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Pro-Rich Inflation and Optimal Income Taxation

Abstract

This paper studies the implications of an increase in the price of necessities, which disproportionally hurts the poor, for optimal income taxation. Our analyses show that, when the government is utilitarian and disutility from labor supply is linear, the optimal net nominal tax schedule is unchanged and the government expects households to supply more labor in order to secure their consumption expenditures. Quantitative analyses with convex disutility of labor supply reveal that, because of positive labor supply effects, keeping average tax rates constant suffices to optimally react to the asymmetric price shock. However, the poorest agents are expected to increase their labor supply the most. Thus, optimal income tax policy in response to asymmetric price changes does not prevent the disproportional decline in the indirect utility of poorer households.

JEL-Codes: H210, E310.

Keywords: pro-rich inflation, optimal income taxation.

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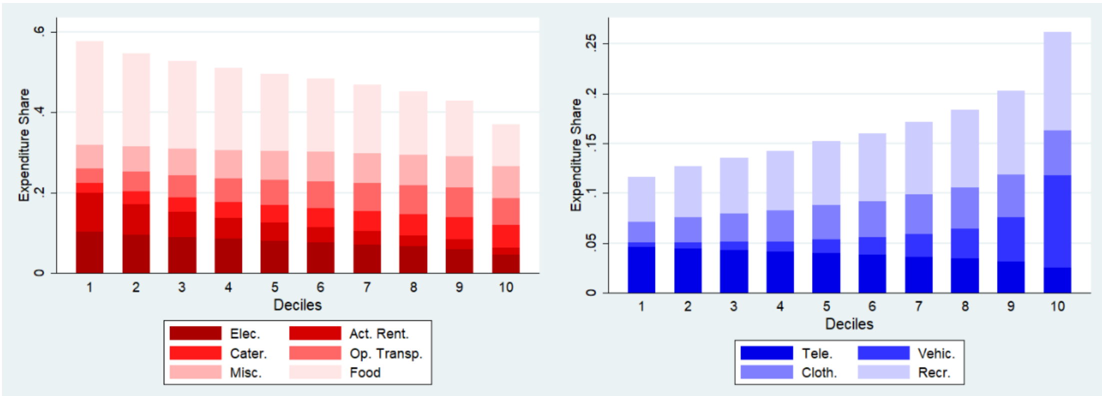
1. Introduction

The expenditure share of necessities in the total budget of households usually declines in income leading to non-linear Engel curves. Hence, a change in the relative price of necessities has an asymmetric impact on the utilities of households across the income distribution.[1] This may create a case for the government to adapt redistributive policies in an optimal income tax setting. The impact of such price changes on the optimal income tax policy has remained largely unexplored.

Figure 1: Pro-rich Inflation in Europe



Notes: Based on unweighted averages across 25 EU countries between 2001 and 2015. Elec.: electricity, gas and other fuels.; Act. Rent.: actual rentals of housing; Cater.: catering services; Op. Transp.: operation of personal transport and equipment; Misc.: miscellaneous goods and services; Tele.: telephone and telefax services and equipment; Vehic.: purchase of vehicles; Cloth.: clothing; Recr.: recreation and culture.
Source: Gürer and Weichenrieder (2020)

At the same time, possible implications of a systematic variation in expenditure shares and prices on income inequality (hence, on total welfare from a utilitarian perspective) have been widely discussed.[2] Recently, Gürer and Weichenrieder (2020) describe diverging price developments for 25 EU countries over the period of 2001-15. Figure 1, taken from Gürer and Weichenrieder (2020), summarizes the systematic variation for this period.[3] In the figure, items depicted in red (left panel) represent a price increase above the average Consumer Price Index (CPI), whereas blue items (right panel) experienced a

[1] See Muellbauer (1974).
[2] See, e.g., Cage et al. (2002), Crawford and Smith (2002), Garner et al. (2003), Goni et al. (2006), Arndt. et al. (2015), Lluberas (2018), among others.
[3] Expenditure shares and prices are simple averages across 25 EU countries. See Gürer and Weichenrieder (2020) for further details on the construction of Figure 1.

price increase below the CPI. The darker red (blue) the item gets, the higher (lower) the price increase has been. Expenditure groups that can qualify as necessities, such as "Actual Rentals of Housing", "Electricity, gas and other fuels" and "Food", constitute a significantly higher fraction of the total budget for the lower deciles. At the same time, these items have been exposed to an above-average price increase. We name this phenomenon as "pro-rich inflation".

This study explores the implications of pro-rich inflation for optimal income tax policy. We use a model with multiple consumption goods for which subsistence levels and therefore expenditure shares differ across rich and poor households. First, we derive the comparative statics of a basic intuitive model with a linear disutility of labor. Interestingly, based on Stone-Geary utility, our analytical results show that an increase in the price of necessities increases households' labor supply such that the price increase on the subsistence consumption can be covered out of the additional market income. Given our assumptions of homogenous preferences and identical national prices across households, the additional gross income requirement is the same for all households irrespective of their position in the income distribution. Price increases that fall on items with high subsistence levels (hence, with higher expenditure shares for the poor) particularly harms the indirect utility of lower ability households because they must work more hours to provide the same additional income.

In a next step, we use the price data for 12 consumption goods for the period 1996-2017 and calibrate our model to three EU countries that empirically have been quite differently affected by pro-rich inflation during this time period: Germany, the United Kingdom and Czech Republic. Unlike in our first part, this calibration allows for non-linear disutility of labor. Our results show that the optimal government response is to increase net nominal taxation. Average taxes, on the other hand, hardly respond to asymmetric price changes. Given that taxes had been optimal before the relative price changes, the mere additional net nominal taxes (subsidies) on the rich (poor) that arise due to the increasing labor supplies (and gross incomes) suffice to respond optimally to the price changes.

On the household side, similar to the analytical results, poorer agents must increase their labor supply more in order to meet additional income requirement brought about by higher prices. However, poorer households still lose a higher percentage of their total indirect utility compared to richer, as in the case of linear disutility.

So far, the literature on optimal income taxation (initiated by Mirrlees (1971)) includes only very few contributions that, as ours does, consider the implications of introducing subsistence levels of consumption. Unlike our study, however, the existing literature primarily focuses on the heterogeneity of this subsistence level across individuals. Row and Woolley (1999) provide an example with four agents. Kaplow (2008) considers heterogeneity in many dimensions as well as subsistence levels. Judd et al. (2018) simulates optimal income tax schedules with households that differ with respect to up to five characteristics, including basic needs (subsistence levels).

Another feature of our paper is the introduction of differentiated prices for different goods. Again, the literature on this is sparse, but some examples exist. Albuoy (2009) considers regionally differentiated price levels with an emphasis on federal taxation when cost-of-living differs across cities. Kushnir and Zubrickas (2019) build a general equilibrium model and quantifies the effect of endogenously determined housing prices on the optimal income tax schedule. Kessing et al. (2020) study productivity enhancing taxation with regions that vary in productivity and hence in the price of labor.

