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Elasticity of Marginal Utility of Consumption: The Equal-Sacrifice Approach Applied for the Czech Republic

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Abstract:
We provide the first estimate of the elasticity of marginal utility of consumption, η, for a post-transition economy in the Central & Eastern European region, the Czech Republic, based on individual-level data. The parameter η is a crucial component of the social discount rate (SDR), which determines the inter-temporal allocations that are acceptable to society. Using the equal-sacrifice income tax approach, we obtain a central estimate of η at 1.34, which varies between 1.24 and 1.42 within the study period that covers 2005-2019. Moreover, the estimate of elasticity of marginal utility of consumption differs between various income groups and employment status. Importantly, the magnitude of η estimate depends on whether social benefits are included into gross income or social and health insurance payments are included in the definition of taxes. Our results suggest that SDR for the Czech Republic may be around 3–5 percent for a reasonable pure rate of time preference and positive forecast for per capita consumption growth.

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

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1. Introduction

Estimation of the social welfare of policy measures represents one of the most important tasks for economists and policy makers. The welfare estimation has remarkable implications for the allocation of funds to various social projects. The efficiency of such social projects is usually evaluated through cost-benefit analysis (CBA). The key aspect of the estimation of social welfare lies in determining the social discount rate (SDR), which states the rate at which society is willing to accept the inter-temporal trade-offs of consumption. Therefore, the higher the value of SDR, the lower the present value of costs and benefits that will occur at a later date. Furthermore, SDR has an enormous impact on the speed at which social projects (such as energy transition, climate change mitigation or other environmental policies) should achieve their objectives. In order to compute SDR, (Ramsey, 1928) suggested using the following formula known as the Ramsey rule:[1]

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

where r is the social rate of return, ρ is the rate of pure time preference, $g(C)$ is the real growth rate of per capita consumption and μ is the elasticity of marginal utility of consumption. The term μ measures the responsiveness of the agent's marginal utility to changes in consumption and is sometimes also referred to as the elasticity of marginal felicity (Dasgupta, 2008). In the literature (Evans, 2005; Groom & Maddison, 2019), the right hand side of the Ramsey rule is referred to as a risk-free social rate of time preference (SRTP) and is commonly used as SDR in public project appraisal.

The pure rate of time preference (PRTP), ρ, is intuitively defined as the marginal rate of substitution between present and future consumption, assuming that the consumption levels are equal in both periods (Anthoff et al., 2009). PRTP is also known as the social rate of time preference, utility discounting, or 'normal' discount rate in the discounted utilitarian approach (Heal, 2005). PRTP is the rate at which we discount the welfare of future people just because they are in the future and it is, as noted by Heal (2009), the rate of intergenerational discrimination. The larger ρ, the larger SDR and larger PRTP would imply an ethical preference for greater inequality in consumption across the generations. In other words, while ρ =0 infers that there is equal weight given to all generations that would imply a dictate of future generations, $\rho \to \infty$ would imply a dictate of the present generation. Typically, the value of ρ in the global impact assessment studies equals 3%, 1%, 0%, or a near-zero rate of time preference as in the case of the 2006 Stern Review on the Economics of Climate Change (Dasgupta, 2021; Tol, 2013).[2]

[1] See Groom and Maddison (2019) chapter 2 for references about using the Ramsay rule in the context of a public project.

[2] Nordhaus's DICE model used 3% of pure rate of time preference (Nordhaus, 1994), the Stern Review relied on 0.1% (Stern, 2006), while Cline (1992) assumed 0% PRTP.

Per capita consumption growth rate, $g(C)$, does not need any deeper explanation. It is worth noting, however, that while ρ is exogenous to the welfare assessment, i.e., ρ is independent of time, g(C) is a function of consumption that varies over time, and hence it is endogenous in the impact assessment evaluation.

The elasticity of marginal utility of consumption, μ, attracts various economic interpretations: μ refers to intra-temporal inequality aversion, inter-temporal inequality aversion or risk aversion (Dasgupta, 2008; Drupp et al., 2018; Sælen et al., 2009).[3] Given these various interpretations of the parameter μ, there are different methods of its estimation. In general, the parameter μ can be estimated relying on indirect behavioural evidence, social values revealed through acceptance of tax schedules, or survey data that contain information about felicity (Evans, 2005).[4] For instance, Chetty (2006) employs indirect behavioural evidence and develops a new method of estimating μ using data on labour supply behaviour.[5] Groom and Maddison (2019) use both the indirect behavioural approach and revealed social values to derive μ with the equal-sacrifice income tax approach, the Frisch additive-preferences approach, risk aversion in insurance markets, and the Euler-equation approach (the only one belonging to the indirect behavioural approach).

In this study, we ask several research questions: First, what is the value of the elasticity of marginal utility of income for the Czech Republic? Does the magnitude of its estimate vary over time and across individuals, grouped by income levels and employment status in particular? Is our estimate in line with the estimates coming from elsewhere? And, last, what is the implication of our research on the value of the social discount rate?

To answer these questions, this study focuses on a robust estimation of the parameter μ for the Czech Republic using income tax schedules and relying on one of the revealed social values methods, namely the equal-sacrifice approach. We utilize individual-level data from Statistics on Income and Living Conditions (SILC) covering the period of 2005-2019. Given the structure of the dataset, the tax-based equal-sacrifice approach is the most appropriate method for this study. As far as we know, this is the first study that estimates the parameter μ using micro-level data to estimate the elasticity of marginal utility of consumption for the representative population over several years and for several income groups and household segments defined by employment status. Our study also contributes to the literature by providing the first robust estimate of the parameter μ for a post-transition country.

Our central estimate of the elasticity of marginal utility of consumption is 1.34, and the 95% confidence interval exceeding unity is in line with other studies. With a few exceptional cases, all our

[3]The elasticity of marginal utility of consumption is also known as the elasticity of marginal well-being with respect to per capita consumption or the elasticity of marginal felicity (Dasgupta, 2008, 2021).
[4]In his study, Evans (2005) recognizes the survey method as a unique approach to elicit μ, but a survey method is more of a way to obtain data than an approach itself.
[5]The method was extended by (Asplund, 2017), who includes household production.

estimates derived for various years and for different segments lie above the unity and there is none greater than 1.6, with most in the range of 1.2 to 1.4. Our findings are in line with estimates from other studies, particularly with those that applied the same approach. The parameter μ affects the value of SDR at least as much as other two components of SDR, ρ and g(C). Based on our study estimate, we recommend the social discount rate of around 3–5 percent for a cost-benefit analysis of medium- and long-term projects or policies implemented in the Czech Republic.

The paper is organized as follows: Section 2 provides the literature background. Section 3 describes the employed methodology and data. Section 4 shows the results. In Section 5, we discuss our findings and provide the implication for policy-makers. Finally, Section 6 offers concluding remarks and a potential direction for further research.

2. The elasticity of marginal utility of consumption in the literature

There are two established approaches to estimate the parameter μ: revealed social values and indirect behavioural evidence that may also include stated preference techniques.[6] Given these various approaches, we can see a disagreement on the value of μ. There are also different interpretations of this parameter; the elasticity may indicate intra-temporal inequality aversion, inter-temporal inequality aversion or risk aversion (Dasgupta, 2008; Drupp et al., 2018). The appropriate value of μ is usually discussed in terms of welfare evaluation of policies with long-lasting effects, such as climate change mitigation, energy transition or use of natural capital and the optimal setting of these policies (Cowell & Gardiner, 1999; Nordhaus, 2017; Stern, 2006).

One of the main sources of disagreement comes from the concern about appropriate information used to calibrate SDR, i.e., whether normative/prescriptive views or positive/descriptive views are employed. Arrow et al. (2013) provide conclusions from the views of the panel of twelve economists on the topic of discount rate. Those in favour of a normative approach argue that the parameters of SDR could be based mainly on ethical aspects. On the other hand, those who prefer a descriptive approach (for example by inferring the value of μ from the progressivity of the income tax structure) argue that SDR should reflect the preferences observed in society (Groom & Maddison, 2019). Our study favours the positive view; thus, we derive μ from the income tax structure in the Czech Republic.

Formally, the elasticity of marginal utility of consumption with respect to level of consumption C is defined as

[6] As we noted earlier, the third 'direct survey' method as classified by Evans (2005) is more of a way to gather data than an approach itself.

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

and hence μ is a measure of the curvature of utility, U(C). Typically, μ is independent of the reference consumption path, C(t), although there is no obvious reason why it should be so (Dasgupta, 2008). As a standard, for the class of utility functions for which μ is constant, the larger μ, the greater is the curvature of U(C). For the typical specification of the utility, U(C) is bounded above but unbounded below if $\mu > 1$, while it is opposite if $\mu < 1$. Most studies that have quantified global climate change impacts assume $\mu = 1$; however, there is a growing number of studies that rely on the elasticity of marginal utility of consumption above the unity (e.g., Cline (1992) assumed $\mu = 1.5$).

What value of the elasticity of marginal utility with respect to consumption is provided by the literature? Let us focus on studies that use the income tax-based method, i.e. the equal-sacrifice approach, to elicit the value of μ. In his study, Stern (1977) used income tax data for the UK and suggests the value of μ around 2, but ranging between 1 and 10. Cowell and Gardiner (1999) suggest μ between 1.28 and 1.41 based on income tax data for 1999 again from the UK, depending on the inclusion of National Insurance Contribution (NIC). In a recent study, Groom and Maddison (2019) use the income tax schedule in the UK between 2000 and 2010 and derive μ between 1.27 and 1.63 (depending on the inclusion of NIC).

Evans (2005) derived the parameter μ for 20 OECD countries. Similarly, he uses the income tax-based method and suggests μ equal to 1.40 for high income levels and 1.08 for low earnings in the UK. The average value of μ for the 20 OECD countries is 1.42 for high earnings and 1.34 for low earnings, with median values 1.39 and 1.34, respectively. In all 40 cases, the lowest value of the elasticity is 1.00 (for Ireland) and the highest is 1.82 (for Australia). The average over both low and high wage levels is 1.4 and, based on the pooled income regression for the preferred restricted model, the lower and upper 95% confidence limits for average μ are 1.21 and 1.51 (Evans, 2005).

The issue whether or not to include NIC has not been fully resolved in the literature. Evans (2005), for example, does not include NIC in his calculation. He argues that only income tax fully corresponds to the equal absolute sacrifice assumption, which is the major one when using the income tax-based method. Reed and Dixon (2005) share the opposite view, claiming there is no difference between NIC and income tax, and thus, both should be included in the computation. In line with this argument, we admit that both the social and/or health insurance contributions (SHIS) and personal income tax (PIT) are in most cases based on gross earnings and their magnitude may be given artificially depending on how these two are constructed within general labour taxation legislation. Nevertheless, the Czech Republic is considered to have one of the highest social and health insurance contributions in the European Union (OECD, 2020), and for that reason it is important to examine how the inclusion of

SHIS affects the magnitude of the parameter μ.[7] Therefore, we perform a sensitivity analysis and estimate μ when social and health insurance payments are omitted, as Groom and Maddison (2019) do in their study.

Another method of eliciting the elasticity of marginal utility of consumption employs a direct survey method to gather the data. These estimates are highly sensitive to the nature of questions as well as the sample definition. Barsky et al. (1997) surveyed 11,707 middle-aged respondents in US to elicit measures of risk tolerance, the elasticity of intertemporal substitution, and time preference. They find that there is substantial heterogeneity in these preference parameters. In their study, they report the mean of the coefficient of relative risk aversion between 0.7 and 15.8, with the average at about 4.0. Other studies using the direct survey method are, for example, Gollier (2006) and Drupp et al. (2018), who estimate the value of μ between 1.3 and 4.

