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NEW ESTIMATE OF THE ELASTICITY OF MARGINAL UTILITY OF CONSUMPTION FOR EUROPE: IMPLICATIONS FOR THE SOCIAL DISCOUNT RATE

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New Estimate of the Elasticity of Marginal Utility of Consumption for Europe: Implications for the Social Discount Rate

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Abstract:
We provide the first estimate of the elasticity of marginal utility of consumption, μ, for Europe and for thirty individual European countries, using the income-tax individual-level data. Specifically, we rely on the absolute equal-sacrifice approach and CRRA utility function to elicit the revealed preferences of income tax payers on their acceptance of the tax schedule. Our central estimate of μ equals to 1.42. With few exceptional cases, μ's for European countries exceed unity, ranging between 1.2 and 1.90. We further discuss the implications of our estimate of μ for the social discount rate and Social Cost of Carbon. We conclude that the social discount rate might be slightly higher than traditionally assumed, implying lower magnitude of Social Cost of Carbon, at least for Europe.

JEL: D60, D61, H24, R13
Keywords: elasticity of marginal utility of consumption; equal-sacrifice approach; income tax schedules; marginal tax rate; social discount rate

1 Introduction

One of the most challenging tasks that economists and policy-makers need to face is to decide on socially desirable policy and optimal path of the economy in log run. Any such assessment will need to rely on social welfare (utility) estimated for any point in future time. This is typically done through estimation of the social welfare function which weights all future benefits and costs. The weighting is just the primary object of this paper.

The estimation of social welfare function highly impacts the allocation of funds to various investment projects. The efficiency of such investment projects is usually evaluated through cost-benefit analysis (CBA). One of the key questions in CBA remains – what is the future cost (or benefits) at present value. To answer this question we need to determine the social discount rate (SDR), which states the rate at which society is willing to accept the inter-temporal trade-offs of consumption. Using other words, the higher the value of SDR, the lower the present value of costs and benefits that will occur at a later date.

The computation of the SDR follows the formula known as the Ramsey rule (Ramsey, 1928):

$$r = \rho + \mu g(C),$$

where r is the social rate of return (usually called social discount rate), ρ is the pure rate of time preference (PRTP), $g(C)$ is the real growth rate of per capita consumption and μ is the elasticity of marginal utility of consumption – the parameter of our interest in this study.

PRTP describes the marginal rate of substitution between present and future consumption when holding consumption levels equal in both periods (Anthoff, Tol, & Yohe, 2009). Importantly, large ρ rise the ethical preference for greater inequality in consumption across generations. For example, assuming $\rho = 0$ we put the same weight to all generations, which implies a dictate of future generations. On the other hand, non–zero values of ρ imply higher weight on decisions made by present generation. There is long and vivid discussion in the economics and non-economics literature on the right value of ρ, however, despite that fact, ρ has been set in a range of 0% to 3% in the most of the IA studies so far (Dasgupta, 2021; Stern, 2007; Tol, 2013).

The real growth rate per capita consumption, $g(C)$, is self explaining, however, on the contrary of ρ, $g(C)$ is time dependent, and therefore, it is endogenous in the impact assessment models.

Finally, μ, the elasticity of marginal utility of consumption is considered as the key determinant of the social discount rate (SDR) in the current literature (Atkinson, Dietz, Helgeson, Hepburn, & Sælen, 2009; Evans, 2005; Groom & Maddison, 2019; Venmans & Groom, 2021). Nevertheless, its interpretation remains ambiguous. As (Atkinson et al., 2009) state, the main source of disagreement about the meaning of μ comes from the fact that it represents preferences over three significant dimensions – risk aversion, inequality aversion within a generation and inequality between generations (Berger & Emmerling, 2020). In principle, there are two main methods to elicit the parameter μ. Namely, indirect behavioural evidence and revealed preferences of social values, for instance, through acceptance of tax schedules.

In this study we use the latter to elicit the elasticity of marginal utility of consumption for thirty European countries. Specifically, we use the absolute equal-sacrifice approach in the same way as (Groom & Maddison, 2019; Opatrny & Scasny, 2021) used in their study carried out for the United Kingdom, and the Czech Republic, respectively. Given the absolute version of the equal-sacrifice approach, the results are relevant for the income taxpayers (Lambert & Naughton, 2009). We employ the household-level data from the The European Union Statistics on Income and Living Conditions (EU–SILC) covering the period 2004–2020 for all EU countries (except Croatia) together with Iceland, Norway, Switzerland and the UK.

Our study enriches the current stream of literature by empirical estimates of μ for countries in the European region. Specifically, we provide unique estimate of a key component, μ , in the formulae for the social welfare function for all of the European countries covered by the EUROSTAT database. Moreover, we estimate the effect of pre-tax income on μ, which shows economically negligible effect. Our central estimate of μ for the Europe equals to 1.42 and with a few exceptional cases, the estimates for all analysed countries in Europe exceed unity with the range of 1.2 to 1.9. Our results are in line with other empirical studies (Evans, 2005; Groom & Maddison, 2019).

The paper is organized as follows: Section 2 provides the literature background. Section 3 describes the employed methodology and the data. Section 4 shows the results. Section 5 discusses our findings and it provides the implication for policy-makers. Last section concludes and it offers a potential direction for further research.

2 Ambiguous Interpretation of μ in the Literature

As Dasgupta (2008) claims, the social discount rate is neither ethical primitives nor observable as market interest rate, but it should be derived from economic forecasts and society's preferences about allocation of goods and services. In this context, Arrow et al. (2013) provide conclusion from the discussion of twelve economists on the topic of social discount rate. As usual, there is no clear agreement. Those who prefer normative approach argue that SDR should be based on ethical principles. On the contrary, others claim that SDR should reflect the revealed preferences of the society. In the other words, SDR should be elicited by employing the positive approach (inferring μ from the progressivity of tax schedule is one of them).

We share the positive view, therefore, we use the equal sacrifice approach in the taxation context to elicit one of the main component of SDR, namely μ. Formally, μ is defined as:

$$\mu = -\frac{CU''(C)}{U'(C)} > 0,$$

where C denotes consumption and μ measures the curvature of utility, U(C). Given the definition, we can call μ as the Arrow-Pratt measure of relative risk aversion (Arrow, 1971; Pratt, 1964). It implies that the higher the μ the more risk averse the agent is.

In this context, H.M. Treasury (1997) provides the following clarification (p.84, footnote 7, $-b$ denotes our μ): *"The elasticity of marginal utility of consumption, $-b$, is given by CU''/U', where C is consumption and U is utility of consumption. It can be visualised in terms of how much the pleasure given to someone by an extra £1 of money to spend depends upon his or her income ...*[1] *The judgement required is conceptually fairly simple. It is nothing to do with the morality of more or less income redistribution. It is only very loosely related to attitudes to risk, for it is about the marginal utility of small variations in income which are not directly perceived (as distinct from gains or losses, such as theft, or*

[1] *If an extra £1 would give to someone the same pleasure, whether his income were £10,000 pa or £20,000 pa, this would imply for that person an elasticity of zero... An elasticity of -1 would imply that, with an income of £10,000, the extra £1 would give twice as much pleasure as it would with an income of £20,000. Elasticities of -2 and -3 would imply respectively four times (2^2) and eight times (2^3) as much.*

fluctuations in the value of personal financial assets, relative to a known baseline, which have much more complex impacts).”

However, the interpretation of μ in the Ramsey context remains ambiguous – intra-temporal inequality aversion, inter-temporal inequality aversion or risk aversion (Groom & Maddison, 2019). Moreover, Atkinson, Dietz, Helgeson, Hepburn, and Sælen (2009) claim that the numerical estimates in the literature are typically based on only one of the three dimensions of μ, and it is not clear that these estimates are equally valid to all three dimensions. As a consequence, we can see two main approaches how to elicit the parameter μ in the literature – indirect behavioural evidence and revealed preferences of social values (Evans, 2005).[2] For each approach there are several techniques of deriving the parameter of interest. Thus, the value of μ ranges between 0.2 up to even 10 (Atkinson et al., 2009; Evans, 2005; Groom & Maddison, 2019).

For example, Groom and Maddison (2019) use four revealed preference techniques: the absolute equal-sacrifice income tax approach, the subjective-well-being approach, the Frisch additive-preferences approach and risk aversion in insurance markets to determine μ for the United Kingdom. They offer the central estimate of $\mu = 1.5$. Evans (2005) using aggregated tax-income data for 20 OECD countries estimates μ close to 1.4.

Venmans and Groom (2021) employed revealed preferences approach with a multiple price list (MPL) technique. Respondents allocated environmental quality to one of two projects against a backdrop of different distributions of environmental quality over time and space, with different frames (loss–gain, within/between-regions) and different domains of environmental quality (forests, clean air and soil fertility). They surveyed 363 respondents and received in total 40,747 responses. They find that inequality aversion differs across intra-temporal ($\mu = 2.9$) and inter-temporal settings with a degrading environment ($\mu = 2.0$) or an improving environment ($\mu = 1.4$).

