviations. S1, by construction, excludes the possibility of cross-border transfers. Percent changes in total gross income use S1 as the benchmark. Income weighted marginal tax rates (MTR) are calculated by weighting the MTR of an agent by the share of the agent's gross income in the total gross income of its country

Table 10 Parameters of log-normal wage rate distributions and population shares (Nominal Euro)

Country	(μ, σ)	s_k	Country	(μ, σ)	s_k
Belgium (BE)	(2.955, 0.348)	0.017	Lithuania (LT)	(0.451, 0.357)	0.009
Bulgaria (BG)	(0.690, 0.561)	0.018	Luxembourg (LU)	(3.012, 0.474)	0.002
Cyprus (CY)	(2.167, 0.562)	0.003	Latvia (LV)	(1.315, 0.544)	0.005
Czech Republic (CZ)	(1.490, 0.490)	0.036	Malta (MT)	(2.223, 0.426)	0.001
Germany (DE)	(2.819, 0.533)	0.202	Netherlands (NL)	(2.932, 0.441)	0.032
Denmark (DK)	(3.224, 0.387)	0.007	Poland (PL)	(1.538, 0.566)	0.067
Estonia (EE)	(1.611, 0.542)	0.004	Portugal (PT)	(1.821, 0.573)	0.019
Spain (ES)	(2.358, 0.451)	0.078	Romania (RO)	(0.823, 0.606)	0.039
Finland (FI)	(2.926, 0.346)	0.012	Sweden (SE)	(3.016, 0.315)	0.023
France (FR)	(2.757, 0.417)	0.139	Slovenia (SI)	(2.017, 0.460)	0.006
Hungary (HU)	(1.270, 0.535)	0.023	Slovakia (SK)	(1.535, 0.491)	0.015
Italy (IT)	(2.621, 0.438)	0.075	United Kingdom (UK)	(2.870, 0.508)	0.168

μ and σ respectively denote the mean and the standard deviation of the estimated log-normal wage rate distributions over nominal Euro units. s_k denotes the population share of the corresponding country within 24 countries in the sample

Table 10 suggest that the welfare improvement brought about by S2 is higher compared to the calculations with PPS currency units. The likely cause is that low-income countries experience higher utility gains due to concavity. Improvement in S3 does not meaningfully differ, suggesting a higher portion of the gains under European tax and transfer system arise due to cross-border transfers. In both S2 and

Table 11 Results at the EU-level (without income effects and nominal Euro)

	Scenario 1	Scenario 2	Scenario 3
EU welfare (utils)	70.227	72.260	72.352
% change	–	+ 2.89%	+ 3.03%
Fraction better off	–	24.4%	24.5%
Total gross income (% change)	–	− 0.80%	− 0.37%

% change in welfare, fraction better off and % change in gross income in S2 and S3 are in comparison to the benchmark, S1

Fig. 12 Transfers (as a fraction of total gross income) in European tax and transfer systems (Nominal Euro). See Table 1 for a guide to country abbreviations. Notice the difference between x-axis scales of left and right panels. The left panel and the right panel respectively incorporate the countries that transfer resources and the receivers of the transfers in S2 (blue) and S3 (red) (colour figure online)

S3, fractions of the agents that are better off is lower compared to the main text. This outcome can also be explained by the starker grouping in terms of mean wage rates. Given that the need for redistribution is higher, a higher fraction within high-mean countries become worse off in order to meet this need.

Finally, a European tax and transfer system yields lower contraction in total output. Recalling two-country examples is helpful in order to understand this result. Figures 9 and 10 respectively suggest that, everything else equal, higher mean or higher standard deviation call for higher distortion across the distribution. Therefore, a pooled wage rate distribution puts downwards (upwards) pressure on marginal taxes due to lower mean (higher standard deviation). Given the starker grouping of countries with nominal Euro currencies, effect of the lower mean is stronger compared to the main text. Yet, as in the main text, standard deviation effect still dominates, yielding a contraction, albeit a lower one in both S2 and S3.