The indirect behavioural evidence approach was theoretically set out by Cowell and Gardiner (1999). They suggest that estimates of μ can be derived from the saving decisions of individual households. Thus, households are optimising their consumption over time to maximise their multiperiod discounted utility function subject to an intertemporal wealth constraint. Using this approach, Evans and Sezer (2002) estimate the value of μ of 1.60 by employing data on the UK's households between 1967 and 1997. A basic model of the Euler equation for consumption gives the estimate for the UK using FES data for 1970-1986 of 1.20-1.40 (Blundell et al., 1994). The recent study by Groom and Maddison (2019) suggests μ of 1.58 for the UK with confidence interval 1.18-2.00 when using quarterly data from 1975 to 2011 from the Office for National Statistics and the Bank of England websites.

Using the dataset from the Czech Statistical Office, which covers individual-level data on the gross income and tax structure of every member of the household, we take the approach based on revealed social values. More specifically, in our study we employ the most appropriate method of income tax schedules: the equal-sacrifice approach.

3. Estimating μ Using Income Tax Schedules: The Equal-Sacrifice Approach

Methodology

We estimate μ using the concept of revealed social values. For this concept, we employ information on the progressivity of income tax schedule, as was used in other studies (Cowell & Gardiner, 1999; Evans, 2005; Evans & Sezer, 2002; Groom & Maddison, 2019). The main reason for using the

[7] Although NIC differs in its structure from Czech social and health insurance contributions (SHIS), the main principle is the same and therefore we do not distinguish between NIC and SHIS when comparing the results for the Czech Republic and the UK.

income tax schedule to estimate the value of μ lies in the argument that the electorate has agreed on the tax structure such that each consumer should equally sacrifice (Groom & Maddison, 2019). Consequently, this approach requires the use of the iso-elastic utility function, and thus the fraction of wealth optimally placed in the risky option is independent of the level of initial wealth.[8] This is an important feature, because we can aggregate individuals with different wealth levels into a single representative agent with the same utility function. Using these assumptions, we obtain the following (Evans, 2005):

$$(1) \qquad U(Y) - U\big(Y - T(Y)\big) = k$$

where k is a constant, Y is gross income, U denotes the utility function and $T(Y)$ is the total tax liability. Assuming iso-elastic form of the utility function

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

and substituting (2) into (1) we obtain the following equation

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

Taking derivative with respect to Y we obtain

$$(4) \qquad Y^{-\mu} - \big(Y - T(Y)\big)^{-\mu}(1 - MTR) \ = 0.$$

where $MTR = \frac{\partial T(Y)}{\partial Y}$ corresponds to the marginal tax rate. Finally, taking natural logarithm and simplifying the equation we obtain

[8] The family of functions with this property are called constant relative risk aversion (CRRA) functions.

$$(5) \qquad \mu = \frac{\ln(1 - MTR)}{\ln(1 - \frac{T(Y)}{Y})}$$

where $\frac{T(Y)}{Y}$ is the average tax rate (ATR). Given the iso-elastic utility function, we refer μ to be the coefficient of relative risk aversion. Moreover, we explicitly assume that μ is constant in a given income or social group. Therefore, the higher the μ, the more risk averse the income or social group. Further, the iso-elastic utility function is consistent with the fact that μ rises with the income level (Evans, 2005). Our results partly confirm these properties (MTR increases at a higher rate than $\frac{T(Y)}{Y}$, see summary statistics in the Appendix).

Given the structure of the data, we derive the marginal tax rate (MTR) for each year and each social (or income) group following this equation:

$$(6) \qquad T(Y)_{t,j,i}^{(PIT+SHSC)} = MTR_{t,j} * Y_{t,j,i}^{Income} + e_{t,j,i}$$

where i represents an individual belonging to social (or income) group j and t denotes a particular time period (i.e. year). Regarding our central estimate $j \in (1^{st}$ quintile, …, 5^{th} quintile) and $t \in (2005, \dots, 2019)$.[9] Thus, we attribute the identical MTR for all individuals belonging to the same income/social group in the same year. Consequently, we calculate the average tax rate (ATR) for each individual (regardless of the year, income or social group) as:

$$(7) \qquad ATR_i = \frac{T(Y)_i^{(PIT+SHSC)}}{Y_i^{(Income)}}$$

Finally, using the equation (5) we calculate μ for each individual and average through the whole period and sample:[10]

$$(8) \qquad \mu = \frac{\sum_{i=1}^{n} \frac{\ln(1 - MTR_i)}{\ln(1 - ATR_i)}}{n}$$

As a robustness check we derive ATR by averaging it within each social (or income) group:

[9] The year 2014 is not included.

[10] Note that MTR_i is the same within the income or social group j.

$$(9) \qquad ATR_{t,j} = \frac{\sum_{i=1}^{ns} T(Y)_{t,i}^{(PIT+SHSC)}}{\sum_{i=1}^{ns} Y_{t,i}^{(Income)}}$$

where *ns* is the number of individuals in group *j* and we do the following first: we calculate μ using a slightly modified equation (8) with index *j* instead of *i* for the whole-time span[11], and then we estimate μ using the data for the whole-time span (referred to as μ *Regressed* in the Results section) as follows:[12]

$$(9) \qquad \ln(1 - MTR_{t,j}) = \beta_j \ln(1 - ATR_{t,j}) + \varepsilon_{t,j},$$

where β corresponds to the parameter μ. Note that we obtain the coefficient β for each social or income group, respectively, only from 14 observations corresponding to the number of years analysed in our study.

In conclusion, we use three methods to derive the parameter μ for income or social groups: the computational method, pooling panel data method with individual fixed effect (for income or social group), and linear regression method for each group through the whole-time periods.[13] While the computational method allows us to directly obtain μ using the equation (8), the other two methods provide the estimates of μ. The panel data method differs from the linear method in the assumption that we have the same structure of groups across years, i.e., the 1st quintile comprises the same individuals, which is not necessarily true. However, at the aggregate level, we are very close to that assumption. Moreover, we add so-called fixed effects, which capture all unobserved time-constant factors that affect the dependent variable. On the other hand, the linear regression method may suffer from omitted variable bias, which could result in a wider confidence interval (see the Results section). In the case of the computational method and linear regression method, we use the bootstrap technique to elicit the 95% confidence set.

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[11] For example, in the case of dividing the sample into *s* social groups, we modify equation (8) to $\mu_t = \sum_{j=1}^{s} w_j \frac{\ln(1-MTR_{j,t})}{\ln(1-ATR_{j,t})}$, where $w_j = \frac{ns_{t,j}}{N_t}$ and $\mu_j = \sum_{t=1}^{T} \frac{\ln(1-MTR_{t,j})}{\ln(1-ATR_{t,j})}$ where *t* denotes year (2005,.., 2019), $ns_{t,j}$ is the number of individuals belonging to group *s* in the year *t*, and N_t is the sample size in the year *t*.

[12] We use the pooling panel data method with individual effect and weights (see software R for references). As another approach, we use linear regression within each social group, and we bootstrap the confidence set. In both regression methods we omit the intercept.

[13] When using social groups, we add weights to both computation and regression methods.

Data

We use datasets covering information about individuals between 2005 and 2019 (we exclude the year 2014, which does not contain information about tax, social and health insurance contributions). We define the following variables:

- Income: gross domestic income from the main job; gross income from secondary job; gross income from main business; gross income from secondary business,[14]
- Personal income taxes (PIT) paid from a job, main or secondary business (free-lancers),
- Obligatory social and health insurance payments paid by employees (SHIS),[15]
- Social benefits provided to people from the public social security system – these include all social benefits, which are non-taxable.

Given that our estimation method uses income tax schedules, we provide some historical background about PIT and SHIS in the Czech Republic. The non-linear progressive income taxation with increasing block rates for four bands was applied until 2007. Since January 2008, the non-linear income taxation has been switched to linear taxation with a 15% rate applied on gross income and later on super-gross incomes, i.e., gross income plus SHIS paid by employers. To keep progressivity of personal income tax, tax deductibles and tax credits have been applied to a taxpayer, her/his children under age 18, and her/his not-economically-active spouse. Since 2013, a so-called solidarity income tax has been introduced, applied as 7% on top of the standard tax rate on income above a certain threshold (around one million CZK). SHIS paid by employees have been calculated as a certain percentage, given by law, (11 percent for most of the period) from gross earnings. SHIS paid by employers are also computed as a certain percentage, again given by law, (34 percent for most of the period) from gross earnings, but this part of the obligatory insurance payments is not included in the definition of taxes, nor when ATR and MTR are calculated in our study. All social benefits are not subject to income tax, except for pensions provided to retired persons above 43,800 CZK per month (in reality, there is a negligible number of such pensioners as in our sample, as in the Czech population). SHIS are paid from the social security system for all economically-inactive persons, such as retirees without earnings, the involuntarily unemployed, disabled, people on maternity/parental leave, and students under age 26 (or under 28 when the student is in a doctoral programme for first time and has no other employment).

[14] As a robustness check we include pensions; however, given the methodology, these results impart a strong upward bias to the value of μ for the retirees (denominator in equation (5) is close to zero because, on average, retirees pay low taxes).
[15] As a robustness check, we exclude health and social insurance payments paid by employees.

We perform the analysis using the data for

- the entire sample,
- several household groups defined by gross labour income creating 20 quantiles and 5 quintiles, and
- groups defined by working status, yielding nine distinct groups: full-time employed, part-time employed, full-time self-employed, part-time self-employed, unemployed, student, retired, disabled person, and parental/maternity leave.[16]

In total, our datasets cover information on 276,785 individuals. However, we include only persons with non-zero income, given the definitions of income for the purpose of this study. Therefore, our datasets include information from a range of individuals depending on the method of computing ATR and whether we include social benefits into income. Table 1 summarizes the used datasets when computing ATR individually or averaged by income or social groups.

Total number of observations **276,785** (raw data)	Number of individuals with income > 0	
	Social benefits **are not** included in Income*	Social benefits **are** included in Income**
ATR computed individually, MTR by quintiles (results in Table 2)[+]	**111,123**	**114,897**
ATR, MTR computed by income and social groups (results in Table 3)	**127,878**	**206,721**

Notes: [+] When individually computing ATR, we include only those observation with ATR>0, otherwise we would obtain zero in the denominator in equation (8). Moreover, we exclude around 550 and 955 observations with $\mu > 100$, which is less than 0.5% and 0.83% of the sample in the case of not-included social benefits into income, and included social benefits, respectively.

* Effectively, these are everyone actively working.