The remainder of this paper proceeds as follows. The next section introduces the features of the general framework used throughout the paper. Section 3 derives comparative statics over a basic version of the model. Section 4 calibrates the model to three EU countries (Germany, the UK, and the Czech Republic) and presents the results. Finally, Section 6 concludes.

2. The Model

This section introduces the general theoretical framework. We employ a discrete version of the Mirrlees optimal income tax model with multiple consumption goods.

There are discrete sets of agents and goods, respectively indexed by $i \in I$ and $g \in G$, in the economy. Fractions of agents are denoted by f^i, with $\sum_{i \in I} f^i = 1$. Every agent i has a wage rate w^i and supplies labor l^i to earn gross income $Y_G^i = w^i l^i$. The information structure of the model is standard. The government observes Y_G^i but not w^i when optimally choosing a non-linear income tax schedule $T(Y_G^i)$. Following the payment of taxes, agents end up with net income $Y_N^i = Y_G^i - T(Y_G^i)$.

Agents have an identical utility function U^i, which is a function of consumption goods and labor supply:

$$U^i = \sum_{g \in G} u_g\left(c_g^i - \gamma_g\right) - v(l^i) \tag{1}$$

We assume that $u'(.) > 0, u''(.) < 0$. Properties of $v(.)$ are introduced as we proceed. In Equation (1), γ_g is the subsistence parameter for good g. The introduction of the subsistence parameters renders the sub-utility of consumption non-homothetic and allows us to generate diverse expenditure shares for different individuals, depending on their income.

It should be noted that, in our model, individual preferences are homogeneous and exhibit separability between consumption goods and labor supply. Hence, the uniform commodity taxation theorem of Atkinson and Stiglitz (1976) holds.[4] Therefore, optimal income taxation emerges as the dominant tool to redistribute income in this framework and differential taxes on goods may be ignored.

An agent's budget constraint reads:

$$\sum_{g \in G} p_g c_g^i = Y_N^i \tag{2}$$

where p_g represents the price of good g. We use exogenous changes in the p_g's to generate pro-rich inflation in the model.

Consider a utilitarian government that maximizes the weighted sum of individual utilities. Formally, the government maximizes social welfare by assigning Y_G^i, Y_N^i pairs for each $i \in I$. The social welfare function reads:

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[4] Revesz (2014) investigates differentiated commodity taxation when households have heterogenous expenditure shares on the various goods. However, agents in his model have heterogeneous preferences.

$$W = \sum_{i \in I} f^i U^i \tag{3}$$

While maximizing W, the government has to ensure that resulting allocations are feasible and incentive compatible. Hence, equations (4) and (5) enter to the maximization problem of the government as constraints.

$$\sum_{i \in I} f^i \left(Y_G^i - Y_N^i\right) = 0 \tag{4}$$

$$U^i \geq U^{i|i'} \tag{5}$$

In inequality (5), $U^{i|i'}$ represents the utility of the agent with ability w^i who is mimicking the allocations of the agent with ability $w^{i'}$, that is $Y_G^{i'}, Y_N^{i'}$. In the rest of this paper, we assume $w^i > w^{i'}$, rendering (5) a downwards binding incentive compatibility constraint.[5]

It is intuitive to consider our economy in two separate stages. In the first stage, agents supply labor and earn gross income. Simultaneously, the government chooses an optimal non-linear income tax schedule. Payment of the taxes determines the net incomes of individuals. This completes the first stage. In the second stage, agents choose their consumption bundles by deciding the amount of expenditure on each good.

In order to solve the model, we proceed backwards. First, considering net incomes as exogenous, we maximize the sub-utility of consumption (first term in (1)) with respect to the budget constraint given in (2). This straightforward maximization yields the demand of each good as a function of Y_N^i. This completes the solution of the second stage. After substituting the demand functions into (3), equations (3), (4) and (5) represent a standard Mirrleesian optimal income tax problem that can be solved using standard techniques.

We should note that, in principle, a change of consumption prices might be accompanied by a change of the wages across ability types.

[5] If the utility function is concave and Spence-Mirrlees single-crossing condition is satisfied, using only downwards binding incentive compatibility constraints is sufficient. See Hellwig (2007). Both conditions hold in our framework.

The analysis in this paper abstracts from this. A wage invariance may result if, for example, domestic price increases derive from a price increase of a foreign sourced input, say energy, leading to income increases abroad rather than in the country under consideration. Another justification for this simplification is that optimal redistribution as a function of the wage structure is well understood in the literature on optimal taxation and the policy discussion in many countries seems to monitor wage developments carefully. The same cannot be claimed for income dependent inflation effects.

3. Analytical Results When Disutility of Labor Is Linear

In order to build intuition, this section derives some comparative statics over a simple version of the model presented in the previous section.

In the spirit of Stiglitz (1982), there are high and low productivity agents in the economy, that is $i \in \{H, L\}$. They consume two consumption goods, labelled as necessities (c_n) and luxuries (c_x). The price of the necessity good is denoted by p_n, whereas the price of the luxury good is normalized to 1. Hence, p_n can be considered as the price of necessities relative to luxuries. For the subsistence parameters, we assume that $\gamma_n > 0$ and $\gamma_x = 0$ in order to generate a higher expenditure share on necessities for poorer households.

Agents' utility function reads:

$$U^i = \beta_n log(c_n^i - \gamma_n) + \beta_x \log(c_x^i) - v \frac{Y_G^i}{w^i} \tag{6}$$

where $\beta_n > 0$ and $\beta_x > 0$ are marginal budget shares that satisfy $\beta_n + \beta_x = 1$. Note that sub-utility from consumption satisfies usual concavity conditions (and corresponds to Stone-Geary preferences). Linear disutility from labor supply is a simplification introduced for two reasons.[6] The first reason, obviously, is its analytical convenience, which allows closed-form expressions for optimal net taxes. The

[6] See Hamilton and Pestiau (2005), Aronsson and Blomquist (2008) for two examples of optimal tax analysis with linear disutility from labor supply.

second reason is that linear disutility produces an interesting special case that highlights an important labor-supply mechanism, which is triggered by price changes.

As explained in the previous section, the solution of the model starts with the second stage where households choose consumption bundles given their net incomes. This is equivalent to maximization of the sub-utility of consumption in (6) given the budget constraint $p_n c_n^i + c_x^i = Y_N^i$. The maximization yields the following demand functions.[7]

$$c_n^i = \gamma_n + \frac{\beta_n}{p_n}(Y_N^i - p_n\gamma_n) \tag{7}$$

$$c_x^i = \beta_x(y_N^i - p_n\gamma_n) \tag{8}$$

After substituting (7) and (8) into (6), we are ready to construct and solve the government's maximization problem represented by equations (3), (4) and (5).[8]

Our main interest is to understand how optimal income taxes react to a price increase in necessities, p_n. Proposition 1 summarizes our results.

Proposition 1:

(i) $\frac{\partial T(Y_G^i)}{\partial p_n} = 0$, for $i = H, L$

(ii) $\frac{\partial Y_G^i}{\partial p_n} = \frac{\partial Y_N^i}{\partial p_n} = \gamma_n$, for $i = H, L$

(iii) $\frac{\partial l^L}{\partial p_n} > \frac{\partial l^H}{\partial p_n}$

See Appendix A for the proof.