Comparing Fig. 12 above and Fig. 2 in the main text indicates that winners and losers of a European tax and transfer system do not change. On the other hand, transfers relative to countries' total output are lower (higher) for high- (low-) mean countries, using nominal Euro currencies. Once again, polarization of the countries provides the justification. Total output for high-mean countries is higher in the case of nominal Euro currencies, whereas the opposite is true for low-mean countries.

Hence, lower transfers relative to a high-mean country's size appears as a higher transfer relative to a low-mean country's size.[35]

B.5 Elasticity of labor supply

This section repeats analysis with a higher and a lower value of elasticity of labor supply compared to $\epsilon = 0.5$ of the main text. Table 12 and Fig. 13 report the EU-level results and transfers across countries for $\epsilon = 0.33$ (reported in Chetty (2012)). Table 13 and Fig. 14 presents the same set of results for $\epsilon = 0.75$. Overall, numerical outcomes slightly differ but the central intuition and results presented in the main text are robust.

Convexity of the disutility from labor supply increase, as the labor supply elasticity decrease. While all countries produce less in all three scenarios, decline in the total output of high productivity countries is sharper due to convexity. Thus, although transfers (relative to a country's total output) from high-productivity countries increase, these transfers correspond to a lower fraction of the output of the low-productivity countries (see Fig. 13). As a result, improvement in welfare slightly decline. Finally, because higher convexity of the disutility from labor supply discourages the social planner from further redistribution, contractions resulting from S2 and S3 decline compared to the main text. Analogous of the results hold for $\epsilon = 0.75$.

B.6 Inequality aversion

Consider the following generalized utilitarian social welfare function:

$$G(U) = \frac{U^{1-\rho} - 1}{1 - \rho} \tag{17}$$

Concavity of $G(.)$ increase in ρ, rendering the social planner more inequality averse. In the main text, I consider $log(.)$ social welfare function which corresponds to $\rho = 1$. In this section, the analyses are repeated for $\rho = 0.5$ and $\rho = 2$. EU-level results and transfers across countries are reported for both cases respectively in Table 14, Fig. 15 and Table 15, Fig. 16.

As expected, transfers across countries increase (decrease) as the social planner is more (less) inequality averse. Nevertheless, winners and losers of the centralized tax and transfer system do not change. Furthermore, EU-level winning-loosing fractions of the total population and contractions brought about by S2 and S3 are similar to the main text both in direction and level.

[35] Relative transfers in S3 are lower compared to S2 for Lithuania, Romania and Bulgaria. Note that these three countries have the lowest mean wage rates. Hence, the extra distortion implied by pooled wage rate distribution causes a sharp decline in the total output of these countries. As a result, although net transfers to these countries are higher in S3 compared to S2 (not reported here), the outcome is reversed for the relative transfers.

Table 12 Results at the EU-level for $\epsilon = 0.33$

	Scenario 1	Scenario 2	Scenario 3
EU welfare (utils)	75.362	77.119	77.449
% change	–	+ 2.33%	+ 2.77%
Fraction better off	–	31.9%	32.3%
Total gross income (% change)	–	− 2.17%	− 0.43%

% change in welfare, fraction better off and % change in gross income in S2 and S3 are in comparison to the benchmark, S1

Fig. 13 Transfers (as a fraction of total gross income) for $\epsilon = 0.33$ in European tax and transfer systems. See Table 1 for a guide to country abbreviations. Notice the difference between x-axis scales of left and right panels. The left panel and the right panel respectively incorporate the countries that transfer resources and the receivers of the transfers in S2 (blue) and S3 (red) (colour figure online)

Table 13 Results at the EU-level for $\epsilon = 0.75$

	Scenario 1	Scenario 2	Scenario 3
EU welfare (utils)	96.031	98.793	99.224
% change	–	+2.88%	+3.32%
Fraction better off	–	33.7%	32.3%
Total gross income (% change)	–	− 3.09%	− 0.88%

% change in welfare, fraction better off and % change in gross income in S2 and S3 are in comparison to the benchmark, S1

One result, however, is noteworthy. Notice that, compared to the case of $\rho = 1$ in the main text, welfare gains from an EU-level tax-and-transfer system decline through both directions. This indicates that that, if inequality aversion of the planner is optimized together with the tax system, there would be interior solution for optimal ρ which maximizes the gains from centralizing the tax schemes.[36] If the inequality aversion of the social planner is too low, then redistributive benefits of a centralized tax system would diminish from a social welfare perspective. On the other hand, if the planner has a very high inequality aversion, then room for welfare

[36] Note that individual social welfare functions of the countries for S1 and the social welfare function of the planners in S2 and S3 must be the same. Otherwise, welfare levels would not be comparable.