** This sample also includes those who are not actively working but receive social benefits (non-taxable income).

Table 1: Summary of the Datasets

Descriptive statistics for the entire sample and the five quintiles are provided in Table A1 in the Appendix (when individuals without any earnings from labour are excluded). Average gross annual labour income (excluding social benefits) is 258,000 CZK2015 (s.d.=206,000 CZK) with median at 226,000 CZK. Personal income tax (PIT) is 27,800 CZK a year (s.d.=43,100 CZK), representing on

[16] Employment status of economically-inactive persons such as unemployed, disabled or on maternity/parental leave is recorded in the time of the survey. For this reason, these persons might be economically active before the survey was conducted in a given year and hence receive earnings. Moreover, students, retired persons and persons on parental leave might receive both social benefits and earnings at the same time.

average 11% of gross income. Average obligatory payments to social and health insurance (SHIS) is 25,000 CZK a year (s.d.=20,500 CZK), representing 9.7% of gross income, and the average of the sum of PIT and SHIS is 52,800 CZK (s.d.=57,100 CZK), representing 20.5% of gross income. We note that SHIS do not cover payments of this insurance by employers from the labour income of their employees. Social benefits provided to all eligible persons are on average 10,500 CZK (s.d.=35,800 CZK) with the median at zero, which is because there are only 9.7% households receiving these benefits in the entire sample and this share is declining across incomes (with 29% in the lowest quintile and only 3.6% in the highest quintile).

Individual income corresponds to the previous year, i.e., the 2018 collection includes income for the whole year of 2017 and is considered a pre-tax income without deduction of standard tax allowances.[17] All values were multiplied by the weighting factor for converting the data, and hence the results are representative for the whole population of the Czech Republic (variable pkoef in SILC-CZ). On average, each year covers information about 9,134 individuals, yielding in total 127,878 observations.

4. Results

Central estimate of μ

Our central estimate of μ is 1.34 with the 95% confidence interval excluding unity. In the words of Dasgupta (2008: 150), *"any proportionate increase in someone's consumption level should be of higher social worth to that same proportionate increase in the consumption of anyone else who is a contemporary regardless of how rich that contemporary happens to be."*

Table 2 shows the overall results for μ for all relevant combinations of the input variables (i.e., gross incomes with/without social benefits, PIT with/without SHIS). In general, we distinguish the results by two criteria. The first one tackles the structure of the income, i.e., whether social benefits are included or not. The second criterion corresponds to the labour taxation, i.e., whether we include social and health insurance payments (indicated as Ins in the abbreviation) or not (only personal income tax). Here, the elasticity of marginal utility of consumption is computed from the original data, without regressing ln(1–MTR) on ln(1–ATR), as in eq. (9).

[17] As Evans (2005) argues, it is better to use pre-tax income after the deduction of standard tax allowances. Nevertheless, we do not have data at this level.

	Social benefits **are not** included in Income		Social benefits **are** included in Income	
	μ	$\mu(Ins)$	μ	$\mu(Ins)$
μ (95% CI)	**2.00** (1.98 – 2.03)	**1.34** (1.33 – 1.35)	**1.82** (1.80 – 1.84)	**1.53** (1.51 – 1.55)

Notes: Numbers in parentheses indicate 95% Confidence Intervals. Ins in the abbreviation refers to the inclusion of social and health insurance into Taxes and Levies in equations (6) and (7).

Table 2: Overall Results - MTR computed by 5 quintiles group using equation (6); ATR computed for each individual using equation (7)

The results in Table 2 aggregate μ through the whole period and all income groups. It is important to mention that MTR in this case is computed as an average for the five quintiles group, whereas ATR is computed for each individual (this is the difference with the results below, where we compute average ATR per quintile, quantile, or social group). Given individually-computed ATR, the results are more sensitive to extreme values and we drop out the outliers when deriving the central estimate of μ.[18]

We can see that the results differ significantly according to definitions used for income and income taxes. Naturally, other things being equal, when including social benefits, we are increasing non-taxable income, and therefore the denominator in equation (5) is closer to zero (decreasing in absolute value). On the other hand, other things being equal, when including social and health insurance, the denominator in equation (5) increases in absolute value. We can see the only anomaly when comparing μ in the first and third columns (2.00 without social benefits vs 1.82 with social benefits). The main reason comes from the fact that low-income individuals (appearing mainly in the first and the second quintiles) pay almost zero taxes and payments to social and health insurance (we do not include SHIS) but receive non-taxable social benefits. This effect is stronger in the case of individually-computed ATR than when using average ATR for income groups (see Table 3).

[18] We excluded around 550 observations with $\mu > 100$ (less than 0.5% of the sample).

	Social benefits **are not** included in Income					
	Quintiles		Quantiles		Social Groups	
	μ	$\mu(Ins)$	μ	$\mu(Ins)$	μ	$\mu(Ins)$
Panel data, pooling by group	**1.55** (1.52-1.59)	**1.18** (1.16-1.20)	**1.50** (1.46-1.54)	**1.22** (1.19-1.25)	**1.66** (1.64-1.67)	**1.33** (1.32-1.34)
Computed (95% Bootstrap CI)	**1.45** (1.04-1.63)	**1.18** (1.11-1.25)	**1.49** (1.25-1.62)	**1.23** (1.16-1.28)	**1.68** (1.30-1.79)	**1.35** (1.21-1.48)
Linear regression (95% Bootstrap CI)	**1.42** (1.30-1.55)	**1.17** (1.11-1.23)	**1.46** (1.09-1.86)	**1.22** (0.99-1.45)	**1.66** (1.57-1.74)	**1.35** (1.30-1.40)
	Social benefits **are** included in Income					
	Quintiles		Quantiles		Social Groups	
	μ	$\mu(Ins)$	μ	$\mu(Ins)$	μ	$\mu(Ins)$
Panel data, pooling by group	**1.90** (1.84-1.96)	**1.57** (1.48-1.66)	**1.73** (1.97-1.79)	**1.58** (1.51-1.65)	**1.72** (1.68-1.77)	**1.37** (1.34-1.40)
Computed (95% Bootstrap CI)	**2.04** (0.34-3.23)	**1.91** (0.60-2.98)	**2.39** (1.54-3.14)	**2.11** (1.46-2.78)	**4.67** (1.81-5.57)	**4.11** (1.57-5.17)
Linear regression (95% Bootstrap CI)	**2.09** (1.81-2.34)	**1.91** (1.72-2.10)	**2.19** (0.75-3.42)	**2.05** (1.20-3.03)	**4.83** (3.77-7.03)	**4.16** (3.57-5.65)

Notes: Number in parentheses indicates 95% Confidence Intervals. Ins in the abbreviation refers to the inclusion of social and health insurance into Taxes in equation (6).

Table 3: Overall Results - MTR and ATR computed by quintiles, quantiles or social groups

Estimate of μ for different income and by employment status

The parameter averaged across the given groups is 1.18 (quintiles), 1.23 (quantiles) and 1.35 (social groups), see Table 3. This table also reports the results for the μ estimate for all relevant combinations of the input variables and three computational methods how μ can be derived from our data (simple computation, linear regression, panel data estimation).

We find that the estimate of μ is relatively stable also across income and social groups. Looking at income quintiles first, the parameter μ is not statistically different from the group-average for any quintile but the lowest one, for which it is about 1.1, see Appendix, Figure A4 and Table A3. The result for quantiles is qualitatively the same as for the quintiles; 95% confidence intervals overlap for each quantile, except for the two lowest and the highest one (the μ is around the unity for all of these special cases), see Appendix, Figure A5. The elasticity estimate is between 1.2 and 1.7 for each social group, except the elasticity for the group of students, for whom it is slightly less than the unity (the sample of this group is, however, very small, representing less than 2% of the entire sample), see

Appendix, Figure A6 and Table A6. We also find the consumption elasticity of marginal utility is lower for groups with lower incomes (students, old age pensioners, disabled persons, those on maternity/parental leave), with the exception of the unemployed, who share comparable elasticity to employed persons, indicating that less wealthy individuals are less risk averse – a finding consistent with the results of Evans (2005) and that comes from the assumption of the iso-elastic utility function.

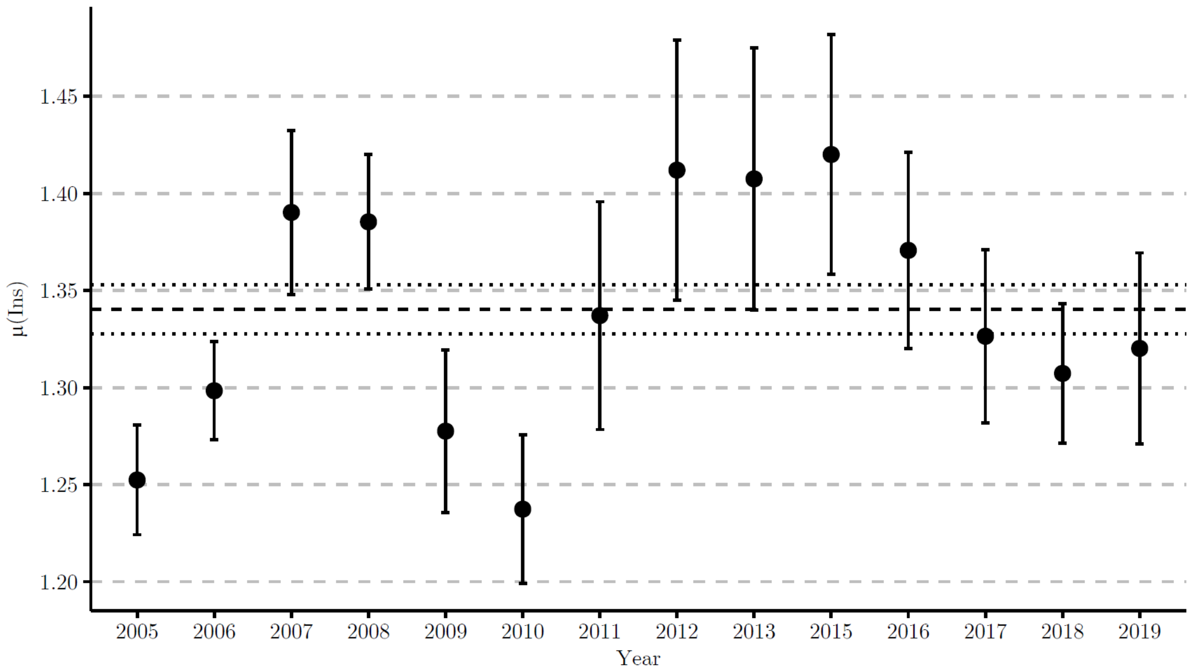
As noted above, if social benefits are included, gross incomes are increased by the non-taxable component, which results in a lower denominator in eq. (5), approaching zero in the case of no taxable incomes. As a consequence, the parameter μ is becoming larger for the group of pensioners, as shown in Appendix, Figure A7.

Considering the panel data regression (reported in the first lines in both panels), μ is significantly greater for all groups (quintiles, quantiles, or social groups) when social benefits are included. When using other methods (with results reported in the second and the third line), μ is significantly higher only in the case of social groups. This comes from the fact that the input data are more sensitive to extreme values, mainly in the case of old age pensioners (see Appendix, Figure A7). When using quintiles or quantiles, the estimates are more smoothed.

In general, the results for included social benefits in income yield a higher value of the parameter μ. This is the intuitive finding given the computational method and the fact that respondents who receive an old age pension are, on average, paying a lower amount of taxes from labour (see Table A1 in the Appendix). This is the main reason we prefer the central estimate to be based on incomes that exclude social benefits.

Estimate of μ across various years

The estimate of parameter μ is stable across years, within the analysed time span of 2005-2019 (2014 data are missing). The elasticity of marginal utility of consumption is in a range of 1.0 to 1.46 for all years and for each of the three specifications. Figure 1 shows the estimation of μ when ATR is computed for each individual, while MTR is averaged for each income quintile. The estimates of μ cover a narrower band after 2010 (1.31–1.42) than before 2010 (1.24–1.39). In this case, SHIS are included in labour taxation, but social benefits are not included in gross incomes.



