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One vs. Two Instruments for Redistribution: The Case of Public Utility Pricing

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One vs. Two Instruments for Redistribution: The Case of Public Utility Pricing ¹

February 15, 2017

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Abstract

Since the seminal Atkinson-Stiglitz (1976) theorem, a number of theoretical papers have addressed the issue whether one instrument vs. two instruments are adequate for income redistribution. We employ a large panel data set on around 180,000 households in the Swiss Canton of Bern and the years 2008-2013 including detailed energy consumption and household income and tax payment characteristics to shed light on this issue. We structurally estimate a model combining both public utility pricing and income taxation. We analyse whether the government should draw on one instrument (the income tax) or two instruments (the income tax and public utility pricing) for efficiency and redistribution purposes. Our results show that assuming heterogeneous tastes and a simplified taxation scheme there is a role for redistribution through public good pricing markups. In the case of Switzerland's energy market, setting a negative markup is optimal if poor households receive a higher welfare weight. As opposed to this, a welfare weight as a function of energy consumption instead of income is associated with a positive markup and hence with two instruments being adequate for redistribution. In our data we observe a markup of 43% which may imply the government stresses the importance of energy efficiency goals.

JEL-classification: D12; D31; H21; H22; H24; L51; L94; L98

Keywords: Atkinson-Stiglitz theorem; redistribution; public utility pricing; energy; welfare;

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1 Introduction

Our project belongs to the more general body of literature which seeks to address the redistributive impact of different energy policies and the equity efficiency trade-off in public utility pricing. It is still an open debate as to whether the state or public utilities should intervene in income redistribution other than via income taxes. Some argue that equity issues should be addressed via income tax policy solely, and that the government should not intervene in the pricing of different commodities. Still, in practice, the governments of various countries do care about the affordability and distributional effects of basic goods and services such as energy. The ambiguous conclusions of the theoretical literature justify the need of more extensive empirical research. Our paper is one of the first to employ an extensive household level panel data set to empirically test the theoretical predictions of the mainly theoretical literature on commodity taxation. Furthermore, we extend the model of Munk (1977) to account for labor responses to taxation and to allow consumption based welfare weights.

Our empirical analysis draws on residential electricity market data and information. In most countries, electricity prices are heavily regulated and its corresponding infrastructure is provided by (partial) state monopolies. Additionally, governments usually finance infrastructure costs through energy price markups. From a theoretical perspective this is equivalent to a commodity tax. Alternatively, electricity could be sold at the market price while increasing direct income taxation to cover the costs of the energy grid. This constellation is thus similar to the theoretical debate mentioned above, with respect to the economic justification of two tax instruments rather than one for income redistribution purposes.

The role of a second instrument for redistribution besides the nonlinear income tax has a long tradition of being a contentious issue in public economics since the seminal contribution of the Atkinson-Stiglitz (1976) theorem. Their influential work showed that, assuming weak separability between leisure and consumption goods as well as homogeneous sub-utility of consumption across individuals, differential commodity taxation is redundant in the presence of optimal non-linear income taxation. This result can be extended to apply to public sector pricing as well. The intuition is that, under the consumption-leisure