Drupp, Freeman, Groom, and Nesje (2018) tried to disentangle SDR into its component parts, including pure time preference, the wealth effect, and return to capital. They used revealed preference approach and surveyed over 200 experts and report a mean value of $\mu = 1.35$ (with min = 0 and max = 5). Interestingly, those experts who answered their survey do not follow the Ramsey Rule and recommend the median risk-free SDR of 2

[2] Evans (2005) recognizes third approach – direct survey method. However, we consider it more as a method how to obtain the data.

percent. As they point out, it is substantially lower than what Weitzman (2001) found with the similar approach (median value of 3 percent).[3]

The indirect behavioural approach derives μ, for instance, from the saving decisions of individual households (Cowell & Gardiner, 1999). They employ the life-cycle model of households behaviour, which assumes that households are maximising their consumption over different time periods constrained by their wealth. One of the advantages of this approach lies in avoiding the non-testable equal-sacrifice assumption (Groom & Maddison, 2019). Thus, the parameter μ is derived from the life-cycle model by so called Euler-equation. Formally, the estimator is presented as the elasticity of intertemporal substitution (EIS), which equals to $1/\mu$.

Havránek (2015) conducted a meta-analysis and examined 2,735 estimates of the EIS reported in 169 published studies. When correcting the mean his estimate reaches 0.3–0.4 for estimates associated with asset holders (therefore excluding macro data), which corresponds to μ between 2.5 and 3.3. Moreover, Groom and Maddison (2019) use the quarterly data of UK households from 1975Q1 through to 2011Q1 and estimate EIS at 0.63, which corresponds to $\mu = 1.59$.

Given the Eurostat dataset which contains the household's data about gross income and income tax together with social and health insurance paid, we estimate the parameter μ, relying on the positive approach and, specifically, on the income tax schedule that is the key of the equal sacrifice approach.

3 The Absolute Equal Sacrifice Method

3.1 Each Consumer Should Equally Sacrifice

Our study relies on the concept of revealed social values through the acceptance of income tax schedule. The same approach has been used in several related studies (Cowell & Gardiner, 1999; Evans, 2005; Groom & Maddison, 2019; Opatrny & Scasny, 2021). In general, the core idea says that the electorate agreed on the tax structure, thus, each consumer should equally sacrifice (Groom & Maddison, 2019).

There are several versions of the equal sacrifice approach: proportional, absolute and

[3] Weitzman (2001) asked over 2,000 economists for the appropriate "real interest rate" for the analysis of climate change mitigation.

marginal sacrifice (Lambert & Naughton, 2009). Absolute version means that everyone should give up the same amount of utility to be equally sacrificed. The proportional version can be seen as the transformation of the absolute version – a tax schedule $T(Y)$ generates equal proportional sacrifice for some utility function V(x) if and only if the same schedule results in equal absolute sacrifice for the utility function $U(x) = \exp(V(x))$. Whereas, the marginal equal sacrifice says that everyone should give up the same percentage in utility (Young, 1987).

In addition to the absolute equal sacrifice assumption we need to add another one that allows us to aggregate individuals with different wealth levels into a single representative agent with the same utility function. Therefore, we require the iso-elastic utility function, which means that the fraction of wealth optimally placed in the risky option is independent of the level of initial wealth. Formally, such utility function is called the constant relative risk aversion (CRRA) function. Given these assumptions we get the following formula (Evans, 2005):

$$U(Y) - U(Y - T(Y)) = k \tag{1}$$

where $k > 0$ is a constant, Y is gross income, U denotes the utility function and $T(Y)$ is the total income tax liability. Importantly, Lambert and Naughton (2009) claim that Y must be bounded away zero, if this is not the case we have $Y \to 0$ and $T(0) > 0$, which is the impossible state of affairs. Moreover, it implies that $0 < T(Y) < Y$, which means that the absolute equal sacrifice approach involve only the population of taxpayers.

It is important to note that $T(Y)$, total tax liability, was not defined in applications uniquely. In fact, the results derived from the equal-sacrifice income tax approach are sensitive to the inclusion (or not inclusion) of social and health insurance contributions (SHIC), like the UK National Insurance Contributions (NIC).[4] In the literature we can find both views. For example, Evans (2005) favours excluding SHIC, because only income tax fully corresponds to the equal absolute sacrifice assumption. On the other hand, Reed and Dixon (2005) argue that there is no difference between SHIC and personal income tax (PIT), as it is the case in many European countries, and both should be included

[4] Definition of the social and health security contributions vary depending on national legislation that defines the base from that these contributions are calculated and the rate(s). Despite these differences, SHIC are quantified on the basis of certain percentage from personal income.

in the formula. We share the view of Reed and Dixon (2005), because SHIC and PIT are both based on gross earnings and their magnitudes are agreed by the general public (and reflected in a nation-wide legislation). Moreover, we are restricted with our dataset, which does not record SHIC and PIT separately.

As a next step we use the iso-elastic form of the utility function:

$$U(Y) = \frac{Y^{1-\mu} - 1}{1-\mu} \tag{2}$$

and we plug it into the equation 1:

$$\frac{Y^{1-\mu} - 1}{1-\mu} - \frac{(Y - T(Y))^{1-\mu} - 1}{1-\mu} = k \tag{3}$$

Using the equation 3 we can infer the progressivity of taxation from the value of μ (Lambert & Naughton, 2009). Formally, note that

$$T(Y) = Y - [Y^{1-\mu} - (1-\mu)k]^{\frac{1}{1-\mu}}, \tag{4}$$

therefore,

$$T(Y)' = 1 - [1 - \frac{T(Y)}{Y}]^{\mu}. \tag{5}$$

As a result, $T(Y)$ is progressive with respect to income if $\mu > 1$, proportional (i.e. linear) if $\mu = 1$, and regressive if $\mu < 1$. We note that if social and health insurance contributions are included in the definition of tax liability T(Y), then $\mu > 1$ indicates progressivity of the PIT+SHIC aggregate, whilst $\mu > 1$ indicates the progressivity of personal income tax if SHIC are excluded from T(Y). This caveat needs to be considered in interpretation of the results; for example, $\mu = 0.96$, as estimated in this study for Switzerland, indicates regressivity of total taxation of labour (PIT plus SHIC), although PIT is likely progressive in Switzerland.

As a next step to derive the formula for μ, we take derivative of equation 3 with respect to Y and we obtain

$$Y^{-\mu} - (Y - T(Y))^{-\mu}(1 - MTR) = 0, \tag{6}$$

where $MTR = \frac{dT(Y)}{dY}$ is the marginal tax rate. In the final stage, we take the natural logarithm and simplify the equation 6 to

$$\mu = \frac{ln(1 - MTR)}{ln(1 - \frac{T(Y)}{Y})}, \tag{7}$$

where $\frac{T(Y)}{Y}$ denotes the average tax rate. Note that given the iso-elastic utility function, μ refers to the coefficient of relative risk aversion or Arrow-Pratt measure of relative risk aversion. Nevertheless, in the context of progressivity of taxation, μ can be interpreted as the measure of the inequality aversion. Therefore, the higher the μ, the more progressive tax the society have, which implies higher inequality aversion.

Our study differs from other similar papers in the way of deriving the marginal tax rate (MTR). We employ the data driven approach, specifically, for each country we estimate the following equation:

$$T(Y)^{PIT+SHIC}_{t,j,h} = MTR_{t,j} * Y^{Income}_{t,j,h} + e_{t,j,h}, \forall\{j, t\}, \tag{8}$$

where h denotes household belonging to income group $j \in (1^{st} decile, ..., 10^{th} decile)$ in a year period $t \in (2004, ..., 2020)$. Importantly, we use the weighted ordinary least square (OLS) estimation with the household cross-sectional weights given by the Eurostat.[5] As a result, we get the same MTR for each household belonging to the same decile and year. The average tax rate (ATR) is computed as:

$$ATR_h = \frac{T(Y)^{PIT+SHIC}_h}{Y^{Income}_h}, \tag{9}$$

thus, for each household separately. However, for the purpose of the regression we use weighted average of ATR for each decile with the household cross-sectional weight.

Finally, we estimate μ using the data for the whole–time span for each country as follows:[6]

[5]Formal description of the variable by the Eurostat is as follows: *The household cross-sectional weights are obtained after adjustment of the design weights in order to correct the non-response at the household level and to improve the accuracy of the estimates, by calibration to true known totals. This variable must be recorded each year the household appears in the survey and be filled for all the households of the sample.*

[6]We use the pooling panel data fixed effect method with individual effect and weights (see software R for references). As other approach, we use linear regression within each social group, and we bootstrap the confidence set. Finally, we use within fixed effect estimation. We omit the intercept in regression methods in the same way as Groom and Maddison (2019).

$$ln(1 - MTR_{t,j}) = \mu * ln(1 - ATR_{t,j}) + \epsilon_{t,j}. \tag{10}$$

As a robustness check we directly compute μ_j as:

$$\mu_j = \frac{\sum_{t=1}^{T} \frac{ln(1-MTR_{t,j})}{ln(1-ATR_{t,j})}}{T}, \tag{11}$$

where T denotes the number of used years in each country. Finally, μ for each country is derived as the (simple) average of μ_j for $j \in (1^{st}decile, ..., 10^{th}decile)$.