Fig. 14 Transfers (as a fraction of total gross income) for $\epsilon = 0.75$ in European tax and transfer systems. See Table 1 for a guide to country abbreviations. Notice the difference between x-axis scales of left and right panels. The left panel and the right panel respectively incorporate the countries that transfer resources and the receivers of the transfers in S2 (blue) and S3 (red) (colour figure online)

Table 14 Results at the EU-level for $\rho = 0.5$

	Scenario 1	Scenario 2	Scenario 3
EU welfare (utils)	238.98	243.59	245.30
% change	–	+ 1.93%	+ 2.64%
Fraction better off	–	34.6%	32.3%
Total gross income (% change)	–	− 2.20%	− 0.56%

% change in welfare, fraction better off and % change in gross income in S2 and S3 are in comparison to the benchmark, S1

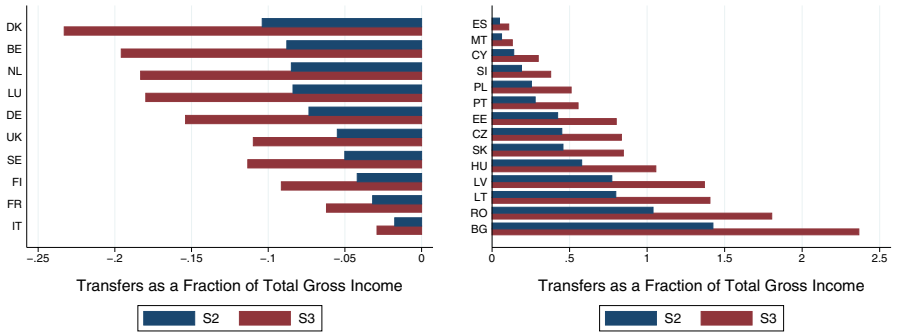

Fig. 15 Transfers (as a fraction of total gross income) for $\rho = 0.5$ in European tax and transfer systems. See Table 1 for a guide to country abbreviations. Notice the difference between x-axis scales of left and right panels. The left panel and the right panel respectively incorporate the countries that transfer resources and the receivers of the transfers in S2 (blue) and S3 (red) (colour figure online)

Table 15 Results at the EU-level for $\rho = 2$

	Scenario 1	Scenario 2	Scenario 3
EU welfare (utils)	23.069	23.282	23.296
% change	–	+ 0.92%	+ 0.98%
Fraction better off	–	31.3%	32.3%
Total gross income (% change)	–	− 2.86%	− 0.58%

% change in welfare, fraction better off and % change in gross income in S2 and S3 are in comparison to the benchmark, S1

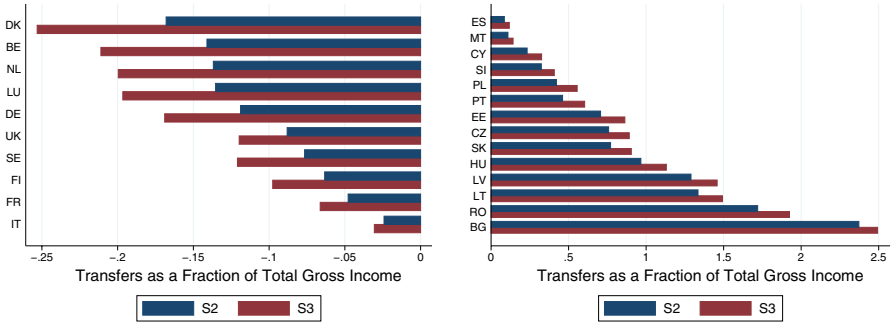

Fig. 16 Transfers (as a fraction of total gross income) for $\rho = 2$ in European tax and transfer systems. See Table 1 for a guide to country abbreviations. Notice the difference between x-axis scales of left and right panels. The left panel and the right panel respectively incorporate the countries that transfer resources and the receivers of the transfers in S2 (blue) and S3 (red) (colour figure online)

gains through redistribution to the poor would be little because countries would have redistributed to the needy without the centralized tax system. I find that $\rho = 0.92$ and $\rho = 0.83$ respectively maximize the gains from S2 and S3.