separability, differential taxation cannot relax the incentive compatibility constraint inherent in the optimal tax problem and hence reduce the underlying distortion of the labour leisure choice (Kaplow, 2006), but add further distortions in choices between consumption goods. Later on Saez (2002) showed that the crucial assumption does not relate to the leisure-consumption choice separability but rather to the conjecture of taste homogeneity - in other words the fact that the entire population has the same subutility of consumption. Saez (2002) has shown that a differential commodity tax can be desirable if consumption patterns are related to leisure choices or earnings power. In such circumstances, there may be a case for differential commodity taxes if cross-sectional demand for a commodity is more elastic than individual demand. In other words, if high income individuals have a relative preference for a specific commodity, or if leisure and consumption of this commodity are positively correlated, a small specific commodity tax may be desirable. The Atkinson-Stiglitz result applies when, conditional on income, the government sets the same social weights on similar individuals in terms of income. It has been challenged in the course of time, for instance by Stiglitz (1982), Naito (1999; 2007) or Christiansen (1984). Stiglitz (1982) showed that the result breaks down when labour taxation is based solely on income. Naito (1999) also questioned the result when prices and wages are endogenous and when there is imperfect substitution in labour types. Christiansen (1984) showed that goods that are complementary to leisure should be taxed. Further contributions which ascribe a role to commodity taxation for redistribution purposes relax the underlying assumptions of the Atkinson-Stiglitz theorem. Hence, with different underlying production technologies (Naito, 2007), heterogeneity between agents besides their ability (Cremer, Pestieau, and Rochet, 2001), different evasion characteristics of income vs consumption taxes (Boadway and Richter, 2005) or wage uncertainty (Cremer and Gahvari, 1995), there is a scope for redistributive policy via a second instrument. Still, Saez (2004) showed that whereas these departures from the original result may be valid in the short-run, the Atkinson-Stiglitz result is restored and hence indirect tax instruments are sub-optimal in the long run. The intuition is that in the short run individuals do not change occupation and skills are exogenous, whereas with a longer term perspective individuals respond to tax changes via the occupation margin. The validity of the theorem to the case when income taxation is not optimal has been extended by Kaplow (2006).

Whereas the above mentioned papers deal with the commodity tax as a second in-

strument for redistribution, an analogy can be drawn to public utility pricing. Feldstein (1972a and b) was the first to consider the equity efficiency trade-off in public sector pricing. His contributions show that as long as the publicly produced commodity is not inferior, optimal prices will exceed marginal costs. Such a tariff structure implies gains in distributional equity because high-income individuals would implicitly bare a larger fraction of fixed costs.⁴⁵ The derived markup is a function of price and income elasticity of demand, mean and variance of the income distribution in the population as well as a distributional parameter. He shows that the optimal price is i.a. higher, the higher the income demand elasticity or the relative variance of income. Munk (1977) extends Feldstein's framework to a general equilibrium framework and to the case where the alternative revenue source is an income tax. He shows that public sector prices below marginal costs are much more likely than in Feldstein's model. Furthermore, when prices are below marginal costs and accordingly the commodity needs to be subsidized, the redistributive costs are lower when the government can resort to an income as opposed to a head tax. Furthermore, optimal prices depend on the distributional characteristics of the income tax. His analysis shows that as long as the income elasticity of a tax increase is higher than the income elasticity of the commodity, the optimal price will be below the marginal cost. Finally, Cremer and Gahvari (2002), ascribe a redistributive role to nonlinear utility pricing in the presence of an optimal nonlinear income tax. When individuals differ both in earning ability and tastes, the marginal price a person with a low valuation of public sector output faces has to exceed the marginal cost. In addition, Cremer and Gahvari (2002) show that assuming earning ability and tastes are perfectly correlated, the marginal cost of the commodity should be strictly below its price - and this should hold for the entire population. This latter result is sometimes employed in the public debate as an argument for providing support for low income customers. Hellwig (2007) proves that redistributive

⁴An optimal two part tariff with a fixed fee and marginal prices equal to marginal costs is regressive due to the fixed component. Feldstein (1972a) implicitly assumes the alternative source of revenue is a head tax, as consumers cannot reduce the consumption of the publicly produced commodity to zero. In this two part tariff approach consumers are charged a constant marginal price per unit purchased as well as a fixed fee. This pricing scheme has been criticized from an equity point of view, as the fixed charge can be interpreted as a regressive head tax.

⁵The difference between the price and the cost set by a public utility can be interpreted in a similar fashion to the wedge between the producer and the consumer price introduced by a consumption tax (Bös, 1984).

concerns may deliver an argument for charging user fees and public good provision (in case of excludable public goods) may be financed by levying an equal lump sum tax on every individual.