Note: Central estimate of μ is shown by the black dashed line, with its 95% confidence interval shown by dotted lines.

Figure 1: Estimate of the parameter μ, by Income Quintile (including SHIS but excluding social benefits); MTR computed for 5 quintiles following eq. (6), while ATR is computed for each individual as in eq. (7); computation method, including SHIS but excluding social benefits

The parameter estimates for every year computed as an average for each quintile, quantile and social groups are reported in Appendix, Figures A1-A3 and Table A3 with detailed information on ATR and MTR reported in Appendix, Table A2 (here SHIS are included, but social benefits are not included). Considering ATR and MTR for quintiles, the parameter μ across the years is between 1.10 and 1.28, with slightly greater values after 2011. Except for the years 2013-2015, all estimates lie within the 95% confidence interval of the average estimate derived for the whole period (1.18), see Appendix, Figure A1. Obviously, the parameter estimates vary more (0.97 – 1.46) and differ in more years from the whole period average when these estimates are based on quantiles (see Appendix, Figure A2). Still, the estimates of μ cover quite a narrow band (1.1 – 1.4). The results based on ATR and MTR for social groups over the years are qualitatively the same, yielding the estimates of μ between 1.1 and 1.5, with the exception of 2009-2010 when μ is about 1.1.

We provide additional results to show how μ changes between various incomes or groups defined by employment status (Figures A4-A7 in the Appendix).[19] The results show that the lowest income group

[19] With averaged ATR by income or social groups. Additionally, the reader can find the results in Tables A1 to A6b in the Appendix.

is the least risk averse. This finding is consistent with the results of Evans (2005) and comes from the assumption of the iso-elastic utility function.

As Anthoff et al. (2009: 2) suggest, "…*curvature in the utility function can be viewed as a reflection of risk aversion. Therefore, 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."* Our results suggest that irrespective of the methods used and how the variables are defined, the coefficient of relative risk aversion of individuals is higher than the unity. Since the elasticity of marginal utility has been assumed often to be one, given our results, Czech people are willing to pay more for reducing uncertainty about the outcome than it has been widely expected in evaluation studies (such as $\mu = 1$).

ATR and MTR

During 2005-2019, the average labour tax rate (ATR) in the Czech Republic is 18.6% when social and health insurance contributions paid by employees are included in taxation (and social benefits are excluded from incomes). ATR is growing by the level of income, reflecting progressivity in the labour taxation system; it is 14.7% for Q1, 18.7% in Q3, and 22.5% in Q5, see Table A2 in the Appendix. ATR also vary across groups defined by employment status; it is 22% and 18% for full-time and part-time employed persons, while it is 14.4% and 12.6% for full-time and part-time self-employed, respectively, and it is in a range of 14–20 percent for other groups defined by employment status, see Table A4 and A5 in the Appendix with SHIS excluded and included, respectively.

Marginal labour tax rate (MTR) is 21.5% (including SHIS and excluding social benefits), see Table A2 in the Appendix. As in the case of ATR, MTR is also declining over time from 24% in 2005 to 20% in 2009–2013, and since then is again growing to 21%. MTR is also an increasing function of income; MTR is 15.3% for Q1, 18.7% for Q3, and 25.5% for Q5. MTR is 27.8% and 23.9% for full-time and part-time employed and 22.3% and 19.9% for full-time and part-time self-employed, respectively. It is quite high for the unemployed and old-age pensioners, about 24%, and it gets much smaller values for persons on parental leave (19.9%) and for students (15%), see Table A4 and A5 in the Appendix.

5. Discussion and Implications

As noted by Dasgupta (2021:267), SDR is not a primary ethical object and it *"cannot be plucked from the air."* In fact, all three components of SDR – ρ, μ, and the forecast, g(C) – play a key role together in determining its value. Since $SDR_t = \rho + \mu \cdot g(C_t)$, the social discount rate increases with ρ and

$g(C_t)$, respectively, and increases with μ if and only if $g(C_t) > 0$. It implies that if per capita consumption is growing in the future, ρ and μ play a similar role in the determination of SDR. A higher value of parameter ρ and μ would reflect a greater aversion towards intergenerational consumption inequality. However, if per capita consumption is declining in the future, ρ and μ bring diametrically opposite directives: a larger μ would lower SDR, which would act as a corrective to consumption inequality across the generations (Dasgupta, 2008). It is also worth noting that even if the rate of time preference is assumed to be close to zero, the social discount rate applied in a cost-benefit analysis may get non-zero values if per capita consumption is growing over time (since $\mu > 0$).

How can these two parameters be interpreted and how can they determine the SDR?[20] If $\rho = 0$, any increase in consumption today ought to be of equal social worth to that same increase in consumption at any future date no matter how rich or poor people will be at that future date. To assume $\mu = 1$ is to insist 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.[21] Larger values of μ, say $\mu = 2$, correspond to a situation of high relative risk aversion and hence low willingness to substitute consumption inter-temporally. If μ is considered the coefficient of relative risk aversion, and specifically to measure risk premium associated with damage uncertainty[22], a large premium may also imply that future damage is high, as it incorporates a large risk premium, and agents would have a stronger preference to consume everything today (see Markandya et al., 2019).[23]

With respect to the global long-term impact assessment, most Integrated Impact Assessment (IAM) models, including DICE, PAGE, FUND, and WITCH, have used the values of the pure rate of time preference (PRTP) at 3%, 1%, and 0.1%, with 0% used in a sensitivity analysis and $\mu = 1$ or $\mu = 1.5$. The central value of our estimate of μ for the Czech Republic, 1.34, is just between these two values. It is also worth mentioning that all our estimates are above the unity, with the exception of a few cases (the lowest quantile, students).

[20] Both parameters also determine optimal rate of savings, s*, which equals (r – ρ)/ $\mu \cdot r$, where r is the rate of return on investment, and savings are defined here as a proportion of wealth, $\frac{(K_t - C_t)}{K_t}$, where K and C denote capital and consumption in a given time, respectively. Suppose r=5% a year, then at $\rho = 0.1\%$ and $\mu = 1$, s* is 98%, in other words, these two assumptions would yield an absurdly high rate of savings. The optimal rate of savings would decrease with larger μ's; for instance, s* gets to 65% and 49% at $\mu = 1.5$, and $\mu = 2.0$, respectively, even if $\rho = 0.1\%$ (with r=5% p.a.). To agree with Dasgupta (2008:150), the pair ($\rho \approx 0, \mu = 1$) *"can recommend bizarre policies in classroom models of consumption and savings."*

[21] Standard assumption on utility function implies that for $\mu = 1$ a social planner would regard a 10% decrease in a wealthy person's consumption to be ethically equivalent to a 10% decrease in a poor person's consumption. If $\mu = 2$, our social planner would regard a 10% decrease in wealthy person's consumption to be ethically equivalent to a 0.2% decrease in a poor person's consumption, while $\mu = 3$ would imply an indifference between a 1% decrease in poor person's consumption and a 93% drop in a wealthy person's consumption.

[22] As elaborated by Berger and Emmerling (2020), inequity has three dimensions: across individuals (inequality, intra-generation equity), across generations (intergenerational equity), and across states of world (uncertainty, or risk aversion). Considering this framework, ρ measures inter-, while μ measures intra-generational equity. Berger and Emmerling (2020) find, empirically, that risk aversion is far larger than inequality or intertemporal fluctuation aversion.

[23] Markandya et al. (2019) use the WITCH model to test different risk premium-corrected damage functions under a different value of risk aversion, $\mu = \{1, 1.5, and\ 2\}$. Performing a sensitivity analysis, they also find that for some large values of μ in the WITCH utility function, the model cannot find an equilibrium, and if they assume $\mu = 2$, optimisation for high high-damage regions, such as Sub-Saharan Africa, can be solved only if PRTP is adjusted downward.

With a typical forecast value for real consumption growth at 1.5–2.5% p.a., the combinations of the above mentioned most frequently used values of the parameters ρ and μ give SDR in a range of 1.5–6.0%. While SDR of 2% may seem low, SDR at 6% seems high. To investigate the appropriate rate of SDR, Drupp et al. (2018) followed the original work of Weitzman (2001) and conducted a survey in which they asked more than 200 economists to state what rates they thought would be appropriate for discounting investment projects. [24]

	Pensions **are not** Included in Income		Pensions **are** Included in Income	
	$\mu = 2.00$	$\mu(Ins) = 1.34$ (central estimate)	$\mu = 1.82$	$\mu(Ins) = 1.53$
PRTR=0%	4.56%	3.06 %	4.15 %	3.49 %
PRTP=1%	5.56 %	4.06 %	5.15 %	4.49 %
PRTP=3%	7.56 %	6.06 %	7.15 %	6.49 %

Table 4: The SDR for the Czech Republic, g(C)=2.28% p. a.

While 30% of them recommended Stern's 1.4% or lower, only 9% recommended Nordhaus' 4.5% or higher, with 61% forming the middle ground between the two. Interestingly, more than three-quarters of economists found the median risk-free SDR of 2 percent acceptable and 90% considered a discount rate of 1-3% acceptable for long-run public projects (ibid.).

What SDR can we recommend for the Czech Republic? Assuming the simple Ramsey rule stated in equation (1), we derive SDR for different values of PRTP and μ. For PRTP we assume 0%, 1%, and 3%. For the value of g we take the geometric mean of growth of consumption between 2005 and 2019 for the Czech Republic (covering the period of our study), which gives 2.28 pp. The value of the parameter μ is based on the central estimate in this paper (with and without SHIS and pensions included in the definition of labour taxation, and gross incomes, respectively). These results are reported in Table 3. Assuming PRTP=1%, the SDR would be 4.06% for the central estimate of μ. For the same PRTP and $\mu = 1$, the SDR is 3.28%. Assuming moderate real growth consumption at 1.5% p.a. would obviously result in smaller values of the SDR; for $\rho = 1\%$ and our central estimate of μ, SDR is 3.0%. In sum, the larger g(C) or ρ, the greater SDR, see Figure 2.

[24] Based on the survey conducted by Martin Weitzman on discount rate, the sample mean is 3.96%, with std=2.94% and median at 3% (N=2160). This survey was followed by "balanced blue-ribbon panel" consisting of 50 leading economists and the aggregate response of their expert opinion yields the mean at 4.09% and std=3.07% (Weitzman, 2001).

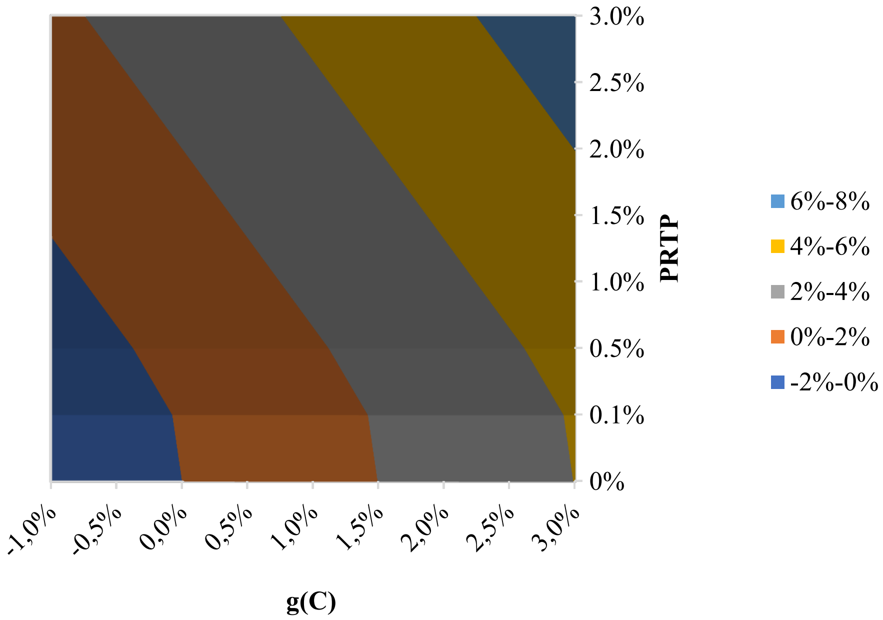


Figure 2: SDR for various values of g(C) and ρ, μ=1.34.