In Proposition 1, (i) suggests that the government does not change the net tax (subsidy) on high (low) type in response to pro-rich

[7] Let $s_n^i = \frac{p_n c_n^i}{p_n c_n^i + p_n c_x^i}$ denote the expenditure share on necessities. Note that $\frac{\partial s_n^i}{\partial Y_N^i} < 0$. The expenditure share on necessities decreases in net income.

[8] Note that the incentive compatibility constraint given in equation (5) reads: $\beta_n \ln\left(\frac{\beta_n}{p_n} y_N^H - \beta_n\gamma_n\right) + \beta_x \ln(\beta_x(y_N^H - p_n\gamma_n)) - v y_G^H / w^H \geq \beta_n \ln\left(\frac{\beta_n}{p_n} y_N^L - \beta_n\gamma_n\right) + \beta_x \ln(\beta_x(y_N^L - p_n\gamma_n)) - v y_G^L / w^H$.

inflation. (*ii*) clarifies the reason: agents can be expected to compensate the price increase by working more. Both high and low type agents increase their labor supply exactly to the extent that they secure their subsistence consumption expenditure. This corresponds to an increase in net incomes that amounts to $\Delta p_n \gamma_n$.[9] The idea of securing subsistence consumption (made explicit by the term $\Delta p_n \gamma_n$) is the driving force behind most of the results in this study. Note that gross incomes of high and low types increase by the same amount as the net tax and net subsidy stay constant. Despite agents of both types requiring the same additional amount of income, (*iii*) reveals that pro-rich inflation still has an asymmetric impact on the resulting indirect utilities.[10] In order to achieve the same increase in net and gross income, low ability households must work more due to their lower wage.

It should be emphasized that our results do not mean that pro-rich inflation is beneficial for the rich. Indeed, they face the same pressure ($\Delta p_n \gamma_n$) as the poor do in monetary terms. Yet, the poor are less capable of coping with this pressure.

We should note that the optimal reaction of redistribution to a price increase of necessities is different from the reaction that derives from a wage change. One might be tempted to presume that as a price increase on necessities disproportionally hits the low ability type, it is similar in effect to a reduction in the real wage and the productivity of this type. The policy reaction is different, though, as an exogenous reduction of the real wage of the poor indeed would lead to a change in optimal policy. The reason is that a reduced productivity of the low ability type reduces the cost of distorting the labor supply of the poor. Hence, a further distortion becomes optimal to ease the self-selection constraint of the high ability type. The marginal tax rate of the low ability type increases and the absolute tax paid by high ability types goes up as well. In the above model, these effects are absent in case the real wage is affected by a price increase of necessities. Intuitively, the price increase may reduce the consumption value of a euro of redistribution, but does not affect the relative productivities.

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[9] Note that the average tax rate on the high type falls as net tax remains constant and gross income increases.

[10] The decline in the sub-utility of consumption is equal, in absolute terms, for high and low type agents. See Appendix A for a proof.

As mentioned above, Proposition 1 represents an extreme case in which the government does not interfere at all. This is a result of assuming a linear disutility of labor. When the disutility on total welfare is linear, the government is not concerned about the asymmetric changes in the labor supply behavior. What is the extent of governmental compensation in response to pro-rich inflation when disutility of labor is assumed to be convex? How would the resulting indirect utilities of different agents change? The next section offers quantitative evidence from simulation exercises to answer these questions.

4. Exemplary Model Simulations

This section simulates the model presented in Section 2 for three countries (Germany, the United Kingdom, and the Czech Republic) using 1996 and 2017 prices. According to the results of Gürer and Weichenrieder (2020, Figure 6), the severity of pro-rich inflation in these countries can be classified as follows: Germany – low to mid range, the UK – mid to high range, and the Czech Republic – high.

The datasets used in our calibrations are the EU Household Budget Surveys (HBSs) of 2010 and the Harmonized Index of Consumer Prices (HICP). See Appendix B for a description of these datasets. Note that, presently, only the 2010 wave of the EU Household Budget Survey is available for researchers. Therefore, our analysis keeps everything constant, including wages and wage structure, and concentrates on price variations. Fortunately, the Eurostat price data for the period 1996-2017 is available for public use.[11] Our results may be viewed as a worked out example, based on real-world expenditure structures and price developments. Therefore, it is more realistic than the highly stylized model of the previous section.

In essence, by using the 2010 cross-section of the EU HBSs, we construct agents with different income levels in three countries based on expenditure shares observed in 2010. Following this, we separately calibrate the model with the prices of 1996 and 2017 to see how

[11] Unlike in Gürer and Weichenrieder (2020), the data used in this paper begin in 1996. The reason for the differing periods is due to different availability of price data for different COICOP categories. Gürer and Weichenrieder (2020) use a combination of Level 1 and Level 2 categories, whereas this study uses only Level 1 categories.

governments and households optimally react to these exogenous changes in prices when everything else remains unchanged.

4.1 Calibration

In the simulations, we use four agents (set I) and 12 goods (set G) for each country. The agents correspond to the 10th, 33rd, 66th and 90th percentiles (see Appendix D for the construction of agents). The 12 goods represent the first level of COICOP categories (see Table 1 for the names of the categories).

The utility function is specified as follows:

$$U^i = \sum\nolimits_{g \in G} \beta_g log\left(c_g^i - \gamma_g\right) - \frac{\left(\frac{Y_G^i}{w^i}\right)^{(1+\frac{1}{\varepsilon})}}{(1+\frac{1}{\varepsilon})} \tag{9}$$

Note that, in (9), disutility from labor supply is convex for $\varepsilon > 0$: $v'(.) > 0$, $v''(.) > 0$. Marginal budget shares satisfy $\sum_{g \in G} \beta_g = 1$.

Table 1: Results of the Parameter Estimation

	CZ		DE		UK	
Good Categories	β_g	γ_g	β_g	γ_g	β_g	γ_g
Food and Non-alcoholic Beverages	0.184	0.311	0.124	0.897	0.120	0.524
Alcoholic beverages and Tobacco	0.031	0.007	0.016	0.151	0.030	0.026
Clothing and Footwear	0.059	-0.065	0.059	-0.061	0.060	-0.212
Housing	0.190	0.554	0.097	3.609	0.179	0.906
Furnishing, Household Equipment	0.074	-0.075	0.068	-0.286	0.073	-0.189
Health	0.023	0.067	0.053	-0.171	0.013	-0.023
Transport	0.135	-0.299	0.186	-0.723	0.166	-0.512
Communications	0.047	0.034	0.024	0.327	0.029	0.133
Recreation and Culture	0.117	-0.088	0.140	-0.272	0.131	-0.313
Education	0.009	-0.024	0.012	-0.049	0.018	-0.112
Restaurants and Hotels	0.058	-0.060	0.066	-0.160	0.100	-0.235
Misc. Goods	0.073	-0.016	0.155	-0.460	0.081	0.051

Notes: Reported values for γ_g are in annual (000) EUR units.