To sum up we use four methods to elicit the parameter μ – Linear regression method, fixed effects (FE pooling), fixed effects (FE within) and computational method. While the computational method allows us to directly obtain μ using the equation 11, the other three methods provide the estimates of μ. The fixed effects method differs from the linear regression in the assumption that we have the same structure of groups across years, i.e., the 1st decile comprises the homogeneous individuals, which is not necessarily true. Nevertheless, at the aggregate level, the differences are negligible. Moreover, FE capture all unobserved time-constant factors that affect the dependent variable. In the case of linear regression, the estimation results may suffer from omitted variable bias, which could lead to wider confidence interval (see Table A3 in the Appendix). Regarding the computational and linear regression methods we use the bootstrap technique to elicit the 95% confidence interval.

As for the fixed effect panel data model we report the results for both "pooling" as well as "within" approach. "Within" approach is standard FE estimation, which considers the differences between deciles. "Pooling" does not allow for intercept or slope differences among individuals (deciles in our case). Given the assumptions to elicit μ, we do assume that initial wealth does not influence the results, therefore "pooling" estimates seems appropriate and we refer them as the main results.

3.2 Household Tax and Income Information from EU-SILC

We use EU-SILC dataset covering the cross-sectional information about households between 2004 and 2020 (not all countries provide the information for the whole-time span, see Table A3. We define the following variables – gross households income (INC); taxes and social and health insurance paid by household (SHIC) (please see the full definition in the Appendix A.2).

Moreover, we cleaned the data from the missing values of both variables. To satisfy the assumptions of the absolute equal sacrifice approach we removed observations reporting $INC \leq 0$, $SHIC \leq 0$ and observations with $\frac{SHIC}{INC} \geq 1$. Importantly, to maintain the consistency of the definition of INC, we cleared INC from imputed rent until 2007, as it is automatically cleansed by Eurostat in later period.

We perform the analysis using the data for the entire sample, 27 EU Member States plus Iceland, Norway, and the United Kingdom (both using the panel data regression method), and household groups defined by weighted INC creating ten deciles for each country and year. In total we use information from 3,794,346 households from 30 countries during the period 2004–2020. However, some countries do not provide the data for the full study period, or there are missing information about INC or SHIC. Thus, after cleaning the dataset we end up with 3,356,449 observations.[7]

The average INC and SHIC (in abbreviation) for 1st decile varies between 1,033 EUR (41 EUR) per year in Romania and 24,116 EUR (6,373 EUR) in Switzerland. Consequently, the mid 5th decile rise from 4,665 EUR (755 EUR) in Romania to 72,458 EUR (19,533 EUR) in Switzerland. Finally, the 10th decile goes from 19,549 EUR (5,467 EUR) in Romania to 246,752 EUR (72,407 EUR) in Switzerland.

Given the nature of absolute equal sacrifice approach via the tax schedule we provide legislative details about PIT and SHIC for each country through studied period (see details in the Appendix A.1, Table A1 and Table A2). In general, PIT ind SHIC paid by employee varies between 10.42% (Estonia in 2019) and 33% (Denmark in 2019), see Figure A1 for details. However, we do not recognize such variation in terms of the results for μ, what is not the case in terms of the average tax rate (ATR).

Based on our data, the ATR for the 1st decile varies between 2.1% in the Czech republic and 26.4% in Switzerland. In case of 5th decile it rises from 8.4% in Cyprus to 30.8% in Denmark. Finally, in case of 10th decile it grows from 15.2% in Bulgaria up to 39.9% in Denmark, indicating the progressivity in income taxation. Importantly, the lowest spread of the ATR (standard deviation) across the income groups indicates Switzerland (0.008) and the highest one belongs to Slovenia (0.09). In other words, Switzerland reveals the most equal redistribution of ATR, while Slovenia reports the most unequal one. These

[7] Please see supplementary materials, which provide descriptive statistics for each country, year and decile.

findings corresponds with our empirical results for μ, where $\mu_{CH} = 0.96$ (the lowest one) and $\mu_{SI} = 1.75$ (the second highest after Ireland).

The MTR (estimated from household-level data for each decile) varies between -0.9% for Estonia and 31.6% for Denmark for the 1st decile. Consequently, MTR grows from 15% in Cyprus up to 41.4% in Germany for the 5th decile. Finally, MTR rises from 10.9% in Bulgaria to 47.6% in Slovenia in case of 10th decile. The highest spread of MTR indicates Slovenia (0.13), whereas the lowest one is in Poland (0.06). In general, the estimate of MTR varies significantly between countries particularly in case of 1st decile. This is the consequence of country social policy that provides various benefits and tax shields to the households with the lowest income.

4 μ differs from Unity

Our central estimate of μ is 1.42 for the whole sample of 30 countries as well as EU–27 with the 95% confidence interval excluding unity, see the following Table 1. Our central estimate is based on the fixed effect panel data model with "pooling" (not allowing for the intercept) and "within" approach (with the intercept), both weighting the data by the population. Since we do assume that initial wealth does not influence the results, and to be in line with the assumption of absolute equal sacrifice approach, we refer the result based on "pooling" as our central estimate.

Consequently we report aggregated results for each year for the whole sample using the computational method, see Figure 2. We can see that μ does not significantly differ within our study period, implying the stability across years. Precisely, the parameter μ across years is between 1.50 and 1.64, with slightly greater values after 2005. Note that the average, $\mu = 1.57$, differs from our central estimate. The main reason comes from the employed computational method, which does not take into account time and fixed effects for the countries.

Table 1: European Countries Indicate Higher Values of μ than Unity

	Dependent variable:			
	ln(1- MTR)			
	Pooling	Within	Pooling–EU27	Within–EU27
	(1)	(2)	(3)	(4)
ln (1-ATR)	1.419*** (0.007)	1.266*** (0.051)	1.419*** (0.008)	1.207*** (0.056)
Observations	4,570	4,570	3,980	3,980
R^2	0.457	0.122	0.478	0.124
Adjusted R^2	0.457	0.060	0.478	0.063
F Statistic	40,920.840*** (df = 1; 4569)	609.002*** (df = 1; 4269)	35,510.870*** (df = 1; 3979)	471.634*** (df = 1; 3719)