Are our estimates valid? A validity check may be based on the criterion validity, where the estimate from a study is compared with the estimates produced by other, generally trusted approaches (Bishop & Boyle, 2019; Ščasný & Alberini, 2021). To summarize our results, most estimates derived for various years and for different groups lie in a belt given by the values between 1.1 and 1.4, with the central value at 1.34. Using the same methodology on aggregated data, Evans (2005) estimates the value of μ for the Czech Republic at 1.36 for the high level of earnings and 1.22 for the low level of earnings. This estimate is based on 2002 country-level data.

Our closest estimate to that of Evans (2005) is based on SILC-2005 describing earnings for 2004; μ is 1.25 (1.25–1.28). However, in contrast to our approach, Evans does not include social and health insurance in his definition of taxes. Additionally, he obtains similar values of μ*'s* for Belgium, Canada, France, Germany, Hungary, Italy and Norway – all between 1.30 and 1.38. Groom and Maddison (2019) use five different methods for eliciting the elasticity of marginal consumption for the UK. Employing the income tax-based method with weights for income groups and including social and health insurance, they obtain the value of 1.52 with the confidence interval excluding unity. Instead of using individual-level data, they simulate tax payments for several levels of income, relying on data from HM Revenue and Customs (HMRC) covering the 2000 to 2010 tax years.

In fact, past studies provide a wide range of estimates of μ, ranging between 0.2 up to even 10 (Evans, 2005; Groom & Maddison, 2019), with the most cited values between 1.3 and 1.6. As Groom and Maddison (2019) comment, these differences are mainly due to the employed methodology for elicitation of the estimate. We note that the largest values of the estimate are mainly based on studies that allowed examining preference heterogeneity. Our central estimate of 1.34 therefore corresponds reasonably well to the results from the mainstream of the literature.

6. Conclusion

In this study we employ the equal-sacrifice approach that relies on social values revealed on nation-wide income tax schedules to derive the estimate of the elasticity of the marginal utility of consumption. Along with the pure rate of time preference, μ is the key parameter for deriving social discount rate, which is then a key assumption in welfare assessment and cost-benefit analysis of policies.

Using individual-level data from the SILC-CZ, we derive the parameter μ based on the income tax-based method. In contrast to other studies, we use individual-level data from the SILC-CZ to derive the parameter μ using three different approaches when two of them allow us to consider better variations in individual incomes and variability in tax payments. Relying on more accurate input data in our model, we believe we provide a more reliable estimate of μ.

The central value of our estimate of μ for the Czech Republic is 1.34, which corresponds to the literature. Except for a few cases, all our estimates are above unity, with most cases ranging between 1.1 and 1.4 and none above 1.7 and non-taxed pensions are included in the definition of income. We show that the value of μ heavily impacts the SDR, as does the assumption on the pure rate of time preference and forecast of per capita consumption growth. For the given PRTP and forecasted g(C), taking our central value estimate, SDR will be 1.34pp greater for every 1pp increase in forecasted per capita consumption growth. Compared to our estimate, assuming $\mu=1$ would favour projects with a long lifetime and benefits generated in the long-term future. At least in this case, a sensitivity analysis on various assumptions on the key parameters should be performed.

In conclusion, there is no doubt that each method of estimating the elasticity of marginal utility of consumption is subject to some criticism. The income tax-based method depends mainly on two assumptions: 1) that the electorate has agreed on the tax structure such that each consumer should equally sacrifice, and 2) that we can aggregate individuals with different wealth levels into a single representative agent with the same utility function. Further research is needed to validate both assumptions.

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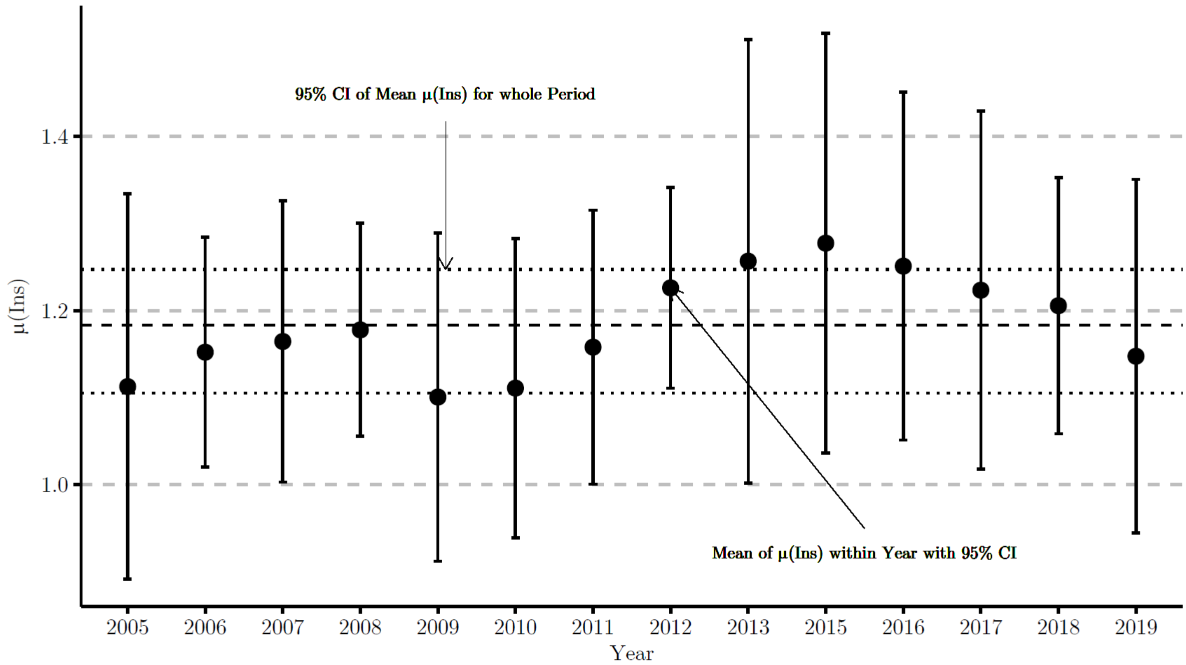
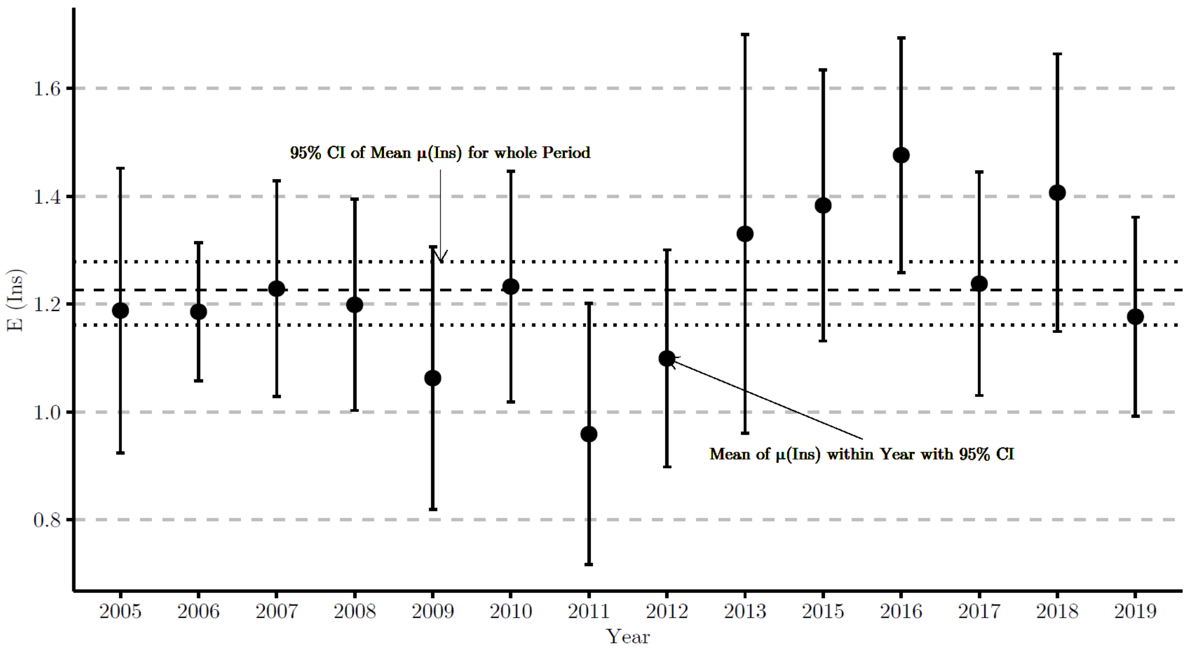
Appendix

Figures



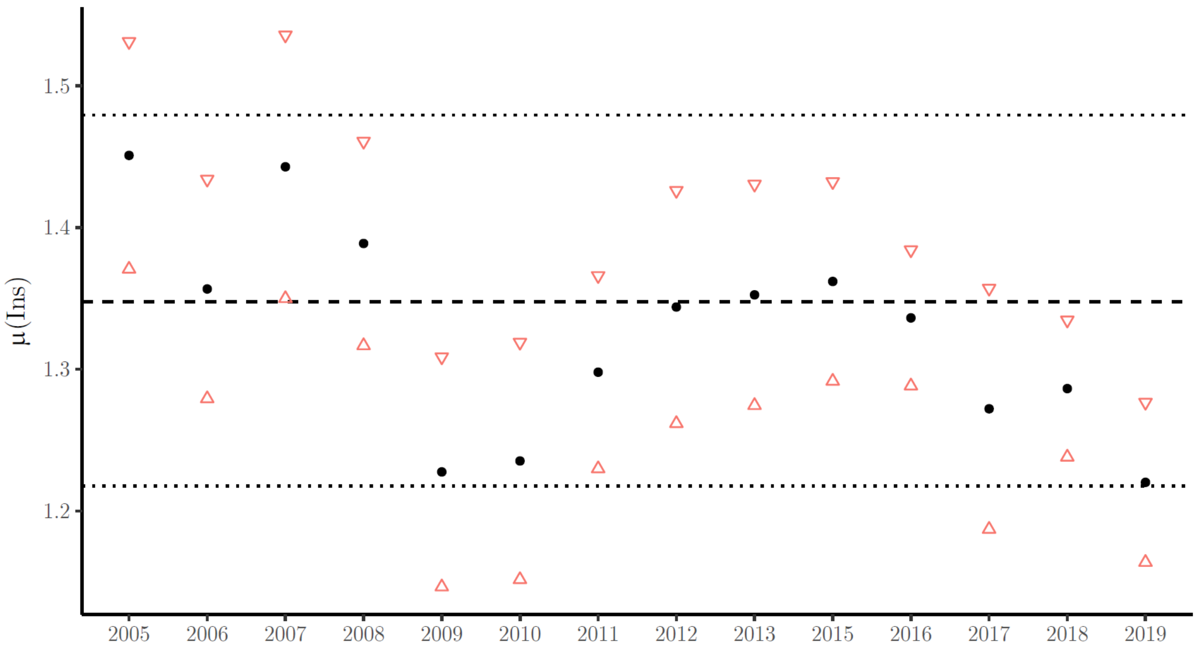
Note: Central estimate of μ shown in dashed line, with its 95% confidence interval by dotted lines; SHIS are included but pensions are excluded in the calculation.