First, by using household level data, we perform a linear expenditure system estimation for each of the three countries in order to recover marginal budget shares (β_g) and subsistence parameters (γ_g). See Appendix C for details regarding the underlying data work and estimation procedure.

Table 1 presents the results of the estimation. Note that categories which can be naively classified as necessities such as "Food and Non-alcoholic Beverages" and "Housing" have higher subsistence parameters compared to the rest of the goods. These high subsistence levels are needed to receive expenditure shares that are declining in income levels. For some goods, there are negative subsistence levels. Pollak (1971) notes the possibility of obtaining negative values as a result of LES estimation. He mentions that interpreting γ_g as the subsistence level may no longer be valid, if it is negative for all goods. This is not the case in our results. Kaplow (2008) suggests that negative subsistence levels can be thought of as endowments, although it is typical to assume that these levels are greater than zero in Stone-Geary preferences. We prefer to keep negative γ_g values in our main specification and stick with the subsistence level interpretation. The reason for this choice is that, when negative γ_g values are not allowed, price elasticity of demand is never greater than one. This outcome is not empirically supported. On the other hand, in Appendix E, we check the robustness of our conclusions by imposing a non-negativity condition on γ_g in the linear expenditure system estimation (Table E.1). Our findings are robust.

Simulations require price observations for each of the 12 categories in three countries in 1996 and 2017. As mentioned earlier, we recover this information from the HICP dataset. Table 2 provides the prices (using 2010 as the base year) and their corresponding rates of increase over the period of interest.

Table 2: Prices in 1996 and 2017

Good Categories	CZ 1996	CZ 2017	CZ Incr.	DE 1996	DE 2017	DE Incr.	UK 1996	UK 2017	UK Incr.
Food and Non-alcoholic Beverages	0.831	1.245	0.499	0.852	1.164	0.366	0.721	1.095	0.519
Alcoholic beverages and Tobacco	0.521	1.250	1.400	0.640	1.181	0.847	0.603	1.384	1.297
Clothing and Footwear	1.226	1.026	-0.163	0.983	1.090	0.109	2.066	1.077	-0.479
Housing	0.293	1.136	2.880	0.731	1.098	0.503	0.611	1.217	0.992
Furnishing, Household Equipment	0.961	0.955	-0.006	0.928	1.046	0.127	0.932	1.121	0.203
Health	0.417	1.109	1.660	0.717	1.056	0.474	0.664	1.196	0.801
Transport	0.734	1.031	0.406	0.733	1.078	0.472	0.651	1.149	0.763
Communications	0.567	0.812	0.433	1.497	0.909	-0.393	1.221	1.196	-0.021
Recreation and Culture	0.781	1.034	0.325	0.954	1.088	0.140	0.977	1.041	0.066
Education	0.474	1.120	1.364	0.603	0.974	0.616	0.394	1.742	3.419
Restaurants and Hotels	0.576	1.154	1.006	0.802	1.198	0.494	0.632	1.219	0.931
Misc. Goods	0.584	1.103	0.889	0.806	1.077	0.336	0.677	1.089	0.609

Notes: 2010 is used as the base year. Incr. denotes the overall price growth between 1996 and 2015.

In our main specification, we set the Frisch elasticity of labor supply (ε) to a widely used value of 0.5. The previous section made it clear that changes in labor supply can be important for optimal policy reactions. Therefore, the choice of ε may play a crucial role for our results. Hence, in Appendix E, we check the robustness of our results to setting ε to 0.33 (see Chetty (2012)) and to 0.75. See Tables E.2 and E.3. Our conclusions are robust to the choice of ε.

The next task is to determine wage rates for four agents in each country. By using empirically observed yearly total expenditure values (that represents the net incomes by assumption) for each country and percentile, we estimate wage rates adopting Saez's (2001) approach. Agents′ first order condition with respect to labor supply reads:

$$1 - T'\left(Y_G^i\right) = \left(\frac{1}{w^i}\right)\left(\frac{Y_G^i}{w^i}\right)^{(1/\varepsilon)}\left(Y_N^i - \sum_{g=1}^{12} p_g\,\gamma_g\right) \tag{10}$$

In (10), we already have the information on p_g, γ_g, ε and Y_N^i. Next, we use the OECD tax-and-benefit model to extract information on the actual tax schedule of three countries in 2010 in order to recover $T'(Y_G^i)$, Y_G^i. See Appendix D for the details of the simulations with OECD tax-and-benefit model. Table 3 presents the marginal effective tax rates (METR) and average tax rates (ATR) on percentiles of interest in three countries. After substituting the relevant variables into (10), it is trivial to obtain yearly wage rates. Note that, in what follows, we set f^i (the fraction of each wage rate type) to 0.25 in each country.

Table 3: Actual Tax Schedules in 2010

	CZ		DE		UK	
Percentiles	METR	AETR	METR	AETR	METR	AETR
10^{th}	0.518	0.097	0.457	0.326	0.353	-6.555
33^{rd}	0.311	0.226	0.524	0.398	0.310	0.213
66^{th}	0.311	0.251	0.469	0.439	0.310	0.254
90^{th}	0.311	0.267	0.469	0.444	0.410	0.303

Notes: METR and AETR, respectively, stand for Marginal Effective Tax Rate and Average Effective Tax Rate. The results of OECD Tax and Benefit model simulations are reported. See Appendix D for details.

4.2 Results

In this section, given the parameters specified in the previous section, we separately compute the optimal policies for 1996 and 2017 prices. The first and second panel of Table 4 present the optimal policies in 1996 and 2017 for each country. Y_G, $T(Y_G)$, τ, $T'(Y_G)$ and V respectively stand for gross income, net tax (subsidy), average tax rate, marginal tax rate and indirect utility. V Loss % and l Incr. % represent the percentage loss in indirect utility and percentage increase in labor supply, respectively.

Table 4: Optimal Policies for 1996 and 2017 Prices

			1996					2017						
	Percentiles	Wage	Y_G	$T(Y_G)$	τ	$T'(Y_G)$	V	Y_G	$T(Y_G)$	τ	$T'(Y_G)$	V	l Incr. %	V Loss %
CZ	10th	7.17	5.71	-3.25	-0.570	0.207	7.16	5.80	-3.30	-0.570	0.214	6.55	1.61 %	8.51 %
	33th	10.38	8.94	-1.56	-0.174	0.248	7.28	9.05	-1.58	-0.174	0.255	6.67	1.30 %	8.30 %
	66th	14.51	13.80	0.86	0.062	0.192	7.41	13.95	0.88	0.063	0.197	6.81	1.12 %	8.08 %
	90th	20.00	21.40	3.95	0.185	0.000	7.59	21.61	4.01	0.185	0.000	7.00	0.99 %	7.81 %
DE	10th	20.48	13.83	-20.67	-1.494	0.282	8.21	13.93	-20.82	-1.494	0.286	7.91	0.73 %	3.66 %
	33th	37.82	31.20	-9.31	-0.298	0.311	8.30	31.39	-9.37	-0.298	0.315	8.00	0.60 %	3.60 %
	66th	57.62	54.27	4.07	0.075	0.261	8.43	54.55	4.12	0.075	0.264	8.14	0.51 %	3.51 %
	90th	88.46	98.90	25.90	0.262	0.000	8.64	99.34	26.07	0.262	0.000	8.34	0.45 %	3.40 %
UK	10th	3.16	1.01	-20.10	-19.994	0.315	7.98	1.01	-20.20	-19.995	0.318	7.55	0.46 %	5.35 %
	33th	21.32	16.01	-8.35	-0.522	0.348	7.99	16.07	-8.38	-0.522	0.351	7.56	0.38 %	5.34 %
	66th	36.15	32.45	2.26	0.070	0.320	8.10	32.55	2.28	0.070	0.322	7.67	0.32 %	5.25 %
	90th	64.72	74.60	26.19	0.351	0.000	8.30	74.81	26.30	0.352	0.000	7.88	0.29 %	5.10 %