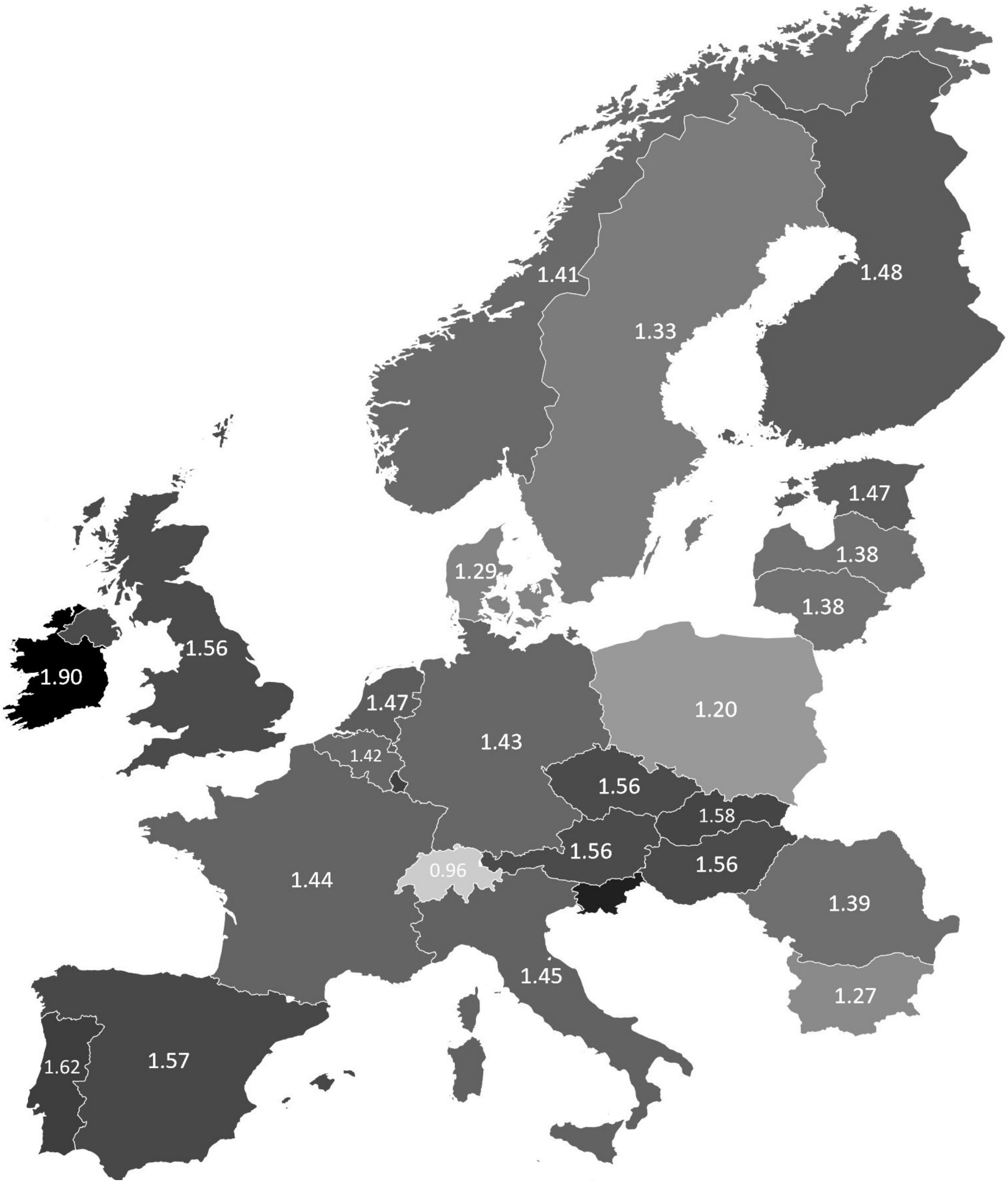
*p<0.1; **p<0.05; ***p<0.01

Note: Fixed Effects on countries and deciles. "Within" is standard FE estimation that considers the differences between deciles, whilst "Pooling" does not allow for the intercept or slope differences among deciles. Pooling and Within EU–27 consider only European Union members.

The following Figure 1 and Figure 2 show the results for all countries in the sample. The parameter μ varies between 0.96 for Switzerland and 1.90 for Ireland with median 47 for Netherlands. In the supplementary materials, we provide additional results to show how μ varies among different income groups and countries. In general, lower income groups yields higher values of μ. On average, the highest $\mu = 2.18$ belongs to 2nd decile, on the other hand, the lowest $\mu = 1.15$ goes to the 10th decile.[8] This is in line with the common sense, that low income groups are more relatively risk averse or they indicate higher intra–generational inequality aversion. However, the results strongly depends on the tax-schedule agreed by the electorate.

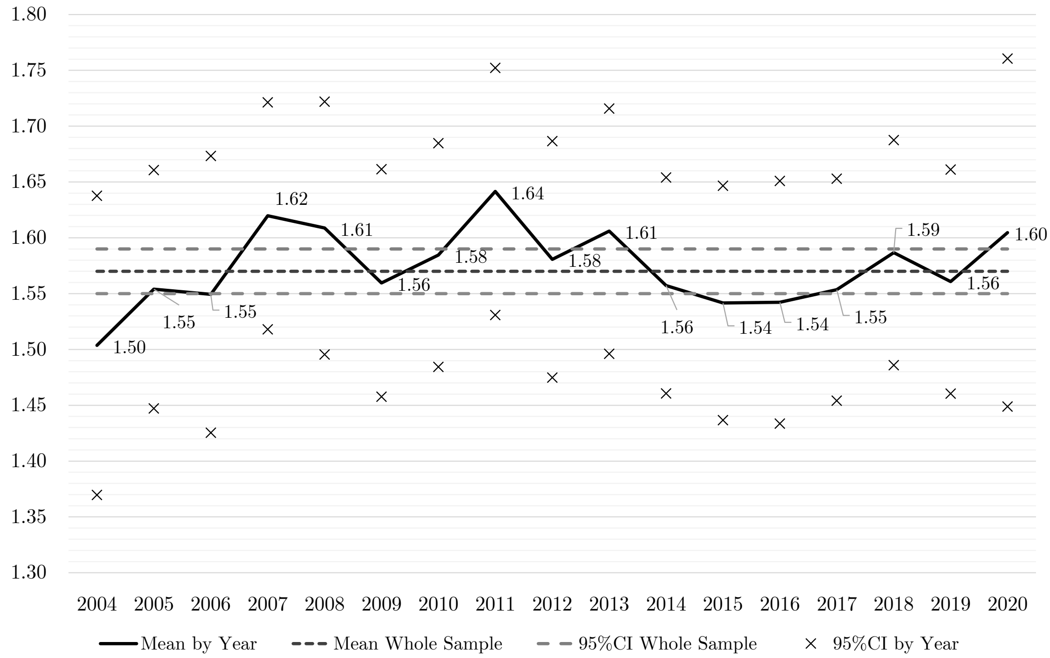
[8]On average, 1st income decile indicates $\mu = 0.85$, however, the result is downward biased due to the fact, that this group pays low taxes thanks to various tax shields and other social benefits.

Figure 1: Ireland and Slovenia Show the Highest Values of μ, Switzerland the Lowest



Note: Slovenia indicates $\mu_{SI} = 1.77$, Luxembourg $\mu_{LU} = 1.61$, Malta $\mu_{MT} = 1.59$, Cyprus $\mu_{CY} = 1.57$, Iceland $\mu_{CY} = 1.40$ and Greece $\mu_{EL} = 1.37$. We use fixed effect pooling method.

Figure 2: μ does not significantly vary within the study period



Note: The estimates are based on computational method.

The results for countries depend on the employed method. We show the estimates in Table A3 in the Appendix. In general, the highest spread of the values of μ indicates the FE within method. Naturally, this method allows the differences in the intercept leading to greater variability. On the other hand, FE pooling, computational and linear regression methods yields comparable results. However, the latter two provide wider confidence intervals. This can be attributed to the omitted variable bias in case of linear regression and the definition of the computed μ itself.

Given the variation of μ among our sample, we explore the correlation between gross household income (INC) and the parameter μ. Specifically, using the panel data and standard linear regression methods with population of each country as weight we estimate the following equation:

$$\mu = \beta * INC_{t,j,c} + \epsilon_{t,j,c}, \forall \{t, j, c\}, \tag{12}$$

where t denotes year, j indicates income decile and c stands for country. Finally, β is the coefficient of our interest and ϵ is the error term. Table 2 shows the results. We do not find economically significant correlation, nevertheless, the results indicate negative correlation between INC and the parameter μ. This is in line with the findings of Kornek, Klenert, Edenhofer, and Fleurbaey (2021).

Table 2: Income does not influence value of μ

	Dependent variable:	
	μ	
	Fixed effect Within	*OLS* Linear Regression
	(1)	(2)
Ln (Pre-tax Income)	-0.048(0.055)	-0.025** (0.011)
Constant		1.769*** (0.112)
Observations	4,570	4,570
R^2	0.0002	0.001
Adjusted R^2	-0.070	0.001
Residual Std. Error		543.906 (df = 4568)
F Statistic	0.775 (df = 1; 4269)	5.353** (df = 1; 4568)

*p<0.1; **p<0.05; ***p<0.01

Note: Fixed Effects on countries and deciles. "Within" is standard FE estimation that considers the differences between deciles. We use natural log transformation for pre-tax income.

To conclude, our results suggest that irrespective of the methods used, the parameter μ is higher than the unity in vast majority of countries. Since the elasticity of marginal utility of consumption, μ, has been assumed often to be one, given our results, most inhabitants in the European region are willing to pay more for reducing uncertainty about the outcome than it has been widely expected in evaluation studies (such as $\mu = 1$).

5 Implications for the Social Discount Rate

The parameter μ affects the value of SDR at least as much as other two components of SDR, ρ and $g(C)$. Given the Ramsey rule $SDR = \rho + \mu g(C_t)$, SDR increases with ρ, $g(C_t)$ and grows with μ if and only if $g(C_t) > 0$. On the other hand, if $g(C_t) < 0$ and $\mu > 0$ it would lower SDR, thus, it works as a corrective to consumption inequality across the generations (Dasgupta, 2008). Importantly, one of the assumptions of the absolute equal sacrifice approach states that only taxpayers should be included in the computation. Therefore, our estimate is most probably biased upwards. Intuitively, it directly comes from the equation 4. The estimate of μ gets non-positive value for non tax payers only, so if we included also individuals who do not pay income taxes, i.e. $T(Y) \leq 0$, μ would get smaller value for the entire population.

The interpretation of the parameter μ in the literature has three options – intra-temporal inequality aversion, inter-temporal inequality aversion or risk aversion. Recent studies are involved in disentangling these three dimensions (Anthoff & Emmerling, 2019; Atkinson et al., 2009; Dasgupta, 2021; Venmans & Groom, 2021). As Anthoff and Emmerling (2019) claim a single parameter cannot represent different degrees of inequality aversion say over time and between countries or regions. However, mostly it depends on the data set and employed approach. Since the fact, that we use the absolute equal sacrifice approach with the iso-elastic utility function we are not able to distinguish between these three dimensions, therefore, our results represent all three dimensions.