B.7 Log-normal: Pareto ability distribution

It is well-known at least for the US that upper tail of the ability distribution is better approximated by a Pareto tail. See, e.g., Saez (2001). Considering the same possibility for the European countries, I repeat the exercise for an alternative ability distribution. 25 PPS per hour approximately corresponds to the 90th percentile in overall European hourly wage rate distribution. I fit a log-normal distribution to hourly wages from 1 to 25 PPS units and a Pareto distribution to the wages above 25 PPS units within every country. As a result, for every country, I recover three parameters that govern the ability distribution: mean–standard deviation of the log-normal section and a Pareto parameter for the upper tail. See Table 16. For each country, I append the two distributions such that the densities are continuous at the

Table 16 Parameters of log-normal—Pareto wage rate distributions and population shares

Country	(μ, σ)	α	s_k	Country	(μ, σ)	α	s_k
BE	(2.756, 0.223)	3.814	0.017	LT	(1.690, 0.508)	3.096	0.009
BG	(1.377, 0.537)	3.221	0.018	LU	(2.640, 0.293)	2.946	0.002
CY	(2.170, 0.477)	3.663	0.003	LV	(1.689, 0.513)	3.199	0.005
CZ	(1.931, 0.444)	2.691	0.036	MT	(2.399, 0.357)	3.272	0.001
DE	(2.611, 0.423)	3.261	0.202	NL	(2.686, 0.306)	3.359	0.032
DK	(2.809, 0.289)	3.750	0.007	PL	(2.045, 0.500)	2.804	0.067
EE	(1.921, 0.507)	3.538	0.004	PT	(2.005, 0.501)	3.346	0.019
ES	(2.399, 0.381)	4.280	0.078	RO	(1.495, 0.564)	3.091	0.039
FI	(2.648, 0.259)	3.912	0.012	SE	(2.689, 0.225)	3.776	0.023
FR	(2.580, 0.316)	3.129	0.139	SI	(2.195, 0.399)	3.377	0.006
HU	(1.800, 0.479)	2.811	0.023	SK	(1.926, 0.445)	2.795	0.015
IT	(2.521, 0.325)	3.225	0.075	UK	(2.554, 0.361)	2.922	0.168

See Table 1 for a guide to country abbreviations. μ and σ respectively denote the estimated mean and the standard deviation of the log-normally distributed section (1–25 PPS). α represents the Pareto parameter for the distribution of the wage rates above 25 PPS. s_k denotes the population share of the corresponding country within 24 countries in the sample

cut-off. Finally, in order to ensure that they integrate to one, I proportionately scale the densities.

Figure 18 demonstrates that, consistent with the well-established findings of the previous literature, a Pareto tail implies slightly increasing marginal taxes through higher incomes. On the other hand, fundamental findings of the study regarding the consequences of different taxation scenarios remain largely unchanged. See also Table 17 and Fig. 17. If anything, contraction in total output and welfare improvement implied by S2 and S3 are somewhat lower. Possibly, this is because higher optimal marginal taxes of S1 (due to Pareto tail) uses up some of the redistributional benefits of an integrated tax and transfer system (Fig. 18).