Figure A1: Estimation of Elasticity of Marginal Utility of Income, by Years, MTR and ATR averaged by Quintiles



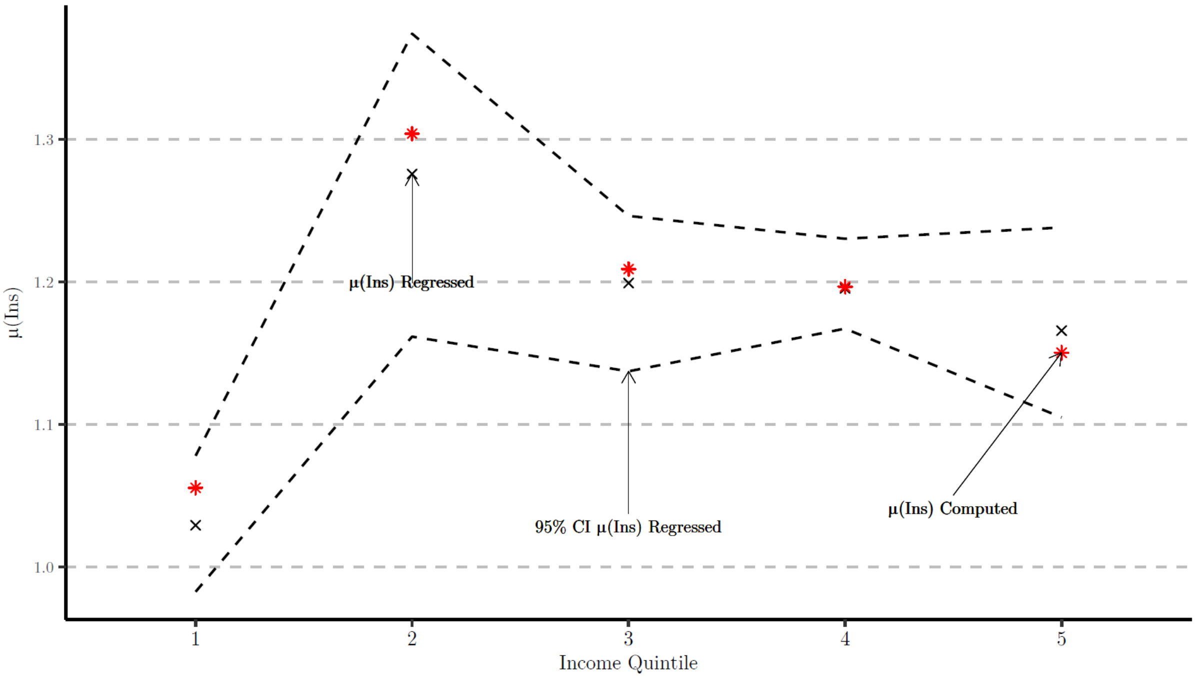
Note: Mean of μ (computed - quantiles) shown in black dashed line, with its 95% confidence interval by dotted lines; SHIS are included but social benefits are excluded in the calculation.

Figure A2: Estimation of Elasticity of Marginal Utility of Income, by Years (SHIS included but social benefits excluded,), MTR and ATR averaged by Quantiles



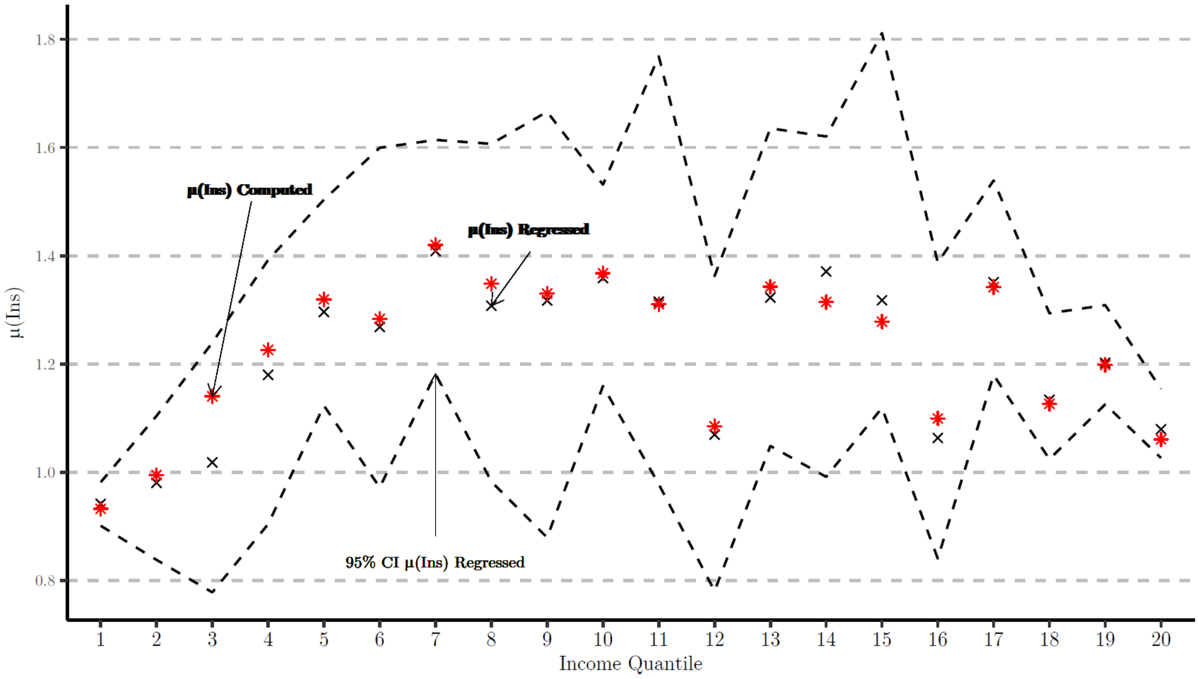
Note: Mean of μ (computed – social groups) shown in dashed line, with its 95% confidence interval by dotted lines; SHIS are included but social benefits are excluded in the calculation. Black circles indicate weighted μ(INS), with its 95% confidence interval by red triangles.

Figure A3: Estimation of Elasticity of Marginal Utility of Income, by Years (SHIS included but social benefits excluded,), MTR and ATR averaged by Social Groups (defined by employment status)



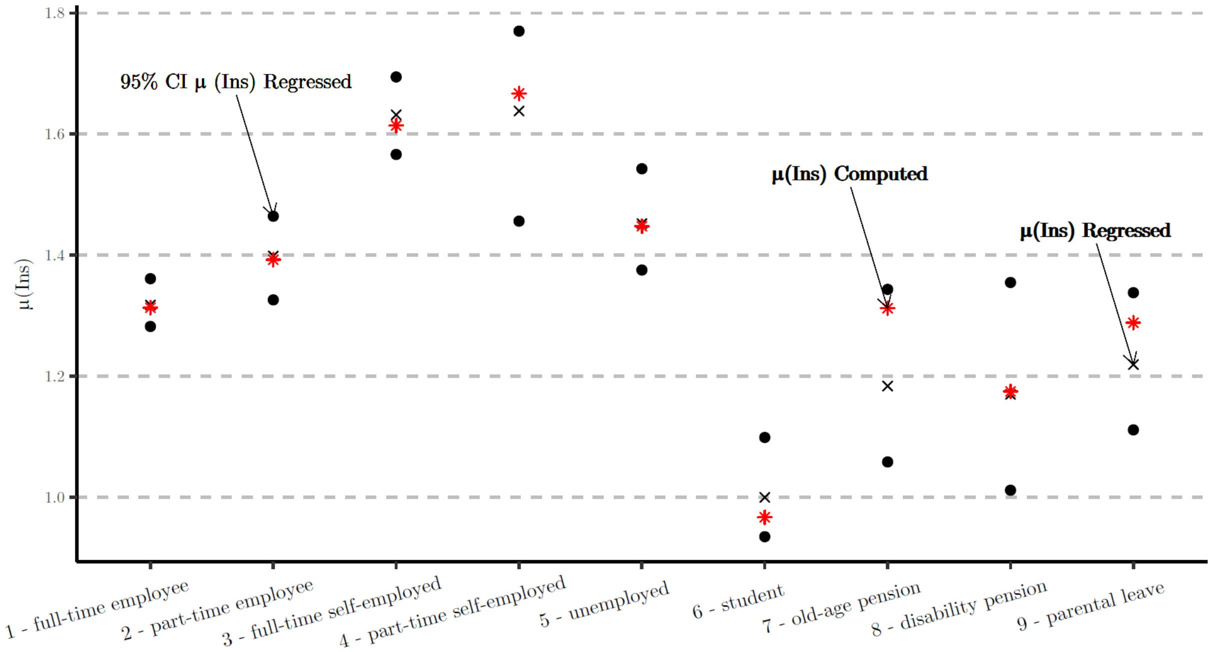
Note: The 95% confidence interval for the estimated mean by dashed lines.

Figure A4: Estimation of Elasticity of Marginal Utility of Income by Income Quintiles (SHIS included but social benefits excluded), 2005–2019



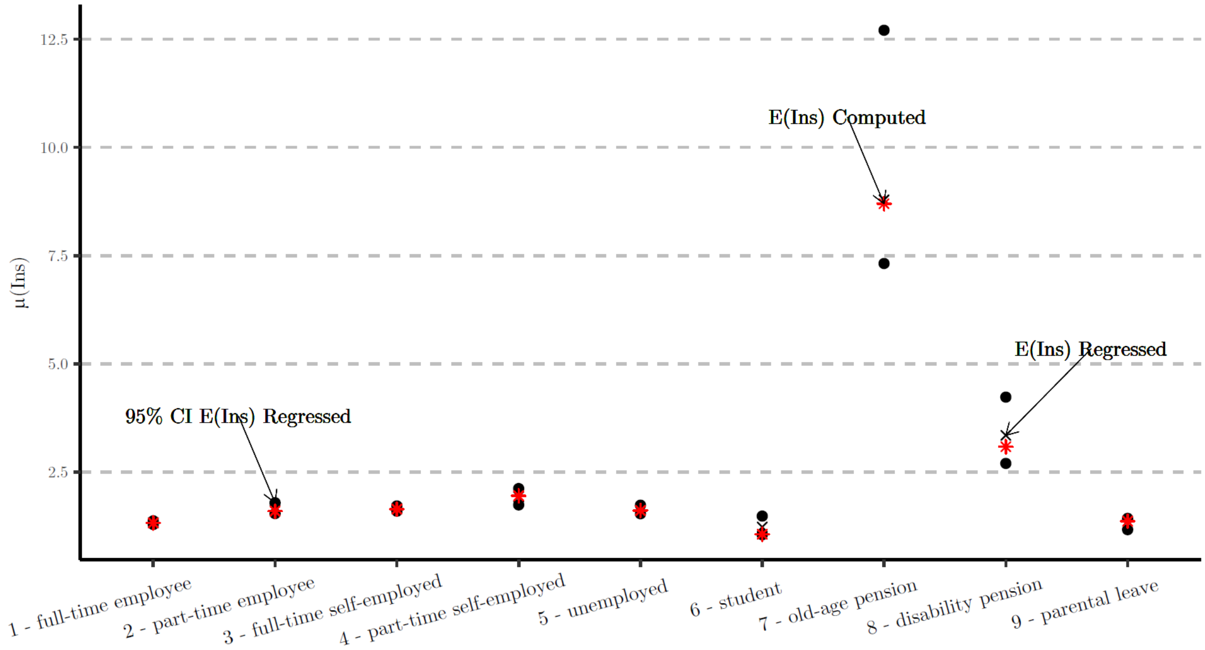
Note: The 95% confidence interval for the estimated mean by dashed lines.