Notes: Y_G: Gross Income, $T(Y_G)$: Net tax, τ: Average tax rate, $T'(Y_G)$: Marginal tax rate, V: Indirect utility, l Incr. %: Percent increase in labor supply, V Loss %: percent loss in indirect utility. Values of wage, Y_G and $T(Y_G)$ are in annual (000) Euro units.

Table 4 presents the optimal policies before (1996) and after (2017) asymmetric price changes for the four agents in three countries whose wages are recovered in the previous section. A comparison of the two panels reveals that, after asymmetric price changes, net nominal taxes (subsidies), $T(Y_G)$, on richer (poorer) percentiles increase in all countries. Comparison of τ in the first and the second panel, on the other hand, suggests that in each country, average tax rates remain almost unchanged. Hence, increased net nominal taxes on the rich, arising from an increased labor supply, suffices to provide the optimal response. Finally, marginal tax rates rise slightly for all agents (except for the agent at the top[12]) in order to meet the requirement of higher net nominal taxation.

On the household side, judging by the increased labor supply behavior of, for example, the 10th percentiles, we can infer that this increased net nominal subsidies do not fully insure poorer households against price increases. Note that labor supply responses are still asymmetric. Agents with lower ability must increase their supply more in response to price increases. Moreover, the indirect utility of low ability agents still declines disproportionately. Hence, it can be concluded that, even if the governments decide to optimally redesign their income tax schedules in response to price increases, poorer households are disproportionally harmed.

It should be noted that our model is not able to take into account possible changes in wage rates. While these rates are held constant in the model, they certainly have changed during the period 1996-2017. Recent trends in income inequality suggest that wage dispersion has increased over time in most countries. In addition, labor market reactions may trigger endogenous wage changes, if the need to work more (following an increase in necessity prices) faces a less than perfectly elastic labor demand.

The relationship of our findings to pro-rich inflation arises from the fact that, pro-rich inflation, as we define it, brings about higher price increases on items with highly positive subsistence levels (such as food and housing). This increases the additional market income requirement, thereby making the results more pronounced. That said, it should be noted that it is difficult to make cross-country comparisons with regards to pro-rich inflation. This is because any

[12] This is due to the well-established zero marginal tax rate at the top result.

result, for example, the magnitudes of declines in indirect utilities, depends on three characteristics of a country: agents' preferences (β_g and γ_g, in particular), price increases, and distribution of wage rates. Therefore, our results should be viewed separately for each country.

5. Conclusion

This study investigates the implications of an above average increase in the price of necessity goods (labelled as pro-rich inflation) on the design of tax policies.

Under the assumptions of utilitarian government and linear disutility from labor supply, tax policies are not affected by asymmetric increases in the labor supply across households. In this simplified case, our comparative statics suggest that each agent increases its labor supply such that he or she can secure the subsistence consumption expenditure. Since the households in a given country are assumed to have the same price changes and preferences, the additional net income required is identical for each agent. The increase in labor supply particularly hurts the indirect utility of low ability agents because they must increase their labor supply more compared to the others in order to provide the same additional income. At the same time, a welfarist government does not intervene when the disutility of labor is linear and is thus indifferent to who bears this utility cost.

Next, using the EU Household Budget Surveys and Harmonized Index of Consumer Prices, we numerically study the effect of an exogenous increase in prices on tax policies for three European countries (Germany, the United Kingdom, and the Czech Republic) while allowing a convex disutility of labor. Net nominal taxes on the rich increase. On the other hand, the average tax rates remain almost unchanged irrespective of the country of interest. Hence, we infer that increased gross incomes arising from increased labor supply largely suffice to provide the optimal response to asymmetric price changes when average taxes are kept constant. However, the optimal policy after price changes does not fully compensate poorer households. As in the highly stylized model of Section 3, the poorest agents in each country are the ones who must increase their labor supply the most. As a result, the optimal response of the government in income taxation does not suffice to prevent poorer households from being disproportionally hurt by such price increases.

Our analyses have excluded a few potentially important aspects. What are the market mechanisms that generate pro-rich inflation? How important would it be to allow for endogenously changing wage rates in a general equilibrium framework? Investigating these issues may be fruitful for future work in this field.

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Appendix

A. Proof of Proposition 1

After substituting the demand functions given by (7) and (8) into (6), the Lagrangean of the government's maximization problem reads:

$$L = f_H \left\{\beta_n \ln\left(\frac{\beta_n}{p_n} y_N^H - \beta_n \gamma_n\right) + \beta_x \ln\left(\beta_x (y_N^H - p_n \gamma_n)\right) - \frac{v y_G^H}{w^H}\right\}$$
$$+ f_L \left\{\beta_n \ln\left(\frac{\beta_n}{p_n} y_N^L - \beta_n \gamma_n\right) + \beta_x \ln\left(\beta_x (y_N^L - p_n \gamma_n)\right) - \frac{v y_G^L}{w^L}\right\}$$
$$+ \lambda \left\{\beta_n \ln\left(\frac{\beta_n}{p_n} y_N^H - \beta_n \gamma_n\right) + \beta_x \ln\left(\beta_x (y_N^H - p_n \gamma_n)\right) - \frac{v y_G^H}{w^H}\right.$$
$$\left. - \beta_n \ln\left(\frac{\beta_n}{p_n} y_N^L - \beta_n \gamma_n\right) - \beta_x \ln\left(\beta_x (y_N^L - p_n \gamma_n)\right) + \frac{v y_G^L}{w^H}\right\}$$
$$+ \alpha\{f_H (y_G^H - y_N^H) + f_L (y_G^L - y_N^L)\}$$