Formally, $\mu = 1$ means that any increase in someone's consumption ought to be of equal social worth to that same increase in the consumption of anyone else, richer or poorer, who is a contemporary. Therefore, the higher the μ the lower willingness to substitute consumption inter-temporally. The interpretation in terms of the coefficient of relative risk aversion provide Anthoff et al. (2009) p.2 :'*... μ explains why risk-averse people buy insurance; they are willing to pay a premium that is proportional in first order approximation to the parameter μ to eliminate variability in outcomes because doing so increases their expected utility.*'

In terms of long-term impact assessment, most Integrated Impact Assessment (IAM) models, including DICE, PAGE, FUND, and WITCH have incorporated the pure rate of time preference (PRTP) at 3%, 1% and 0.1%, with 0% used in a sensitivity analysis and $\mu = 1$ or $\mu = 1.5$.[9] In the following Table 3 we provide SDR for countries in our sample based on our estimate of μ. Based on the Eurostat data the average $g(C)$ between 2004–2019 varies between 0.24 for Switzerland and 4.78 for Romania implying SDR in a range of 0.24%–9.83% with regards to frequently used values for PRTP (see Table 3). While SDR of 0.24% may seem too low, SDR at 9.83% seems too high.

[9] Nordhaus (1994) used PRTP at 3% in his DICE model, the Stern Review assumed 0.1%, while Cline et al. (1992) relied on 0% PRTP.

Table 3: Island and Romania achieve the highest SDR

	Country	μ	Conf. Int. 95%	g(C)	PRTP=0%	PRTP=1%	PRTP=3%
1	IE	1.90	(1.75, 2.05)	0.77	1.46	2.46	4.46
2	SI	1.75	(1.67, 1.83)	1.83	3.21	4.21	6.21
3	PT	1.62	(1.54, 1.7)	1.67	2.70	3.70	5.70
4	LU	1.61	(1.47, 1.74)	1.94	3.12	4.12	6.12
5	MT	1.59	(1.5, 1.67)	1.92	3.05	4.05	6.05
6	SK	1.58	(1.45, 1.72)	2.39	3.78	4.78	6.78
7	CY	1.58	(1.46, 1.7)	1.41	2.23	3.23	5.23
8	ES	1.57	(1.5, 1.64)	1.78	2.80	3.80	5.80
9	CZ	1.56	(1.44, 1.67)	1.85	2.88	3.88	5.88
10	AT	1.56	(1.48, 1.63)	1.94	3.02	4.02	6.02
11	UK	1.56	(1.48, 1.63)	1.86	2.90	3.90	5.90
12	HU	1.56	(1.41, 1.7)	3.66	5.69	6.69	8.69
13	FI	1.48	(1.42, 1.55)	1.58	2.34	3.34	5.34
14	NL	1.47	(1.4, 1.54)	1.46	2.15	3.15	5.15
15	EE	1.47	(1.34, 1.6)	3.55	5.22	6.22	8.22
16	IT	1.45	(1.41, 1.5)	1.48	2.15	3.15	5.15
17	FR	1.44	(1.36, 1.52)	1.14	1.64	2.64	4.64
18	DE	1.43	(1.34, 1.51)	1.23	1.76	2.76	4.76
19	BE	1.42	(1.33, 1.52)	1.83	2.61	3.61	5.61
20	NO	1.41	(1.35, 1.48)	1.86	2.63	3.63	5.63
21	IS	1.40	(1.31, 1.48)	4.64	6.48	7.48	9.48
22	RO	1.39	(1.27, 1.51)	4.78	6.65	7.65	9.65
23	LV	1.38	(1.29, 1.47)	4.13	5.72	6.72	8.72
24	LT	1.38	(1.25, 1.51)	3.07	4.22	5.22	7.22
25	EL	1.35	(1.28, 1.42)	1.14	1.54	2.54	4.54
26	SE	1.33	(1.27, 1.4)	1.24	1.65	2.65	4.65
27	DK	1.29	(1.23, 1.36)	1.39	1.80	2.80	4.80
28	BG	1.27	(1.14, 1.39)	2.86	3.62	4.62	6.62
29	PL	1.20	(1.16, 1.24)	2.03	2.44	3.44	5.44
30	CH	0.96	(0.91, 1.02)	0.24	0.23	1.23	3.23
31	Whole sample	1.42	(1.43, 1.41)	2.10	3.09	4.09	6.09
32	EU 27	1.42	(1.44, 1.40)	1.41	2.10	3.10	5.10

Source: Eurostat, Final consumption expenditure of households by consumption purpose (COICOP 3 digit), Data extracted on 06/10/2021.

Note: Results for μ are obtained from fixed effect pooling method. Consumption growth rate $g(C)$ is the average between 2004–2019. Columns PRTP represent SDR for various values of pure rate of time preference.

In the literature we can find the SDR mostly between 1.5% and 5%. Recently, Drupp et al. (2018) report the results from the survey of 200 economists. Almost 90% of them consider the SDR of 1–3% appropriate for long–run projects, while only 9% recommend Nordhaus's value of 4.5% or higher. Similarly, Weitzman (2001) surveyed 50 leading economists resulting in the mean of SDR at 4.09% and std=3.07%. Assuming real growth in per capita consumption at 2 per cent p.a., our result implicates the SDR at 2.84% for PRTP=0% and 3.84% for PRTP=1%.

We find that there is heterogeneity in the elasticity of marginal utility of consumption among European countries and income deciles, but not over the period. Differences across countries reflect taxation regime rather than differences in income level between the countries. Regarding the income level within the country, the elasticity gets higher for lower income groups, reflecting the fact that increasing consumption of a low-income household leads to a disproportionately larger increase in utility compared to increasing consumption of high income households. This has important implication since higher μ results in higher SDR that *'tends to decrease the social cost of carbon in the country with the largest inequality to avoid abatement costs for low-income households and increases the SCC in more equal countries to avoid damages to low-income households in unequal countries.'* (Kornek et al., 2021).

In conclusion, our estimate are close to that of Evans (2005), who analyses μ for 20 OECD countries. His estimate of μ, using the same approach but older data for 2002, varies between 1.20 in Spain and 1.82 in Australia for high income population and 1.00 in Ireland and 1.79 in Austria for low income population. Importantly, the growing number of studies report $\mu > 1$ with the most cited values between 1.3 and 1.6 (Anthoff & Emmerling, 2019; Groom & Maddison, 2019; H.M. Treasury, 1997; Kornek et al., 2021; Venmans & Groom, 2021). As expected, the difference mainly comes from the employed approach. Finally, we conclude that our estimates fits well to the results of the mainstream literature.

6 Conclusion

Based on the individual–level data from the EU-SILC, we use the equal sacrifice approach in its absolute version that relies on social values revealed on tax schedule to elicit the estimate of the elasticity of the marginal utility of consumption, μ. This is the key parameter for deriving the social discount rate used in the welfare and cost-benefit analyses of various social policies. Since we use the tax-schedule data, our results are relevant for a specific population, i.e. the income tax-payers. Although, the parameter may be different for the entire population of a country, our estimate is still suitable for many standard models that contain a representative household.

The central estimate for the European countries covered by our data set is 1.42, which fits into the current stream of literature. The elasticity of marginal utility of consumption varies across the European countries and income deciles, but not over the period. Irrespective of the method used to derive the elasticity, the parameter μ is higher than unity in vast majority of European countries. Between the European countries, μ varies between 0.96 for Switzerland and 1.90 for Ireland with median 1.47 for Netherlands. It seems that these differences reflect country's taxation regime rather than differences in income level between the countries. To certain extent, the results correspond to redistribution of the average tax rate (ATR) between income groups, where Switzerland reveals the most equal redistribution of ATR, while Slovenia reports the most unequal one (Ireland is the second). Furthermore, we show the impact of μ on the final SDR. Assuming the whole sample, for the given PRTP, averaged $g(C)$ and our central estimate of μ, SDR will be 1.42pp greater for every 1pp increase in per capita consumption growth. Thus, assuming $\mu = 1$ would lead to underestimating the cost of projects with a long lifetime or benefits generated in the long-term future.

To sum up, given the variability in interpretation of μ and the difficulty of its estimation, each method might be subject of some criticism. There are three main assumptions in terms of the absolute equal sacrifice approach: it is suitable only for taxpayers, the tax structure is set in the way that each consumer should equally sacrifice, and given the iso-elastic utility function it is possible to aggregate the individuals with various wealth levels into a single representative agent. Further research is needed to validate each assumption. Last, relying on the equal sacrifice approach implies that the resulting estimate of μ represents risk preferences over all three dimensions: intra-temporal inequality aversion, inter-temporal inequality aversion, and risk aversion.

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Disclaimer

This study is based on data from Eurostat, EU SILC release 2 in 2021 (autumn release), UDB – Cross-sectional 2004–2020 and longitudinal data 2004–2020 – version of 2021–9. The responsibility for all conclusions drawn from the data lies entirely with the authors.