The present paper expands on several theoretical justifications why commodity taxation might be optimal for redistributive purposes. First, in a realistic setting a regulator might not be able to set income taxation schemes optimally. Rather only certain parameters of a preexisting system can be adjusted. Second, we consider how labor supply responses impact the predictions of our model. This includes heterogeneous income elasticities between income groups and a potential complementarity of the energy consumption to leisure. Third, we allow welfare weights to be negatively correlated with energy consumption. Such a weight might be reasonable if the government values energy efficiency and conservation highly.

The paper is structured as follows. We start out by briefly describing our data set. In Section three we present the theoretical model and outline our structural estimation approach. Section four presents the estimation results for the structural parameters and the simulation of optimal prices. In Section five we extend the model to allow for a labor response and a consumption based welfare weight before concluding in Section six.

2 Data

We base our empirical analysis on a unique household level data set for the Canton of Bern, Switzerland. Bern is the second largest Swiss canton in terms of population inhabited by 1,001,281 individuals and covering an area of 5,959 km². Our data set combines data from three different sources. First, we use detailed income, wealth and tax data from the tax administration of Bern. This data also allows us to infer various household characteristics. Second, the three main energy utilities of the canton Bern BKW, Energie Wasser Bern and Energy Thun provided us energy consumption and expenditure data. Third, we can draw on building characteristics information supplied by the Swiss Federal Statistical Office. Our ultimate data set spans the years 2008-2013. For more information on the data and its merging process see Feger, Pavanini and Radulescu (2017).

Table 1 provides summary statistics for the main variables used in our estimation. We have information on 662,889 pooled observations including approximately 150,000 households over 5 years. As Table 1 shows mean taxable income (*TaxableIncome*)⁶ amounts to CHF 72,937 with total wealth (*TotalWealth*) averaging at CHF 542,563. Switzerland is a federal state so taxes are levied on three different levels. The cantonal tax (*CantonalTax*) makes up for the largest part of average tax payments being approximately twice and five times as high as the municipal tax *MunicipalTax* and federal Tax *FederalTax* respectively. Table 1 also shows that the annual mean household energy consumption reaches 4,070 kWh with a corresponding energy bill of 916 CHF, with almost 50% being used to finance the energy infrastructure. Lastly, Table 1 shows several household and building characteristics. The average household in our sample counts two persons, has a 42 percent likelihood to own a house or apartment and lives on 98 square meters.

⁶Taxable income is defined as total income (in the form of labor income or income from self-employment) plus rental value of owner occupied housing less mortgage interest payments and commuting and living expenses.