This leads to the following first-order-conditions:

$$y_N^L:\ -\alpha f_L + \{f_L - \lambda\} \left\{\frac{\beta_n}{(y_N^L - p_n \gamma_n)} + \frac{\beta_x}{(y_N^L - p_n \gamma_n)}\right\} = 0 \tag{11}$$

$$y_N^H:\ -\alpha f_H + \{f_H + \lambda\} \left\{\frac{\beta_n}{(y_N^H - p_n \gamma_n)} + \frac{\beta_x}{(y_N^H - p_n \gamma_n)}\right\} = 0 \tag{12}$$

$$y_G^L:\ \alpha f_L - \frac{f_L v}{w^L} + \frac{\lambda v}{w^H} = 0 \tag{13}$$

$$y_G^H:\ \alpha f_H - \frac{f_H v}{w^H} - \frac{\lambda v}{w^H} = 0 \tag{14}$$

$$\alpha:\ f_H (y_G^H - y_N^H) + f_L (y_G^L - y_N^L) = 0 \tag{15}$$

$$\lambda: \beta_n \ln\left(\frac{\beta_n}{p_n} y_N^H - \beta_n \gamma_n\right) + \beta_x \ln\left(\beta_x (y_N^H - p_n \gamma_n)\right) - \frac{v y_G^H}{w^H} - \beta_n \ln\left(\frac{\beta_n}{p_n} y_N^L - \beta_n \gamma_n\right) -$$
$$\beta_x \ln\left(\beta_x (y_N^L - p_n \gamma_n)\right) + \frac{v y_G^L}{w^H} = 0 \tag{16}$$

With $\beta_n + \beta_x = 1$, rearranging (11) and (12) yields:

$$y_N^L = \frac{f_L - \lambda}{\alpha f_L} + p_n \gamma_n \tag{17}$$

$$y_N^H = \frac{f_H + \lambda}{\alpha f_H} + p_n \gamma_n \tag{18}$$

After plugging in (17) and (18), equation (15) can be rewritten as:

$$f_H y_G^H + f_L y_G^L - (f_H + f_L) p_n \gamma_n - \frac{f_H + f_L}{\alpha} = 0 \tag{19}$$

We define sub-utility from consumption for high and low types as follows:

$$H^c = \beta_n \ln\left(\frac{\beta_n}{p_n} y_N^H - \beta_n \gamma_n\right) + \beta_x \ln\left(\beta_x (y_N^H - p_n \gamma_n)\right) \tag{20}$$

$$L^c = \beta_n \ln\left(\frac{\beta_n}{p_n} y_N^L - \beta_n \gamma_n\right) + \beta_x \ln\left(\beta_x (y_N^L - p_n \gamma_n)\right) \tag{21}$$

Substituting (20) and (21) into (16) and rearranging generates:

$$y_G^L = (L^c - H^c)\frac{w^H}{v} + y_G^H \tag{22}$$

Inserting (21) into (19) and rearranging yields:

$$y_G^H = \frac{f_L}{f_H + f_L}(H^c - L^c)\frac{w^H}{v} + p_n \gamma_n - \frac{1}{\alpha} = 0 \tag{23}$$

y_G^L can be derived analogously:

$$y_G^L = \frac{f_H}{f_H + f_L}(L^c - H^c)\frac{w^H}{v} + p_n \gamma_n - \frac{1}{\alpha} = 0 \tag{24}$$

Note that λ and α are determined completely by exogenous parameters. More explicitly, solving (13) and (14) yields $\lambda = \frac{f_H f_L (w^H - w^L)}{(f_H + f_L) w^L}$ and $\alpha = \frac{v}{w^L} - \frac{\lambda v}{w^H f_L}$. Hence, (17), (18), (23) and (24) represent the closed-form solution of the government's maximization problem. Differentiating (17) and (18) with respect to p_n yields $\frac{\partial Y_N^i}{\partial p_n} = \gamma_n$.

After substituting (17) and (18) into (20) and (21), it can be shown that $\frac{\partial H^c}{\partial p_n} = \frac{\partial L^c}{\partial p_n} = 0$. Hence, differentiating (23) and (24) with respect to

p_n suffices to show that $\frac{\partial Y_G^i}{\partial p_n} = \gamma_n$. This completes the proof of (*i*) and (*ii*) where $T(Y_G^i) = Y_G^i - Y_N^i$.

Dividing (23) and (24) respectively by w^H and w^L gives l^H and l^L. Differentiation of l^H and l^L with respect to p_n yields $\frac{\partial l^L}{\partial p_n} = \frac{\gamma_n}{w^L}$ and $\frac{\partial l^H}{\partial p_n} = \frac{\gamma_n}{w^H}$. Together with the exogenously imposed condition $w^H > w^L$, this completes the proof of (*iii*).

In the next step, we prove the statement in footnote 10, that the sub-utility of consumption decreases by the same amount in absolute terms in the optimum for high and low type agents. In order to see this, insert (17), (18) into (21), (20), respectively. Note that p_n cancels out in sub-utility of consuming luxury goods. Differentiating the sub-utility of consuming necessity goods with respect p_n results in $-\frac{\beta_n}{p_n}$ for both type of agents.

B. Description of the Datasets

European Union Household Budget Surveys (HBSs) are harmonized surveys conducted in all EU member states once every five years since 1988. The main purpose is to calculate national weights for the Consumer Price Index (CPI) and Harmonised Index of Consumer Prices (HICP). Unfortunately, at the time of this study, only the 2010 wave was available for researchers. This wave incorporates 26 countries with more than 270.000 observations.

EU HBSs provide consumption expenditure data (in euro) on many aggregation levels (using identical definitions across countries). Goods categories are represented by the number of digits in the variable code. For example, the 2-digit expenditure category "Food and Non-alcoholic beverages" is further split into two 3-digit categories, "Food" and "Non-alcoholic beverages". Gürer and Weichenrieder (2020) use a combination of 2-digit and 3-digit level expenditure categories in the analysis. This paper, on the other hand, exploits only twelve 2-digit categories for the sake of computational convenience. A list of those 12 categories are provided in Tables 1 and 2. All the expenditure values are reported as annual values; hence, there is no concern about seasonality.

In order to recover price information corresponding to those twelve categories, we use a second Eurostat dataset, the Harmonised Index of Consumer Prices (HICP). Taking a given year as the base year (in which prices of all goods equal 100), HICP provides a comparable measure of changes in the prices of goods in each country across years. Note that the breakdown of consumption expenditure categories in HICP is identical with the one in the HBSs. Hence, there is no additional procedure needed when mapping HICP to HBSs. The panel in HICP runs from 1996 to 2017. Gürer and Weichenrieder (2020) limit the period of analysis to 2001-15 due to lack of price data in some 3-digit level expenditure categories. The present paper uses only 2-digit categories, which allows the inclusion of the price information from 1996 to 2017.

Our final data set incorporates the expenditure shares of households in 2010, on 12 categories, together with the prices of these categories in the period of 1996-2017.

C. Linear Expenditure System Estimation

In this section, we describe how we estimate β_g and γ_g values for agents in three countries.

As mentioned above, we use the expenditure information on twelve 2-digit categories. Although there are 26 countries in our main data set, we are only interested in three of them for our calibration exercise. Germany, the United Kingdom, and the Czech Republic have sample sizes of 53,996, 5,263, and 2,932, respectively, in our data set. Initially, we investigate and drop observations with missing or negative values in any of the twelve 2-digit expenditure categories. As a result, only one UK observation is dropped. Next, we make sure that sum of twelve 2-digit expenditure categories equals the total consumption expenditure. There are no observations in any of the three countries such that the sum of the twelve 2-digit categories exceeds or falls short of total consumption expenditure by 10 euro or more. Nevertheless, we rescale the 2-digit expenditure categories such that they precisely sum up to the total consumption expenditure.