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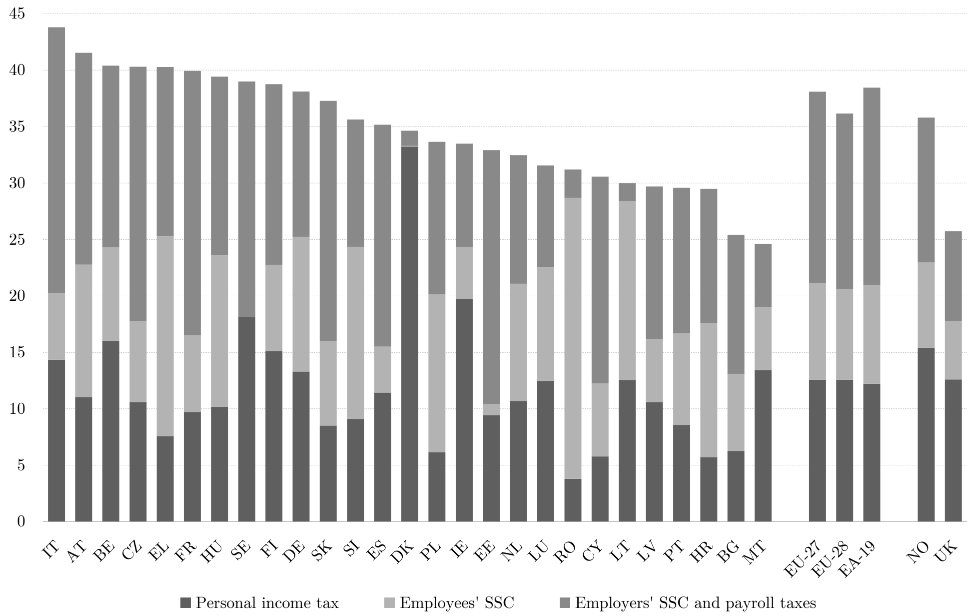
A Appendix

A.1 Descriptive Statistics

All amounts in any currency are stated in nominal values.

Figure A1: Decomposition of Taxes and SHIC in 2019 in % of Gross Income



Source: European Commission, DG Taxation and Customs Union, based on Eurostat data

Note: As for the Switzerland KPMG Switzerland (2021) states that the tax rates for individuals have changed only minimally compared to the previous years and have remained stable with an average maximum tax rate of around 33.75%.

Regarding the development of taxes in European countries we provide some details based on the report from Directorate-General for Taxation and Customs Union (European Commission) (2021). Country notes below are taken from the excel sheet *Statutory tax rates*, which can be found on the European Commission website. Notes are related to the Table A1.

Belgium. Including crisis tax (1993–2002) and (average) local surcharges (Brussels Region rate since 2015). Special social security contributions (capped) are not included.

Bulgaria. The net income of sole proprietors is taxed separately (15% final flat tax – not included in the table).

Czechia. In addition to the flat tax rate (15%), in 2013–2020 a solidarity surcharge (7%) was levied on employment, business and professional income above four times the average wage. The two rates apply to different taxable incomes and therefore cannot be added together. As of 2021, the tax rate is 15%

for the part of the taxable income up to 48 times the average wage and 23% for the part exceeding 48 times the average wage (CZK 1,701,168 represents 48 times the average wage in 2021). For the purpose of income taxes, average wage means the average wage under the act regulating social security premiums.

Denmark. Including local taxes and labour market contribution (8% in 2015–2019) but excluding church tax. The top rate is further capped (at 51.7% in 2013–2014, 51.95% in 2015–2017, 52.02% in 2018, 52.05% in 2019 and 52.06% in 2020), by a decrease in the state tax if needed. The top rate in the table above includes the labour market contribution; for example for 2019 it is calculated as $8\% + (100\% - 8\%) \times 52.05\% = 55.9\%$.

Germany. In addition, a solidarity surcharge of 5.5% of the tax liability is applied, subject to an exemption limit.

Ireland. Including the universal social charge of 8% (for self-employed income in excess of EUR 100 000 it is 11%).

Greece. Including the solidarity contribution for 2011–2016 (for 2011–2014 the rate ranged from 1% to 4%, with the top rate of 4% applicable to net annual income exceeding EUR 100 000). From 2015 the rates changed, to 6% for an annual income of EUR 100 000–500 000 and 8% for income over EUR 500 000. The top-rate calculation for 2015 and 2016 in the table above includes the solidarity contribution for the income band EUR 100 000–500 000 at the rate of 6%. From May 2016 the top PIT rate was increased to 45% and the highest solidarity contribution became 10% for incomes above EUR 200 000. The top-rate calculation for 2017 onward in the above table includes the 10% solidarity contribution for the income band EUR 220 000 and above.

Spain. Regional governments can use their own tax schedules. Up to 2016, this is assumed to have been equal to the central government tax schedule. Since 2017, each autonomous community has applied a different scale, of which currently only one matches the central government tax scale. Therefore, the calculation applies that of the Autonomous Community of Madrid, which is considered the most representative tax scale on various grounds. As a result, the top statutory tax rate decreased in 2017, although the PIT Law tax schedule has remained unchanged.

France. Several contributions are added to PIT, but, while PIT applies to individualised global net personal income, the contributions may vary depending on the income source. The value in the table reflects the top statutory rate for earnings. It includes the top PIT rate (45%), the general social welfare contribution (CSG, applicable rate 9.2%, of which 6.8% is deductible) and the welfare debt repayment levy (CRDS, rate 0.5%). A total of 0.4% of social contributions is deductible from the basis on which PIT is calculated. The 2018 Budget Act introduced the choice between a flat tax and progressive taxation for taxation on capital income. The flat tax on capital income is 30%: 12.8% of income tax and 17.2% of social contributions (without deductible CSG) on capital income (9.9% + 0.5% + 4.5% + 0.3% + 2%). If the taxpayer chooses progressive taxation, then, with CSG (applicable rate 9.9%, of which 6.8% is deductible), CRDS, and additional social and solidarity levies (4.5% + 0.3% and 2%), the top PIT rate becomes $(0.45 \times (1 - 0.068) + 0.099 + 0.005 + 0.045 + 0.003 + 0.02) \times 100 = 59.1\%$. The exceptional contribution for incomes above EUR 250 000 is not shown in the table.

Croatia. Including average crisis tax (2009–2011) and surtax for Zagreb (maximal local surtax rate of 18%).

Italy. Including regional and municipal surcharges (values given for Rome) and, from 2011 to 2016, 3% solidarity contribution (deductible from the tax base). The increases of 0.5% in 2014 and of 1% in 2015 correspond to increases in the Lazio regional surcharge.

Cyprus. Not including the (tax-deductible) special contribution on gross wages (2012–2016) of up to 3.5% (up to 4% for (semi-)public employees).

Latvia. From January 2018, the previous 23% flat rate was replaced by three progressive rates: 20%, 23% and 31.4% (the third rate, 31.4%, is designed as a conditional rate, and it will be calculated only after submission of the annual tax declaration; the PIT part of the solidarity tax is included). From 2021, the third rate is set at 31.0%.

Luxembourg. Including crisis contribution in 2011 and solidarity surcharge for the unemployment fund (since 2002) of 9% (for top incomes), but not the Impot d'équilibrage budgétaire temporaire of 0.5% between 2015 and 2016 (which is added to the social security contributions). Since 1 January 2017, there has been a new rate of 42% for incomes over EUR 200 004. In 2021, the solidarity surcharge is at 9%.

Hungary. Including solidarity tax (2007–2009). In 2010–2012, rates included the effect of a base-increasing component, which was applicable in 2010 and 2011 to total earnings, and in 2012 to the part of monthly earnings above HUF 202 000 (EUR 653), roughly the average wage, leading to a two-rate system: 16% and 20.3%. In 2013, the base-increasing component was phased out and the 16% tax rate applied to all income. From 2016, this was reduced to 15%.

Austria. A rate of 55% on taxable income over EUR 1 000 000. This rate is only for 2016–2021.

Portugal. Including a surcharge levied on all aggregated categories of income (3.5% from 2013 to 2016, 3.21% in 2017, phased out in 2018), and an additional solidarity surcharge (top rate 5% since 2013). (The special rate of 60% applied to unjustified increases in personal wealth (above EUR 100 000) is not included.)

Finland. Including general government taxes plus (average of) municipality taxes. Variation to be attributed to variations in average local taxes.

Sweden. Including general government taxes plus (average of) municipality taxes. Variation to be attributed to variations in average local taxes.

Iceland. Including surcharges when appropriate and (average of) municipality taxes. The lump-sum taxes for the elderly fund and radio broadcast services are excluded.

Norway. Including the 12% surtax up to 2015. In 2016, the surtax was replaced by a bracket tax, the top rate of which in 2019 was 16.2% for 'person income' (essentially gross labour and pension income) above NOK 964 800.

United Kingdom. Rates given are rates for the fiscal year starting in April. An additional higher rate of 50% was introduced for income exceeding GBP 150 000 from the 2010–2011 fiscal year, cut to 45% as of 2013.