Table 17 Results at the EU-level for lognormal—Pareto ability distribution

	Scenario 1	Scenario 2	Scenario 3
EU welfare (utils)	72.254	73.713	74.007
% change	–	+ 2.02%	+ 2.43%
Fraction better off	–	30.6%	32.3%
Total gross income (% change)	–	− 1.92%	− 0.31%

% change in welfare, fraction better off and % change in gross income in S2 and S3 are in comparison to the benchmark, S1

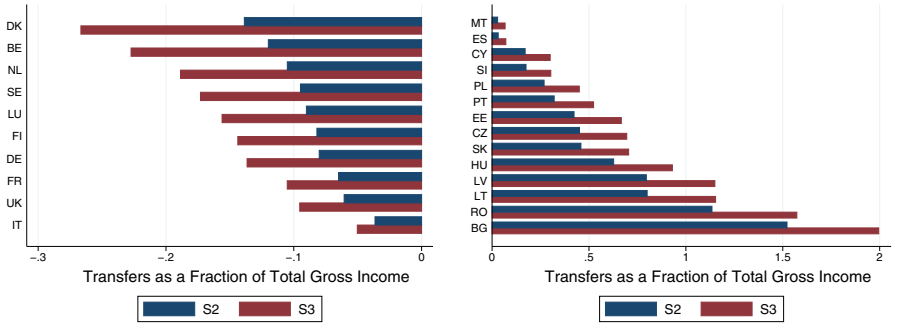

Fig. 17 Transfers (as a fraction of total gross income) for lognormal—Pareto ability distribution in European tax and transfer systems. See Table 1 for a guide to country abbreviations. Notice the difference between x-axis scales of left and right panels. The left panel and the right panel respectively incorporate the countries that transfer resources and the receivers of the transfers in S2 (blue) and S3 (red) (colour figure online)

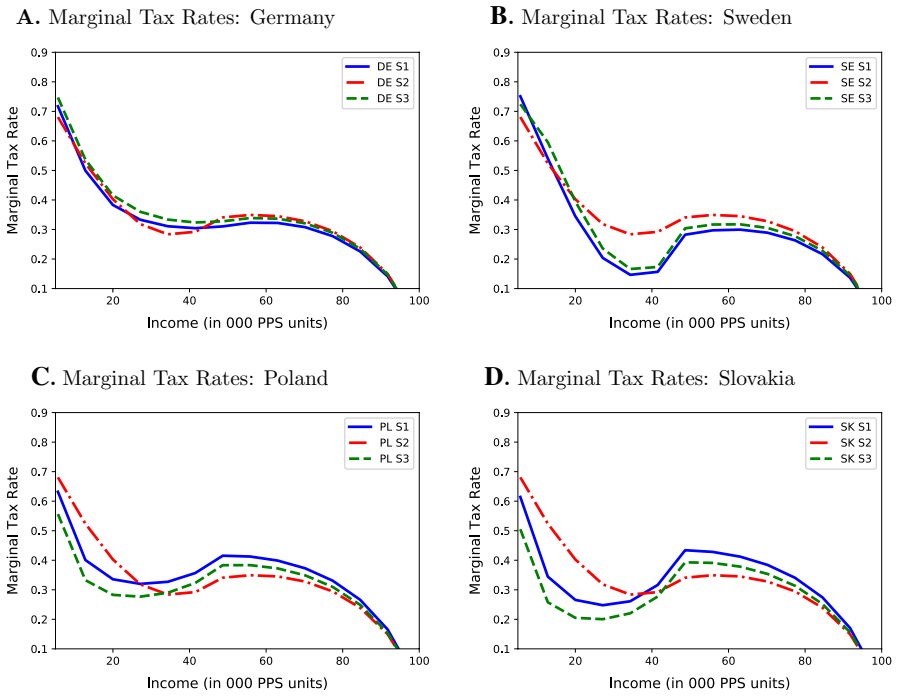

Fig. 18 Resulting tax schedules for lognormal—Pareto ability distribution

B.8 Further results for the more restrictive system

See Figs. 19, 20, 21.