As the next step, we subtract imputed rentals of housing from the 2-digit category "Housing" and total consumption expenditure. The reason for this choice is twofold. First, in contrast to the other consumption goods, price increases in housing do not hurt the agent who, for example, has a large imputed rent from the dwelling it owns. Second, no data exist on imputed rentals for the UK. Hence, we think it for the best to entirely exclude this category from our calculations.

Finally, we calculate the expenditure shares by dividing the consumption expenditure of any category by the total consumption expenditure and then merge the resulting data set with HICP. This concludes the preparation for the LES estimation.

The equation to be estimated is derived by the straightforward optimization problem of stage 2 (as mentioned in Section 2). Essentially, we maximize the first term in Equation (9) with respect to the budget constraint: $\sum_{g \in G} p_g c_g^i \leq Y_N^i$. The resulting demand functions read:

$$c_g^i = \gamma_g + \frac{\beta_g}{p_g}(Y_N^i - \sum\nolimits_{g \in G} p_g \gamma_g) \tag{25}$$

Multiplying both sides with p_g / Y_N^i yields:

$$s_g^i = \frac{p_g \gamma_g}{Y_N^i} + \frac{\beta_g}{Y_N^i}(Y_N^i - \sum\nolimits_{g \in G} p_g \gamma_g) \tag{26}$$

where s_g^i represents the expenditure share of agent i on good g. Note that, in Equation (26), prices enter as factor that affects the estimation results of β_g and γ_g. Given that we only have a 2010 cross-section for the estimation and no price variation on the country-level, we are able to normalize the prices of all goods to one in 2010. Note that, consistent with this, the price data reported in Tables 2 and F.2 uses 2010 as the base year.

Finally, we use non-linear seemingly unrelated regressions in order to perform the LES estimation by using household level data and household weights[13]. Estimation results are reported in Table 1.

[13] More precisely, we use the “nlsur“ command of Stata.

D. Construction of Agents and Simulations with OECD Tax-and-Benefit Model

After completing the LES estimation, we construct the agents (10th, 33rd, 66th, and 90th percentiles) for each country. Note that preferences of the agents in each country are already determined in the previous section. This additional procedure is only necessary to arrive at the empirically observed total consumption expenditure values which are used in OECD tax-and-benefit model simulations and estimation of the wage rates (as explained in Section 4.1).

First, we divide total consumption expenditures of each household by household equivalence scale[14]. Next, we split the population in all three countries into percentiles by using the total consumption expenditures divided by the household equivalence scale. In order to construct four agents in each country, we group the percentiles 8-12, 31-35, 64-68 and 88-92 so that they represent the 10th, 33rd, 66th and 90th percentiles, respectively. The reason for this grouping is to keep the sample size of each agent as large as possible. Finally, we take the mean of the non-equivalized total consumption expenditures of households in these groups to represent the total consumption expenditures of households in our model and OECD tax-and-benefit simulations. The resulting total consumption expenditures and sample sizes for each agent in each country is given in Table E.1.

Table D.1: Sample Sizes and Total Consumption Expenditures of Agents

	CZ		DE		UK	
Percentiles	Sample Size	Total Expenditure	Sample Size	Total Expenditure	Sample Size	Total Expenditure
10th	128	5.37	1814	13.85	259	10.55
33rd	128	7.84	2327	22.03	269	16.07
66th	143	10.68	3037	32.70	261	26.29
90th	163	14.48	3613	49.39	260	42.69

Notes: Reported total consumption expenditures are in annual (000) EUR units.

Equipped with the total consumption expenditures, we are ready to perform OECD tax-and-benefit model simulations in order to recover actual tax schedules to which agents in our model are exposed. Note that OECD tax-and-benefit model reports taxation schemes according

[14] We use the modified OECD equivalence scale which assigns 1 to head of household, 0.5 to each additional adult member, and 0.3 to each child.

to the income in national currencies. In order to have a comparable measure, we use publicly available data on average gross saving rates (Eurostat, 2019a) – to convert total consumption expenditures into income – and euro exchange rates in 2010 (Eurostat, 2019b). The data used can be found in Table E.2. After performing necessary calculations, we arrive at the total income of each agent in each country.

Table D.2: Gross Savings Rate and Euro Exchange Rate in 2010

Country	Savings Rate %	Euro Exchange Rate
CZ	12.71	25.28
DE	16.81	1.00
UK	10.94	0.86

The OECD tax-and-benefit model requires us to impose some initial assumptions regarding the demographics of the agents. We perform the simulations for individuals who are 40 years old, working since they were 18 years old, and single with no child. Moreover, the model only allows the user to select the income of the agent (whose taxation scheme the user is interested in) as a percent of mean yearly wage in a given country.

Our strategy is to select the agents in the OECD tax-and-benefit model such that their total incomes corresponds to the incomes we derived for our. For example, the 10^{th} percentile of the Czech Republic, according to our calculations, should, on average, earn an income of 155,593 Koruna. This approximately corresponds to the 60% of the mean yearly wage. Hence, we take the tax schedule of the agent who earns 60% of the mean yearly wage in OECD tax-and-benefit model as the actual tax schedule of the 10^{th} percentile in the Czech Republic. Note that the OECD tax-and-benefit model only reports the tax schedules of the agents who earn between 1% and 200% of the mean yearly wage. In some cases, e.g., Germany's 90^{th} percentile, the incomes of the agents we derive exceeds 200% of the mean yearly wage. In these cases, we use the tax schedule of the agent who earns the highest possible income in the OECD tax-and benefit model.

Finally, the calculation of the average effective tax rates is straightforward. That is $AETR = \frac{(Gross\ Inc - Net\ Inc)}{Gross\ Inc}$. In order to calculate the marginal tax rates, on the other hand, we need the additional information on the tax schedule of the agent who earns marginally higher than the agent we selected. For this, we consider increments of three percentage points relative to the mean yearly wage in a given country. For example, we already mentioned that the 10^{th} percentile of Czech Republic corresponds to the agent who earns 60 % of the mean yearly wage. Additionally, we extract the information on the same agent who earns 63% of the mean yearly wage. Finally, marginal tax rate is calculated as follows: $METR = 1 - \frac{\Delta Net\ Inc}{\Delta Gross\ Inc}$. The resulting tax schedules for 2010 are reported in Table 3.