Table A1: The Maximum PIT Trends in % of Gross Income

	Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	Belgium	53.65	53.65	53.70	53.70	53.70	53.73	53.73	53.73	53.74	53.76	53.77	53.72	53.19	53.15	53.15	53.14	53.14
2	Bulgaria	29.00	24.00	24.00	24.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
3	Czechia	32.00	32.00	32.00	32.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
4	Denmark	62.28	62.28	62.28	62.28	62.28	62.15	55.38	55.38	55.38	55.56	55.56	55.79	55.80	55.80	55.90	55.90	55.90
5	Germany	47.48	44.31	44.31	47.48	47.48	47.48	47.48	47.48	47.47	47.47	47.47	47.47	47.47	47.47	47.47	47.47	47.47
6	Estonia	26.00	24.00	23.00	22.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	20.00	20.00	20.00	20.00	20.00	20.00
7	Ireland	42.00	42.00	42.00	41.00	41.00	46.00	47.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00	40.00
8	Greece	40.00	40.00	40.00	40.00	40.00	40.00	49.00	49.00	49.00	46.00	46.00	48.00	48.00	55.00	55.00	55.00	54.00
9	Spain	45.00	45.00	45.00	43.00	43.00	43.00	43.00	45.00	52.00	52.00	52.00	45.00	45.00	43.50	43.50	43.50	43.50
10	France	53.36	53.47	45.44	45.44	45.44	45.44	45.44	46.56	50.32	50.32	50.25	50.23	50.21	50.19	51.46	51.46	51.46
11	Croatia	53.10	53.10	53.10	53.10	53.10	56.10	50.15	47.20	47.20	47.20	47.20	47.20	47.20	42.48	42.48	42.48	42.48
12	Italy	46.10	44.10	44.10	44.90	44.90	44.90	45.20	47.30	47.30	47.30	47.80	48.80	48.80	47.23	47.23	47.20	47.20
13	Cyprus	30.00	30.00	30.00	30.00	30.00	30.00	30.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
14	Latvia	25.00	25.00	25.00	25.00	25.00	23.00	26.00	25.00	25.00	24.00	24.00	23.00	23.00	23.00	31.40	31.40	31.40
15	Lithuania	33.00	33.00	27.00	27.00	24.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	27.00	32.00
16	Luxembourg	38.95	38.95	38.95	38.95	38.95	39.00	39.00	42.14	41.34	43.60	43.60	43.60	43.60	45.78	45.78	45.78	45.78
17	Hungary	38.00	38.00	36.00	40.00	40.00	40.00	40.60	20.30	20.30	16.00	16.00	16.00	15.00	15.00	15.00	15.00	15.00
18	Malta	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
19	Netherlands	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	51.95	51.75	49.50
20	Austria	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
21	Poland	40.00	40.00	40.00	40.00	40.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
22	Portugal	40.00	40.00	42.00	42.00	42.00	42.00	45.88	50.00	49.00	56.50	56.50	56.50	56.50	56.21	53.00	53.00	53.00
23	Romania	40.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	10.00	10.00	10.00
24	Slovenia	50.00	50.00	50.00	41.00	41.00	41.00	41.00	41.00	41.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
25	Slovakia	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
26	Finland	52.12	51.00	50.90	50.45	50.05	49.09	48.98	49.17	49.00	51.13	51.49	51.59	51.60	51.41	51.11	51.11	51.11
27	Sweden	56.50	56.60	56.60	56.55	56.44	56.52	56.56	56.55	56.60	56.73	56.86	56.99	57.10	57.10	57.10	57.19	52.28
28	Iceland	43.58	41.73	38.72	35.72	35.72	45.20	46.12	46.21	46.24	46.22	46.24	46.24	46.25	46.25	46.25	46.20	46.24
29	Norway	47.50	43.50	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	39.00	39.00	38.70	38.52	38.40	38.20	38.20
30	United Kingdom	40.00	40.00	40.00	40.00	40.00	40.00	50.00	50.00	50.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00
31	EU-27	41.83	40.46	39.90	39.70	38.38	37.94	38.13	37.92	38.25	38.95	38.98	38.77	38.72	38.75	38.76	39.20	38.79
32	EU-28	41.77	40.45	39.91	39.71	38.44	38.01	38.55	38.35	38.67	39.16	39.20	39.00	38.95	38.98	38.98	39.41	39.01
33	EA-19	40.98	40.55	39.86	39.36	39.13	38.77	39.67	40.60	41.06	42.27	42.31	42.00	41.97	42.26	42.58	43.20	42.87

Source: European Commission, DG Taxation and Customs Union, Taxes in Europe Database and KPMG and IBFD data.

Table A2: Social Contributions as a share of Total Tax Revenue

	Country	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Difference 2009-2019 (pp)	Ranking 2019	Revenue 2019 (million EUR)
1	EU-27	13.67	14.09	14.83	14.62	14.59	14.58	14.61	14.54	14.49	14.63	14.55	14.55	14.58	-0.20		815664.40
2	EU-28	12.75	13.19	14.02	13.74	13.72	13.68	13.70	13.58	13.46	13.66	13.66	13.67	13.73	-0.30		885458.30
3	EA-19	14.48	14.94	15.71	15.57	15.50	15.46	15.50	15.43	15.34	15.51	15.38	15.04	15.01	-0.70		724778.20
4	Belgium	12.07	12.27	13.02	12.62	12.43	12.28	12.13	12.09	12.23	12.26	12.08	12.09	12.37	-0.60	14.00	25663.00
5	Bulgaria	7.75	9.20	10.57	9.24	9.43	10.49	10.35	10.89	10.67	10.58	11.06	11.40	11.59	1.00	15.00	2147.80
6	Czechia	15.86	16.10	16.21	15.92	15.48	15.34	15.07	15.29	15.07	14.97	14.89	15.09	15.24	-1.00	13.00	12313.30
7	Denmark	0.13	0.11	0.11	0.11	0.13	0.12	0.10	0.07	0.09	0.08	0.07	0.08	0.06	0.00	27.00	91.60
8	Germany	22.19	21.93	23.24	23.33	22.92	22.70	22.62	22.64	22.50	22.57	22.66	22.61	22.46	-0.70	5.00	312504.00
9	Estonia	0.96	1.06	2.02	2.80	2.77	2.74	2.14	2.07	1.73	1.69	1.71	1.69	1.67	-0.30	25.00	155.70
10	Ireland	3.86	4.50	7.38	7.57	8.58	8.21	7.74	7.19	7.00	6.79	6.61	6.75	6.69	-0.70	24.00	5271.90
11	Greece	18.13	17.90	17.94	18.36	17.53	17.03	16.85	16.45	17.20	17.11	17.53	16.53	16.68	-1.20	9.00	12080.00
12	Spain	8.63	10.09	11.98	11.17	11.28	11.03	10.24	10.05	9.54	9.43	9.28	9.07	9.30	-2.70	22.00	40253.00
13	France	11.80	11.76	12.33	12.15	11.76	11.71	11.88	12.02	11.99	12.02	11.91	10.44	10.35	-2.00	18.00	114341.00
14	Croatia	15.10	15.10	15.72	15.66	16.13	15.93	15.65	15.63	14.95	15.50	15.66	15.67	15.56	-0.10	12.00	3250.90
15	Italy	9.18	10.00	9.90	9.75	9.74	9.65	9.88	9.81	10.02	10.06	10.09	10.26	10.36	0.50	17.00	78373.00
16	Cyprus	6.07	6.39	7.92	8.09	8.00	7.86	7.64	7.89	8.02	8.09	8.23	8.25	9.69	1.80	20.00	767.60
17	Latvia	7.67	7.86	9.26	7.80	9.15	9.01	8.12	8.62	8.17	6.98	7.66	8.89	9.32	0.00	21.00	874.80
18	Lithuania	5.30	5.30	13.45	14.79	14.35	13.44	13.35	13.24	13.10	13.22	13.30	13.59	29.58	16.10	2.00	4346.60
19	Luxembourg	15.76	16.29	17.13	16.49	16.59	16.57	16.70	16.41	17.05	16.67	16.70	15.86	16.12	-1.00	10.00	4008.20
20	Hungary	9.88	9.77	9.82	11.34	14.21	14.06	14.15	13.67	13.56	13.90	15.00	15.61	15.80	6.00	11.00	8416.30
21	Malta	9.42	9.84	9.68	9.64	9.89	9.67	9.43	9.10	9.13	9.04	8.86	9.01	8.93	-0.80	23.00	374.30
22	Netherlands	23.27	24.73	23.06	23.51	25.19	26.71	27.52	25.47	24.13	24.74	22.48	22.43	20.58	-2.50	6.00	65588.00
23	Austria	17.61	17.46	18.30	18.09	18.02	17.86	18.00	18.02	17.87	18.43	18.49	18.37	18.45	0.10	7.00	31259.90
24	Poland	20.85	19.76	21.14	20.00	21.00	22.36	23.31	22.73	23.26	23.21	22.69	22.67	22.96	1.90	4.00	43018.00
25	Portugal	11.36	11.82	12.86	12.19	11.74	11.61	11.04	11.50	11.30	11.38	11.38	10.80	11.07	-1.80	16.00	8169.30
26	Romania	12.40	12.11	13.26	12.02	12.21	11.59	11.12	11.06	10.96	12.02	12.76	36.16	36.74	23.40	1.00	21343.10
27	Slovenia	23.93	24.72	26.57	26.63	26.71	26.81	26.52	26.41	26.37	26.18	26.29	26.12	26.54	-0.10	3.00	4805.70
28	Slovakia	18.21	17.76	19.72	18.87	18.97	19.57	18.77	18.06	17.68	18.58	17.90	17.63	17.21	-2.50	8.00	5557.20
29	Finland	7.32	7.08	7.82	8.66	8.26	8.90	8.73	9.03	9.14	9.32	9.71	10.11	10.23	2.40	19.00	10385.00
30	Sweden	0.20	0.20	0.20	0.21	0.21	0.20	0.19	0.19	0.18	0.16	0.15	0.15	0.15	-0.10	26.00	305.20
31	Iceland	0.19	0.18	0.23	0.30	0.28	0.26	0.25	0.23	0.23	0.16	0.21	0.21	0.21	0.00		15.90
32	Norway	8.10	8.12	9.09	8.73	8.76	8.87	9.37	10.35	11.18	11.38	11.07	10.58	10.98	1.90		15860.90
33	United Kingdom	7.69	7.65	8.18	7.89	7.83	7.87	7.65	7.58	7.69	7.72	7.83	7.83	8.20	0.00		69793.90