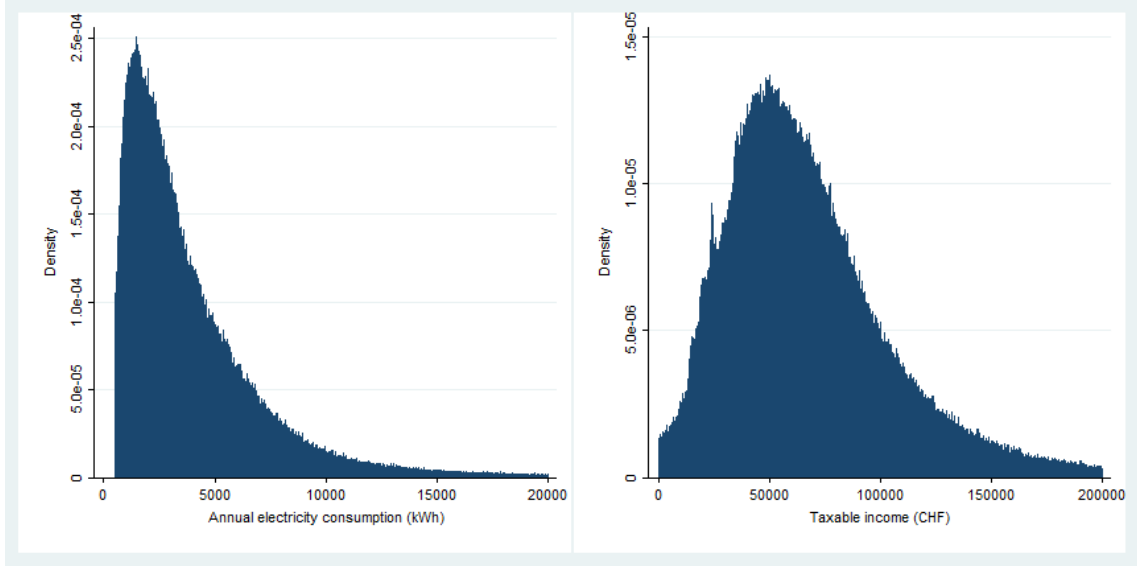
Table 1: Overview Main Variables

	NumbObs	Mean	Stddev	5thPerc	Median	95thPerc
<i>Tax Data</i>						
TaxableIncome	662,889	72,937	114,777	18,844	61,457	153,822
TotalWealth	662,889	474,672	2148424	0	204,984	1507154
CantonalTax	662,889	7,107	13,572	155	5,371	17,982
MunicipalTax	662,889	3,669	6,626	82	2,819	9,187
FederalTax	662,889	1,600	8,973	0	463	5,589
<i>Energy Data</i>						
EnergyCons	662,889	4,070	3,683	856	3,005	10,598
EnergyBill	662,889	916	663	289	738	2,128
<i>Characteristics</i>						
Homeownership	662,889	.42	.49	0	0	1
Householdsize	662,889	1.97	1.13	1	2	4
ApartmentArea	662,889	98	40	53	90	178

Notes: The descriptive statistic is pooled over all companies and years.

The income distribution and the distribution of energy consumption are crucial for the subsequent analysis. Figure 1 depicts the distribution of taxable income and of annual energy consumption. The distribution of energy consumption is heavily skewed to the right, whereas the skewness is less pronounced for the income distribution.

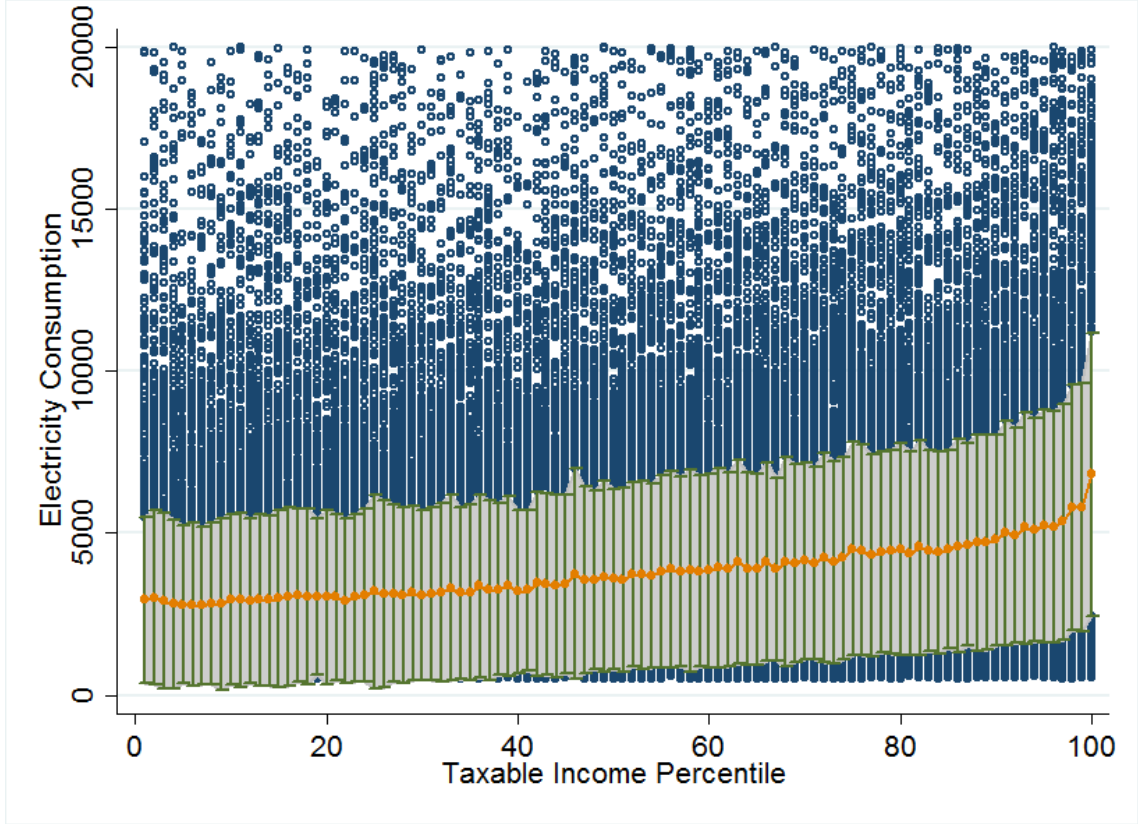
Figure 1: Distribution of Electricity Consumption and Taxable Income