E. Robustness Checks

Table E.1: Optimal Policies with Prices of 1996 and 2017 ($\gamma_g > 0$)

	Percentiles	Wage	1996 Y_G	1996 $T(Y_G)$	1996 τ	1996 $T'(Y_G)$	1996 V	2017 Y_G	2017 $T(Y_G)$	2017 τ	2017 $T'(Y_G)$	2017 V	l Incr. %	V Loss %
CZ	10th	6.86	5.48	-3.37	-0.615	0.220	7.09	5.60	-3.44	-0.614	0.230	6.46	2.22 %	8.87 %
	33rd	10.08	8.75	.1.60	-0.183	0.260	7.21	8.91	-1.63	-0.183	0.270	6.59	1.78 %	8.61 %
	66th	14.21	13.65	0.90	0.066	0.201	7.35	13.86	0.92	0.066	0.208	6.74	1.53 %	8.35 %
	90th	19.70	21.34	4.07	0.191	0.000	7.53	21.63	4.15	0.192	0.000	6.93	1.35 %	8.03 %
DE	10th	19.04	12.73	-21.26	-1.671	0.296	8.14	12.89	-21.53	-1.671	0.303	7.83	1.28 %	3.90 %
	33rd	36.33	30.08	-9.64	-0.320	0.326	8.23	30.39	-9.74	-0.321	0.333	7.91	1.03 %	3.82 %
	66th	56.18	53.41	4.22	0.079	0.273	8.37	53.88	4.29	0.080	0.278	8.06	0.88 %	3.71 %
	90th	87.06	98.57	26.68	0.271	0.000	8.58	99.33	26.98	0.272	0.000	8.27	0.77 %	3.55 %
UK	10th	2.99	0.95	-20.17	-21.197	0.326	7.91	0.96	-20.37	-21.152	0.329	7.46	1.20 %	5.60 %
	33rd	20.59	15.54	-8.66	-0.558	0.362	7.92	15.67	-8.74	-0.558	0.368	7.48	0.82 %	5.59 %
	66th	35.40	32.11	2.22	0.069	0.332	8.03	32.33	2.25	0.070	0.337	7.59	0.69 %	5.47 %
	90th	63.90	74.63	26.62	0.357	0.000	8.24	75.08	26.86	0.358	0.000	7.80	0.61 %	5.28 %

Notes: Y_G: Gross Income, $T(Y_G)$: Net tax, τ: Average tax rate, $T'(Y_G)$: Marginal tax rate, V: Indirect utility, l Incr. %: Percent increase in labor supply, V Loss %: percent loss in indirect utility. Values of wage, Y_G and $T(Y_G)$ are in annual (000) Euro units.

Table E.2: Optimal Policies with Prices of 1996 and 2017 ($\varepsilon = 0.33$)

			1996					2017						
	Percentiles	Wage	Y_G	$T(Y_G)$	τ	$T'(Y_G)$	V	Y_G	$T(Y_G)$	τ	$T'(Y_G)$	V	l Incr. %	V Loss %
CZ	10th	6.84	5.69	-3.79	-0.666	0.205	7.27	5.75	-3.83	-0.667	0.212	6.66	1.11 %	8.36 %
	33rd	10.31	9.25	-1.63	-0.176	0.241	7.37	9.33	-1.64	-0.176	0.248	6.76	0.93 %	8.19 %
	66th	14.45	13.96	1.00	0.072	0.191	7.48	14.07	1.02	0.072	0.196	6.89	0.83 %	8.00 %
	90th	19.94	21.13	4.41	0.209	0.000	7.64	21.29	4.46	0.210	0.000	7.05	0.77 %	7.77 %
DE	10th	20.50	15.60	-22.00	-1.410	0.246	8.33	15.68	-22.12	-1.410	0.249	8.03	0.51 %	3.60 %
	33rd	37.50	32.65	-10.05	-0.308	0.291	8.40	32.78	-10.10	-0.308	0.295	8.10	0.42 %	3.55 %
	66th	57.79	55.68	4.58	0.082	0.245	8.52	55.88	4.61	0.082	0.247	8.22	0.37 %	3.48 %
	90th	88.55	96.96	27.47	0.283	0.000	8.69	97.30	27.61	0.284	0.000	8.40	0.35 %	3.38 %
UK	10th	2.57	1.12	-21.67	-19.267	0.261	8.05	1.13	-21.74	-19.270	0.263	7.63	0.33 %	5.30 %
	33rd	21.09	17.39	-8.20	-0.471	0.316	8.06	17.43	-8.22	-0.472	0.318	7.64	0.27 %	5.29 %
	66th	35.92	33.73	3.06	0.091	0.287	8.16	33.81	3.08	0.091	0.289	7.74	0.24 %	5.21 %
	90th	63.81	71.57	26.80	0.375	0.000	8.43	71.73	26.89	0.375	0.000	7.91	0.23 %	5.08 %

Notes: Y_G: Gross Income, $T(Y_G)$: Net tax, τ: Average tax rate, $T'(Y_G)$: Marginal tax rate, V: Indirect utility, l Incr. %: Percent increase in labor supply, V Loss %: percent loss in indirect utility. Values of wage, Y_G and $T(Y_G)$ are in annual (000) Euro units.

Table E.3: Optimal Policies with Prices of 1996 and 2017 ($\varepsilon = 0.75$)

			1996					2017						
	Percentiles	Wage	Y_G	$T(Y_G)$	τ	$T'(Y_G)$	V	Y_G	$T(Y_G)$	τ	$T'(Y_G)$	V	l Incr. %	V Loss %
CZ	10th	7.57	5.85	-2.76	-0.472	0.190	7.06	5.98	-2.81	-0.469	0.196	6.45	2.28 %	8.66 %
	33rd	10.45	8.63	-1.52	-0.176	0.246	7.18	8.78	-1.54	-0.175	0.253	6.58	1.78 %	8.41 %
	66th	14.58	13.64	0.73	0.053	0.187	7.33	13.84	0.75	0.054	0.192	6.73	1.46 %	8.16 %
	90th	20.08	21.66	3.55	0.164	0.000	7.52	21.93	3.60	0.164	0.000	6.93	1.22 %	7.86 %
DE	10th	20.46	11.82	-19.69	-1.666	0.312	8.10	11.94	-19.87	-1.664	0.316	7.80	1.05 %	3.72 %
	33rd	38.18	29.76	-8.66	-0.291	0.320	8.19	30.00	-8.72	-0.291	0.324	7.89	0.83 %	3.65 %
	66th	57.43	52.77	3.64	0.069	0.270	8.34	53.13	3.69	0.069	0.273	8.04	0.67 %	3.56 %
	90th	88.36	100.92	24.70	0.245	0.000	8.56	101.48	24.90	0.245	0.000	8.27	0.55 %	3.42 %
UK	10th	4.00	0.86	-18.63	-21.730	0.363	7.90	0.86	-18.74	-21.723	0.366	7.47	0.63 %	5.41 %
	33rd	21.58	14.38	-8.68	-0.604	0.370	7.91	14.45	-8.72	-0.604	0.373	7.48	0.53 %	5.41 %
	66th	36.41	30.81	1.37	0.045	0.346	8.03	30.94	1.39	0.045	0.348	7.60	0.43 %	5.30 %
	90th	65.75	77.99	25.94	0.333	0.000	8.24	78.26	26.08	0.333	0.000	7.82	0.35 %	5.14 %

Notes: Y_G: Gross Income, $T(Y_G)$: Net tax, τ: Average tax rate, $T'(Y_G)$: Marginal tax rate, V: Indirect utility, l Incr. %: Percent increase in labor supply, V Loss %: percent loss in indirect utility. Values of wage, Y_G and $T(Y_G)$ are in annual (000) Euro units.