Figure A5: Estimation of Elasticity of Marginal Utility of Income by Income Quantiles (SHIS included but social benefits excluded), 2005–2019



Note: The 95% confidence interval for the estimated mean (black crosses) by black circles. Computed means are shown by red star.

Figure A6: Estimation of Elasticity of Marginal Utility of Income by Social Groups (SHIS included but social benefits excluded), 2005–2019



Note: The 95% confidence interval for the estimated mean (black crosses) by black circles. Computed means are shown by red star.

Figure A7: Estimation of Elasticity of Marginal Utility of Income by Social Groups (SHIS and social benefits included), 2005–2019

Tables

	1st Quintile (N=25,568)	2nd Quintile (N=25,575)	3rd Quintile (N=25,576)	4th Quintile (N=25,574)	5th Quintile (N=25,585)	Entire sample (N=127,878)
Total Income*						
Mean (SD)	74 600 (40 300)	168 000 (33 200)	229 000 (41 200)	296 000 (54 300)	520 000 (303 000)	**258 000 (206 000)**
Median [Min, Max]	77 000 [1, 176 000]	161 000 [105 000, 267 000]	226 000 [149 000, 345 000]	291 000 [192 000, 463 000]	441 000 [248 000, 8 000 000]	**226 000 [1, 8 000 000]**
PIT						
Mean (SD)	2 720 (6 060)	10 100 (7 140)	19 500 (10 300)	30 500 (14 100)	76 400 (74 200)	**27 800 (43 100)**
Median [Min, Max]	540 [0, 427 000]	9 810 [0, 252 000]	19 300 [0, 384 000]	29 700 [0, 243 000]	59 400 [0, 2490 000]	**18 200 [0, 2 490 000]**
SHIS						
Mean (SD)	6 640 (5 590)	16 900 (6 890)	23 500 (8 570)	30 700 (10 800)	47 200 (30 000)	**25 000 (20 500)**
Median [Min, Max]	6 600 [0, 27 000]	18 200 [0, 29 400]	25 100 [0, 38 000]	32 400 [0, 50 900]	46 000 [0, 610 000]	**23 700 [0, 610 000]**
PIT & SHIS						
Mean (SD)	9 370 (8 560)	27 000 (10 700)	43 000 (14 200)	61 200 (18 800)	124 000 (88 600)	**52 800 (57 100)**
Median [Min, Max]	8 800 [0, 427 000]	26 300 [0, 252 000]	42 700 [0, 413 000]	59 500 [0, 279 000]	102 000 [0, 2490 000]	**40 900 [0, 2 490 000]**
Social benefits						
Mean (SD)	31 900 (56 100)	8 290 (30 800)	4 310 (22 900)	4 010 (23 300)	4 160 (25 500)	**10 500 (35 800)**
Median [Min, Max]	0 [0, 593 000]	0 [0, 345 000]	0 [0, 300 000]	0 [0, 390 000]	0 [0, 390 000]	**0 [0, 593 000]**
Share of Individuals receiving social benefits	29.0%	8.3%	4.3%	3.6%	3.6%	**9.7%**

Note: * Social benefits are not included here in household incomes. PIT – Personal Income Tax; SHIS – Social & Health Insurance Contribution.

Table A1: Descriptive Statistics for the key variables (income, PIT, SHIS, social benefits)

Year	1st Quintile		2nd Quintile		3rd Quintile		4th Quintile		5th Quintile		All		No. of Individ. (All)
	MTR	ATR	MTR	ATR	MTR	ATR	MTR	ATR	MTR	ATR	MTR	ATR	
2005	19.9	19.1	19.2	20.4	21.2	21.1	25.5	21.9	32.4	24.7	**23.7**	**21.4**	4,660
2006	19.8	19.4	21.9	20.2	23.5	21.1	26.2	22.0	31.1	25.0	**24.5**	**21.6**	7,935
2007	17.1	17.1	21.1	17.3	20.1	18.8	23.4	20.2	30.9	24.4	**22.5**	**19.6**	10,426
2008	17.6	17.5	21.9	18.4	23.2	19.8	25.0	21.3	30.8	25.2	**23.7**	**20.4**	12,359
2009	15.4	16.8	18.9	17.2	23.0	18.4	23.2	19.6	21.6	21.7	**20.4**	**18.7**	10,873
2010	14.3	15.7	18.8	15.8	19.8	17.0	22.2	18.5	21.5	20.8	**19.3**	**17.6**	9,921
2011	13.9	14.4	18.9	15.3	20.6	17.0	22.0	18.4	22.8	21.0	**19.7**	**17.2**	9,450
2012	13.4	11.7	19.9	15.1	21.8	17.4	22.2	19.1	24.1	21.3	**20.2**	**16.9**	9,305
2013	12.3	11.4	21.8	14.8	23.3	17.1	20.2	18.5	23.4	20.8	**20.2**	**16.5**	8,801
2015	12.9	11.1	24.0	15.9	20.5	17.8	24.7	19.1	23.9	21.7	**21.2**	**17.1**	8,295
2016	13.9	11.9	23.6	16.4	22.1	18.5	23.9	19.3	23.2	21.8	**21.3**	**17.6**	8,962
2017	14.6	12.2	23.6	16.9	23.6	18.9	22.4	20.0	22.3	22.0	**21.3**	**18.0**	8,990
2018	15.2	12.8	24.0	17.7	22.1	19.6	23.2	20.4	24.5	22.4	**21.8**	**18.6**	8,931
2019	13.6	14.6	21.7	16.8	24.4	19.6	22.3	20.6	24.7	22.6	**21.3**	**18.8**	8,970
Average	**15.3**	**14.7**	**21.4**	**17.0**	**22.1**	**18.7**	**23.3**	**19.9**	**25.5**	**22.5**	**21.5**	**18.6**	**127,878**

Note: Results for MTR and ATR are in percentage points (both averaged by quintiles, referring to Table 2). Averaged across means by years.

Table A2: Summary Statistics for MTR and ATR, by Income Quintile (including SHIS but excluding social benefits)

Year	1st Quintile		2nd Quintile		3rd Quintile		4th Quintile		5th Quintile		ALL	
	μ (INS)	μ	μ (INS)	μ	μ (INS)	μ	μ (INS)	μ	μ (INS)	μ	μ (INS)	μ
2005	1.05	1.08	0.94	0.92	1.00	1.23	1.19	1.34	1.38	1.90	**1.11**	**1.29**
2006	1.02	0.97	1.10	1.29	1.13	1.39	1.22	1.39	1.29	1.96	**1.15**	**1.40**
2007	1.00	0.81	1.24	1.74	1.08	1.38	1.18	1.59	1.32	2.01	**1.16**	**1.51**
2008	1.01	0.86	1.21	1.58	1.20	1.57	1.21	1.65	1.27	1.89	**1.18**	**1.51**
2009	0.91	0.57	1.11	1.44	1.28	1.78	1.21	1.76	1.00	1.62	**1.10**	**1.43**
2010	0.90	0.65	1.21	1.36	1.19	1.39	1.22	1.55	1.03	1.60	**1.11**	**1.31**
2011	0.96	0.70	1.27	1.60	1.24	1.58	1.22	1.54	1.10	1.59	**1.16**	**1.40**
2012	1.15	1.19	1.36	1.98	1.29	1.73	1.18	1.42	1.15	1.53	**1.23**	**1.57**
2013	1.09	0.80	1.53	2.32	1.42	1.93	1.11	1.48	1.14	1.55	**1.26**	**1.62**
2015	1.17	0.90	1.59	2.31	1.17	1.45	1.34	1.58	1.11	1.52	**1.28**	**1.55**
2016	1.18	0.97	1.51	2.08	1.22	1.50	1.27	1.46	1.07	1.54	**1.25**	**1.51**
2017	1.21	1.10	1.46	1.92	1.29	1.54	1.14	1.30	1.02	1.50	**1.22**	**1.47**
2018	1.21	1.08	1.41	1.86	1.15	1.39	1.16	1.19	1.11	1.52	**1.21**	**1.41**
2019	0.92	0.75	1.33	1.55	1.28	1.54	1.09	1.30	1.11	1.45	**1.15**	**1.32**
Average	**1.06**	**0.89**	**1.30**	**1.71**	**1.21**	**1.53**	**1.20**	**1.47**	**1.15**	**1.66**	**1.18**	**1.45**

Note: Averaged across means by years.

Table A3: Estimate of μ, by Income Quintile (including SHIS but excluding social benefits). Results derived from Table A2.

Year	Full-time employee			Part-time employee			Self-employed full-time			Self-employed part-time			Unemployed		
	w	MTR	ATR	w	MTR	ATR	w	MTR	ATR	w	MTR	ATR	w	MTR	ATR
2005	78.4	20.6	11.5	3.4	21.5	10.9	10.7	28.4	18.3	0.6	20.3	14.3	3.4	19.9	11.3
2006	77.8	18.8	11.9	3.5	16.5	9.3	10.2	29.5	18.1	0.5	21.7	13.3	3.2	18.3	10.0
2007	78.7	18.6	10.2	2.7	14.3	6.3	10.0	29.4	17.4	0.4	23.7	12.7	2.3	19.1	8.6
2008	78.4	19.3	11.3	2.8	12.5	6.7	10.0	28.9	18.3	0.4	23.9	14.9	1.7	16.7	9.3
2009	75.6	15.9	9.4	2.6	9.4	6.4	10.7	20.1	13.1	0.5	13.5	11.4	3.7	12.4	7.1
2010	74.0	16.1	9.6	2.4	9.4	6.5	11.4	19.6	12.9	0.4	15.2	13.2	4.2	13.7	7.7
2011	74.4	15.7	9.7	2.4	11.5	5.3	11.7	19.7	12.1	0.5	17.1	10.8	3.4	13.8	9.0
2012	74.8	16.3	10.1	2.3	16.0	6.9	11.6	19.3	11.8	0.5	19.1	12.1	2.9	14.0	6.1
2013	74.9	16.1	9.7	2.3	12.0	5.3	11.8	17.8	11.2	0.7	19.9	11.0	3.2	13.3	5.2
2015	75.3	16.8	10.3	2.2	14.1	6.4	11.5	18.8	12.3	0.7	16.7	9.5	2.4	15.8	8.3
2016	75.0	17.2	10.6	2.5	12.5	6.2	11.6	19.2	12.8	0.7	18.2	10.4	2.0	7.3	4.7
2017	75.8	16.9	10.9	2.7	13.9	6.6	10.9	19.7	13.0	0.6	18.8	9.9	1.7	11.7	6.6
2018	74.7	16.5	11.4	3.0	13.0	7.1	11.3	19.7	13.5	1.0	16.9	10.5	1.4	11.0	6.6
2019	73.4	15.8	11.8	3.2	13.8	7.8	11.2	18.8	13.9	0.9	20.8	13.2	1.4	15.1	8.8
Average	**75.8**	**17.2**	**10.6**	**2.7**	**13.6**	**7.0**	**11.0**	**22.1**	**14.2**	**0.6**	**19.0**	**11.9**	**2.6**	**14.4**	**7.8**