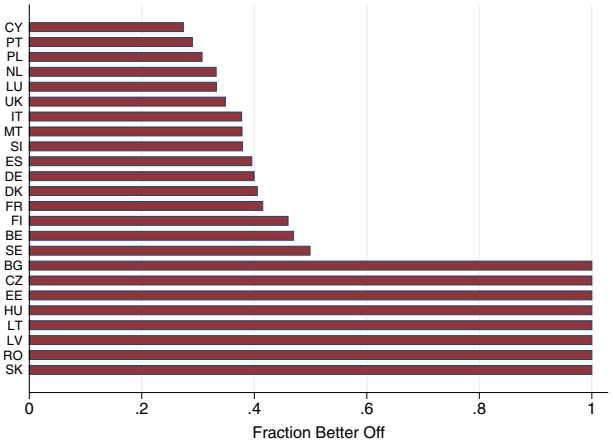

Fig. 19 Fractions better off in S3 with linear country welfare improving system. See Table 1 for a guide to country abbreviations. Fractions better off are in comparison to S1

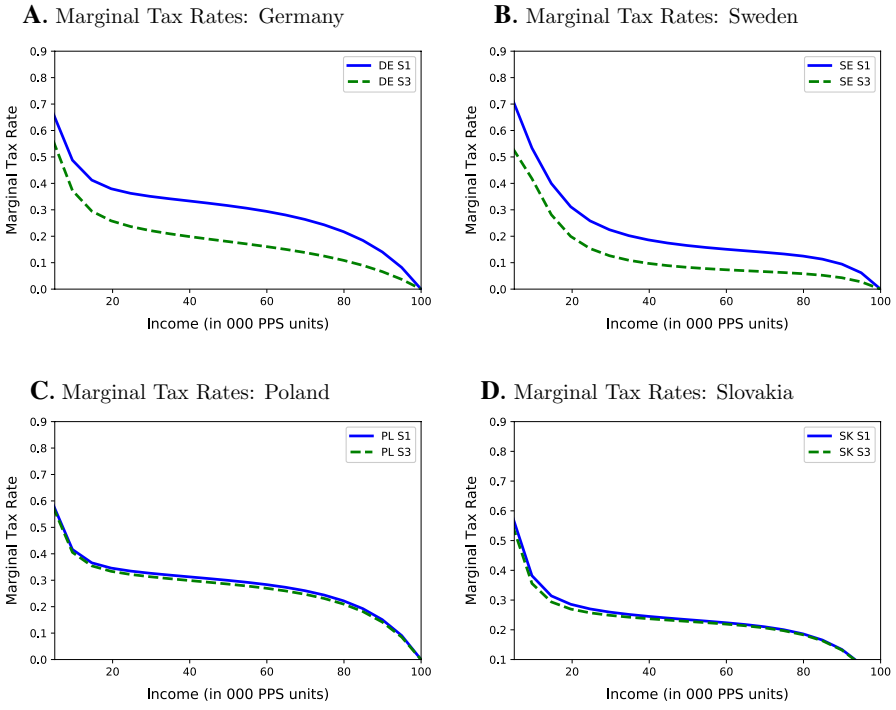

Fig. 20 Resulting tax schedules for linear country welfare improving scenario (S1 and S3). Marginal tax rates are calculated according to Eq. (14). Average tax rates are given by $(z(w) - c(w))/z(w)$ where $z(w)$ and $c(w)$ respectively denote the gross and net income for an agent of type w. Results for S2 are not reported because S2 does not improve welfare compared to the benchmark (see Table 6)

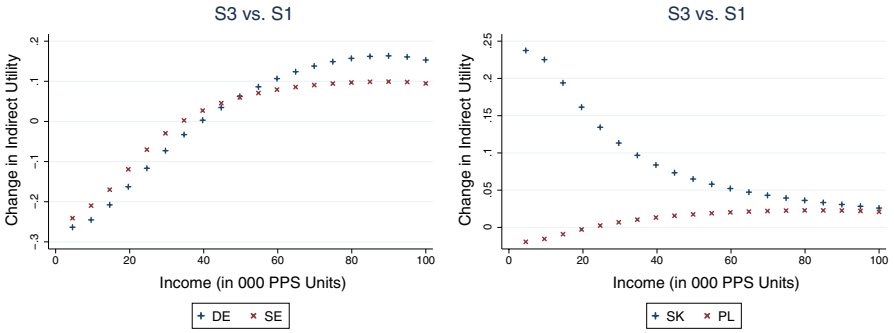

Fig. 21 Changes in indirect utilites with linear country welfare improving system relative to S1. Left (right) panel depicts the changes in the indirect utilites of the agents in S3 compared to S1 for Germany and Sweden (Poland and Slovakia). Results for S2 are not reported because S2 does not improve welfare compared to the benchmark (see Table 6)