Source: European Commission, DG Taxation and Customs Union, Taxes in Europe Database

A.2 Definition of the Variables

Definitions are taken from the Eurostat variable description. The code in abbreviation refers to the column in the data set.

Gross HH income (HY010): The sum for all household members of gross personal income components (gross employee cash or near cash income (PY010G); gross non-cash employee income (PY020G); employers' social insurance contributions (PY030G); gross cash benefits or losses from self-employment (including royalties) (PY050G); value of goods produced for own consumption (PY070G); unemployment benefits (PY090G); old-age benefits (PY100G); survivor' benefits (PY110G), sickness benefits (PY120G); disability benefits (PY130G) and education-related allowances (PY140G)) plus gross income components at household level; income from rental of a property or land (HY040G); family/children related allowances (HY050G); social exclusion not elsewhere classified (HY060G); housing allowances (HY070G); regular inter-household cash transfers received (HY080G); interests, dividends, profit from capital investments in unincorporated business (HY090G); income received by people aged under 16 (HY110G)) less interest paid on mortgage (HY100G).

Taxes and social and health insurance contribution (SHIC; HY140G + HY120G):

Taxes on income include: Taxes on individual, household or tax-unit income (income from employment, property, entrepreneurship, pensions, etc.), including taxes deducted by employers (pay-as-you earn taxes), other taxes at source and taxes on the income of owners of unincorporated enterprise paid during the income reference period.

By way of exception, Member States using data from registers and other Member States, for which this is the most suitable way, can report taxes on 'income received' in the income reference year, if it only marginally affects comparability.

Tax reimbursement received during the income reference period related to tax paid for the income received during the income reference period or for income received in previous years. This value will be taken into account as a reduction of taxes paid. Any interest charged on arrears of taxes due and any fines imposed by taxation authorities

Taxes on income exclude: Fees paid for hunting, shooting and fishing.

Social insurance contributions refers to employees', self-employed and if applicable unemployed, retirement and so on contributions paid during the income reference period to either mandatory government or employer-based social insurance schemes (pension, health, etc.).

A.3 Additional Results

Table A3: Estimated Results by Country with all Methods

	Panel data, within	95_low_w	95_high_w	Panel data, pooling	95_low_p	95_high_p	Computed (BootStrap CI)	95_low_c	95_high_c	Linear regression (BootStrap CI)	95_low_l	95_high_l	Number of Years	Observations	Missing Years	Excluded Observations
IE	2.99	2.09	3.89	1.90	1.75	2.05	2.24	1.80	2.59	2.25	1.82	2.75	16.00	51415.00	1.00	30260.00
SI	2.07	0.75	3.39	1.75	1.67	1.83	1.94	1.54	2.54	1.96	1.71	2.20	16.00	136877.00	1.00	5780.00
PT	2.22	1.62	2.83	1.62	1.54	1.70	1.69	1.33	1.85	1.71	1.46	1.98	13.00	91747.00	4.00	25199.00
LU	2.87	1.69	4.04	1.61	1.47	1.74	1.55	1.33	1.70	1.57	1.21	2.01	16.00	65176.00	1.00	743.00
MT	1.23	0.28	2.19	1.59	1.50	1.67	1.76	1.30	2.30	1.75	1.50	2.04	14.00	49333.00	3.00	5786.00
SK	1.27	0.86	1.68	1.58	1.45	1.72	1.99	1.36	3.16	1.90	1.48	2.41	16.00	83998.00	1.00	2440.00
CY	2.01	1.45	2.58	1.58	1.46	1.70	1.70	1.38	1.87	1.72	1.34	2.03	16.00	55845.00	1.00	8245.00
ES	1.45	0.69	2.20	1.57	1.50	1.64	1.58	1.29	1.74	1.57	1.35	1.78	15.00	171093.00	2.00	56335.00
CZ	1.14	0.34	1.95	1.56	1.44	1.67	1.83	1.50	2.57	1.81	1.33	2.23	16.00	120468.00	1.00	16392.00
AT	2.21	0.77	3.65	1.56	1.48	1.63	1.63	1.42	2.00	1.62	1.46	1.84	17.00	97762.00	0.00	3059.00
UK	1.52	1.00	2.03	1.56	1.48	1.63	1.54	1.03	1.75	1.54	1.37	1.73	14.00	130514.00	3.00	11695.00
HU	1.55	0.78	2.33	1.56	1.41	1.70	1.62	1.34	1.91	1.58	1.13	2.13	16.00	108788.00	1.00	30451.00
FI	0.79	0.33	1.24	1.48	1.42	1.55	1.65	1.38	1.91	1.61	1.46	1.79	17.00	175869.00	0.00	2216.00
NL	1.84	1.33	2.34	1.47	1.40	1.54	1.51	1.34	1.85	1.51	1.37	1.66	15.00	161240.00	2.00	624.00
EE	1.07	0.40	1.74	1.47	1.34	1.60	1.44	0.89	1.93	1.43	1.02	1.92	17.00	79584.00	0.00	12788.00
IT	0.80	-0.04	1.64	1.45	1.41	1.50	1.45	1.25	1.56	1.44	1.33	1.56	13.00	250394.00	4.00	79624.00
FR	1.07	0.24	1.91	1.44	1.36	1.52	1.58	1.38	2.00	1.58	1.37	1.80	13.00	143575.00	4.00	31455.00
DE	0.96	0.04	1.89	1.43	1.34	1.51	1.48	1.23	1.77	1.48	1.33	1.65	15.00	183878.00	2.00	13757.00
BE	1.19	0.19	2.20	1.42	1.33	1.52	1.59	1.33	1.89	1.59	1.37	1.84	17.00	87105.00	0.00	15774.00
NO	4.29	3.20	5.38	1.41	1.35	1.48	1.52	1.30	1.82	1.52	1.39	1.66	17.00	98722.00	0.00	3002.00
IS	0.71	-0.19	1.61	1.40	1.31	1.48	1.47	1.23	1.56	1.46	1.28	1.71	15.00	43841.00	2.00	278.00
RO	1.48	1.09	1.87	1.39	1.27	1.51	1.60	1.18	2.40	1.63	1.21	2.02	14.00	99918.00	3.00	5827.00
LV	0.31	-0.74	1.36	1.38	1.29	1.47	1.58	1.18	2.32	1.53	1.24	1.84	14.00	75684.00	3.00	15101.00
LT	1.35	0.78	1.92	1.38	1.25	1.51	1.48	1.26	1.70	1.49	1.15	1.90	16.00	56994.00	1.00	23064.00
EL	0.64	0.44	0.84	1.35	1.28	1.42	1.49	1.31	1.62	1.33	1.15	1.60	14.00	161185.00	3.00	22636.00
SE	1.72	1.40	2.05	1.33	1.27	1.40	1.36	1.19	1.68	1.37	1.27	1.49	16.00	100879.00	1.00	1529.00
DK	1.21	0.69	1.73	1.29	1.23	1.36	1.31	1.08	1.50	1.31	1.19	1.43	17.00	99159.00	0.00	581.00
BG	1.13	0.59	1.66	1.27	1.14	1.39	1.46	1.08	1.93	1.42	1.04	1.72	14.00	74086.00	3.00	9989.00
PL	1.71	1.14	2.29	1.20	1.16	1.24	1.20	1.07	1.27	1.20	1.11	1.29	15.00	206642.00	2.00	3133.00
CH	-0.31	-1.27	0.64	0.96	0.91	1.02	0.96	0.78	1.06	0.96	0.86	1.07	13.00	94678.00	4.00	134.00

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