Note: Table continuous on the following page

Year	Student (%) w	Student (%) MTR	Student (%) ATR	Old-age pension (%) w	Old-age pension (%) MTR	Old-age pension (%) ATR	Disability pension (%) w	Disability pension (%) MTR	Disability pension (%) ATR	Parental leave (%) w	Parental leave (%) MTR	Parental leave (%) ATR
2005	0.5	12.9	10.0	2.3	14.7	12.6	0.0	NA	NA	0.8	17.5	12.0
2006	1.3	15.4	13.5	2.3	15.5	13.2	0.2	10.2	9.6	1.0	11.9	9.8
2007	1.3	10.9	11.9	3.1	12.8	13.1	0.5	13.0	8.3	1.0	15.4	10.3
2008	1.7	9.8	11.4	3.3	16.9	13.5	0.5	5.4	5.6	1.1	15.9	10.3
2009	1.8	12.8	14.0	3.6	15.8	16.9	0.5	2.8	6.0	1.1	15.2	8.8
2010	1.7	10.9	11.3	4.3	21.0	17.4	0.5	6.1	6.8	1.1	14.8	9.8
2011	1.9	11.0	13.4	4.1	14.4	10.6	0.4	9.6	6.6	1.2	13.1	9.9
2012	1.7	2.8	3.3	4.6	14.0	6.9	0.6	3.5	2.5	1.1	8.6	3.3
2013	1.8	2.8	7.7	3.9	14.5	7.1	0.5	3.9	2.7	0.9	13.1	6.0
2015	1.9	4.6	7.4	4.8	16.2	7.8	0.4	0.3	1.6	0.8	9.4	4.5
2016	2.1	3.3	7.3	4.6	13.1	8.2	0.5	2.9	2.6	1.0	7.1	3.0
2017	1.9	7.4	8.8	4.9	16.3	7.8	0.4	3.0	2.9	1.1	14.6	5.5
2018	2.0	7.3	8.6	4.8	9.9	7.6	0.6	9.3	4.5	1.2	9.7	3.9
2019	1.8	6.2	8.8	6.1	13.3	9.4	0.7	11.1	5.4	1.3	8.3	5.3
Average*	**1.7**	**8.4**	**9.8**	**4.1**	**14.9**	**10.9**	**0.5**	**6.2**	**5.0**	**1.1**	**12.5**	**7.3**

Note: w – share of the group in the sample according to the SILC's weight **Averaged across means by years*

Table A4: Summary Statistics on MTR and ATR, by Social Groups (excluding SHIS and social benefits)

Year	Full-time employee (%)			Part-time employee (%)			Self-employed full-time (%)			Self-employed part-time (%)			Unemployed (%)		
	w	MTR	ATR	w	MTR	ATR	w	MTR	ATR	w	MTR	ATR	w	MTR	ATR
2005	78.3	32.7	23.9	3.4	33.7	23.3	10.6	28.8	18.6	0.6	20.3	14.3	3.4	32.2	22.7
2006	77.8	31.1	24.3	3.5	28.9	21.6	10.2	29.7	18.3	0.5	21.8	13.7	3.2	24.7	19.8
2007	78.7	30.7	22.6	2.7	26.5	18.6	10.0	29.6	17.7	0.4	23.7	13.0	2.3	31.4	19.6
2008	78.4	31.2	23.6	2.8	24.8	19.0	10.0	28.9	18.5	0.4	27.4	16.2	1.7	26.5	19.8
2009	75.6	26.2	21.7	2.6	21.0	18.5	10.7	20.1	13.4	0.5	14.8	12.8	3.7	23.0	18.5
2010	74.0	24.7	20.3	2.4	19.7	17.1	11.4	19.6	13.2	0.4	15.8	14.4	4.2	23.2	17.7
2011	74.4	25.6	20.5	2.4	22.3	15.9	11.7	19.7	12.4	0.5	17.3	11.7	3.4	23.8	18.6
2012	74.8	26.4	20.9	2.3	25.7	17.1	11.6	20.6	12.0	0.5	19.0	12.5	2.9	24.8	16.2
2013	74.9	26.2	20.5	2.3	20.4	15.0	11.8	18.1	11.4	0.7	20.4	12.0	3.2	23.0	14.6
2015	75.3	27.2	21.1	2.2	23.4	16.4	11.5	18.8	12.4	0.7	17.7	10.0	2.4	26.4	17.1
2016	75.0	27.4	21.5	2.5	21.2	16.2	11.6	19.2	13.1	0.7	19.1	10.8	2.0	14.6	13.1
2017	75.8	26.1	21.7	2.7	23.3	16.4	10.9	19.8	13.2	0.6	23.2	10.9	1.7	22.0	15.5
2018	74.7	27.3	22.2	3.0	22.3	17.0	11.3	19.8	13.7	1.0	17.1	10.7	1.4	22.0	16.3
2019	73.4	26.4	22.6	3.2	21.8	17.8	11.2	19.1	14.2	0.9	21.2	13.6	1.4	25.6	18.1
Average*	**75.8**	**27.8**	**22.0**	**2.7**	**23.9**	**17.9**	**11.0**	**22.3**	**14.4**	**0.6**	**19.9**	**12.6**	**2.6**	**24.5**	**17.7**

Note: Table continuous on the following page

Year	Student (%) w	MTR	ATR	Old-age pension (%) w	MTR	ATR	Disability pension (%) w	MTR	ATR	Parental leave (%) w	MTR	ATR
2005	0.5	19.2	19.2	2.2	20.0	22.0				0.8	19.1	19.8
2006	1.3	25.7	21.5	2.3	25.0	23.7	0.2	18.5	17.9	1.0	23.8	21.4
2007	1.3	21.9	20.6	3.1	24.3	23.5	0.5	24.2	17.8	1.0	27.5	21.6
2008	1.7	18.6	18.4	3.3	26.3	23.5	0.5	9.1	13.8	1.1	24.3	21.1
2009	1.8	19.2	20.9	3.6	25.3	26.8	0.5	13.2	15.8	1.1	16.4	17.5
2010	1.7	16.5	17.5	4.3	24.2	25.5	0.5	15.9	15.7	1.1	16.2	17.1
2011	1.9	18.7	19.9	4.1	24.4	19.4	0.4	20.2	16.2	1.2	20.8	18.1
2012	1.7	10.7	9.3	4.6	23.3	15.9	0.6	11.3	11.3	1.1	16.2	11.9
2013	1.8	8.0	11.8	3.9	23.9	14.9	0.5	15.0	11.5	0.9	22.9	14.9
2015	1.9	7.5	10.1	4.8	25.4	15.7	0.4	8.7	9.7	0.8	16.7	13.2
2016	2.1	11.0	11.5	4.6	23.3	16.1	0.5	14.7	11.0	1.0	17.8	11.9
2017	1.9	15.7	13.1	4.9	25.4	15.3	0.4	12.4	11.5	1.1	19.1	12.7
2018	2.0	10.5	11.2	4.8	20.0	14.9	0.6	20.2	12.9	1.2	20.4	12.8
2019	1.8	8.9	11.2	6.1	23.3	16.9	0.7	21.9	13.2	1.3	17.5	13.4
Average	**1.7**	**15.2**	**15.4**	**4.0**	**23.9**	**19.6**	**0.5**	**15.8**	**13.7**	**1.1**	**19.9**	**16.3**

Note: w – share of the group in the sample according to the SILC's *weights, Average across means by years.*

Table A5: Summary Statistics for MTR and ATR, by Social Groups (including SHIS, but excluding social benefits)

Year	Full-time employee		Part-time employee		Self-employed full-time		Self-employed part-time		Unemployed	
	μ (INS)	μ	μ (INS)	μ	μ (INS)	μ	μ (INS)	μ	μ (INS)	μ
2005	1.45	1.89	1.55	2.10	1.66	1.65	1.47	1.48	1.51	1.86
2006	1.34	1.65	1.40	1.84	1.74	1.75	1.67	1.71	1.29	1.92
2007	1.43	1.91	1.50	2.37	1.80	1.82	1.94	1.99	1.73	2.36
2008	1.39	1.79	1.36	1.92	1.67	1.69	1.82	1.69	1.40	1.88
2009	1.25	1.75	1.16	1.49	1.56	1.59	1.17	1.20	1.28	1.79
2010	1.25	1.74	1.17	1.47	1.54	1.58	1.11	1.17	1.35	1.84
2011	1.28	1.67	1.46	2.23	1.66	1.69	1.52	1.65	1.32	1.58
2012	1.31	1.67	1.58	2.44	1.80	1.72	1.58	1.64	1.62	2.39
2013	1.33	1.73	1.40	2.37	1.64	1.66	1.79	1.91	1.66	2.68
2015	1.34	1.70	1.49	2.28	1.57	1.58	1.85	1.84	1.63	1.99
2016	1.32	1.68	1.34	2.08	1.52	1.55	1.86	1.82	1.13	1.59
2017	1.23	1.60	1.49	2.19	1.56	1.58	2.29	2.01	1.48	1.82
2018	1.27	1.50	1.35	1.89	1.50	1.52	1.66	1.66	1.40	1.71
2019	1.20	1.38	1.26	1.82	1.38	1.38	1.62	1.65	1.48	1.78
Average	**1.31**	**1.69**	**1.39**	**2.04**	**1.61**	**1.63**	**1.67**	**1.67**	**1.45**	**1.94**

Note: Table continuous on the following page

	Student		Old-age pension		Disability pension		Parental leave	
Year	μ (INS)	μ	μ (INS)	μ	μ (INS)	μ	μ (INS)	μ
2005	1.00	1.31	0.90	1.18			0.96	1.50
2006	1.23	1.16	1.06	1.19	1.03	1.06	1.13	1.23
2007	1.07	0.91	1.04	0.97	1.41	1.62	1.33	1.53
2008	1.01	0.85	1.14	1.28	0.65	0.97	1.17	1.60
2009	0.91	0.91	0.93	0.93	0.82	0.46	0.93	1.80
2010	0.93	0.96	0.94	1.23	1.02	0.89	0.94	1.55
2011	0.93	0.81	1.30	1.38	1.28	1.48	1.16	1.34
2012	1.16	0.84	1.54	2.10	1.01	1.38	1.39	2.65
2013	0.67	0.35	1.69	2.13	1.33	1.48	1.62	2.27
2015	0.73	0.62	1.71	2.18	0.89	0.18	1.29	2.13
2016	0.95	0.44	1.51	1.64	1.37	1.09	1.54	2.44
2017	1.22	0.84	1.77	2.18	1.08	1.04	1.56	2.79
2018	0.93	0.85	1.39	1.33	1.64	2.11	1.67	2.53
2019	0.79	0.70	1.44	1.45	1.75	2.12	1.34	1.59
Average	**0.97**	**0.82**	**1.31**	**1.51**	**1.17**	**1.22**	**1.29**	**1.93**

Note: Average across means by years.

Table A6: Estimate of μ, by Social Groups (including SHIS but excluding social benefits)

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