B.9 Heterogeneous labor supply elasticities

If labor supply elasticities systematically vary with productivities across countries, there might be ramifications for the main results. In this section, I investigate that possibility by employing the labor supply elasticities for the latest available year estimated by Bargain et al. (2014).[37] There are elasticity estimations for 14 out of 24 countries in my sample. Based on Fig. 22, it is possible to observe a subtle positive relationship between labor supply elasticities and means of the log-normal wage rate distributions across countries.

If labor hours are more responsive to taxes in highly productive countries -which are also more populated-, the social planner would prefer lower distortions in S2 in order to avoid high efficiency costs. Thus, one may expect lower cross-country transfers and, thus, a lower welfare improvement in social welfare as a result of S2.

Given the possibility of tailoring taxes across countries, heterogeneity in elasticities of labor hours might not be as important in S3. Indeed, resulting optimal marginal income taxes of high-productivity countries in S3 would be lower than those presented in the main text. On the other hand, optimal marginal income taxes of S1 would also be lower in the first place. Thus, heterogeneous labor supply elasticities might not have drastic implications for the changes between S1 and S3.

Whereas the reduced form analysis above is a first step towards exploring the impact of heterogeneous elasticities, the outcome of an exploration that does not include a large part of the sample is inevitably inconclusive. In order to have an elaborate understanding, it would be necessary to estimate all the elasticities and, perhaps, to re-run the numerical simulations.

[37] Because the main specification assumes away the income effects, I rely on compensated labor supply elasticities.

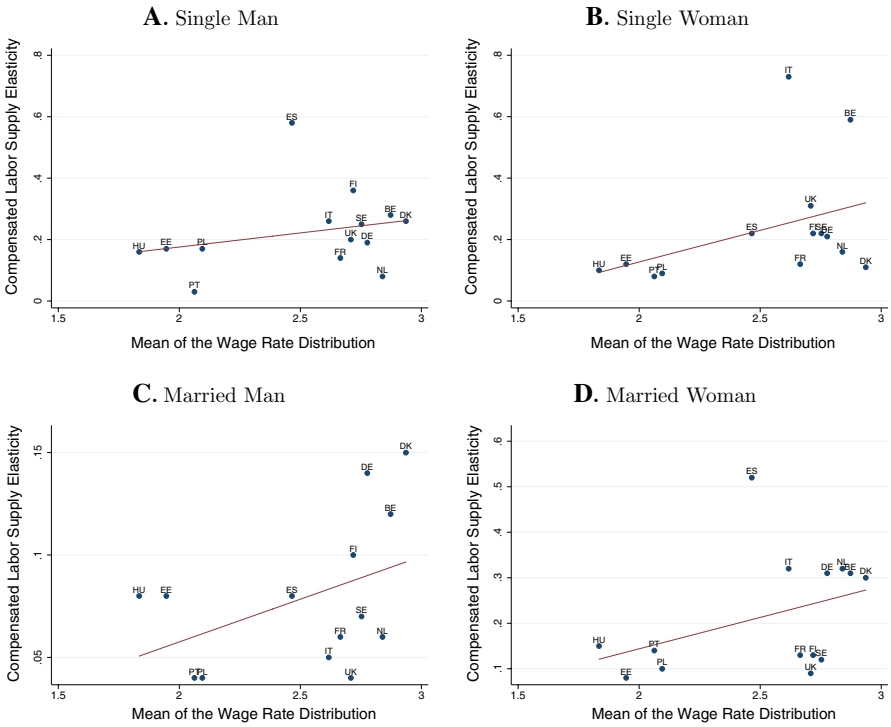

Fig. 22 Compensated labor supply elasticity vs. mean of the log-normal wage rate distributions for different demographic groups. Compensated labor supply elasticites are based on Bargain et al. (2014). Means of the log-normal wage rate distributions are taken from Table 1

Funding Open Access funding enabled and organized by Projekt DEAL..

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