Notes: The figure shows the distribution of energy consumption (left panel) taxable income (right panel) in the sample. All observations with a taxable income below zero or consumption of less than 500 kWh have been excluded from the sample. The maximum level of taxable income and energy in both graphs is chosen for illustrative purposes.

Figure 2 relates energy consumption to income. It shows that the mean energy consumption is increasing with higher income percentiles. This indicates a potential role for taxing energy to redistribute wealth from high to low income households. Nevertheless, we should note at this point that there is a significant amount of variation in energy consumption present in the sample. For instance, many low income households consume energy well above the mean.

Figure 2: Electricity Consumption by Income Decile



Notes: The figure shows the distribution of energy consumption by income decile. The shaded area depicts consumption covered by one standard error while the middle line depicts the mean for each decile. The outliers of this bandwidth are illustrated as dark circles.

3 Theoretical model

Our theoretical model draws on Munk (1977) which is a generalization of Feldstein's (1972a) model. We consider an economy with N households, a public firm producing a single public good and a private outside good produced by competitive firms. In this environment, the regulator sets the price of the public good as well as the income tax scheme to maximize social welfare.

The utility of a household is assumed to be a function of its public good consumption (y_i), private good consumption (x_i), income (z_i) and taste (θ_i). Thus, its optimal decision is characterized by the following constrained maximization:

$$\begin{aligned} \max_{x_i, y_i, z_i} \quad & u = u(y_i, z_i, x_i, \theta_i) \\ \text{s.t.} \quad & p_x x_i + p_y y_i \leq z_i - t(z_i, \tau) + g, \end{aligned} \quad (1)$$

where $t(\cdot)$ is the amount of taxes paid and g is a lump sum transfer from the government. We assume that $u'(\cdot) > 0$ and $u''(\cdot) < 0$. τ denotes the parameter describing the degree of income taxation. Along with income z_i it uniquely determines the tax payment of each household. By inserting the solution of this maximization problem into the utility function we can express a household's indirect utility as:

$$u = u(y_i(p_y, p_x, \tau), x_i(p_y, p_x, \tau), z_i, \theta) = v(z_i, \tau, p_y, p_x, \theta_i). \quad (2)$$

The social planner maximizes the weighted sum of the agents' utilities subject to the governmental budget constraint:

$$\max_{p_y} W = \sum_i w_i \cdot v_i(z_i, \tau(p_y), p_y, \theta_i), \quad (3)$$

s.t.

$$\sum_i [p_y y_i + t(z_i, \tau)] \geq C\left(\sum_i y_i\right) + gN, \quad (4)$$

where w_i is the welfare weight assigned to each household and $C(\sum_i y_i)$ are the total costs of providing the public good. We further assume that $\sum_i t(z_i) \geq gN$ such that we do not allow the utility's revenue to cross-subsidize public lump sum transfers⁷.

The income taxation parameter τ is an important component of this analysis. It is assumed that for the given taxation scheme the regulator is able to adjust this parameter to control the revenue generated by income taxation. That is, increasing τ leads to higher income taxes and more weight on direct taxation. Naturally, this assumption strongly narrows the scope of the regulators decision. Rather than adjusting the overall income tax schedule, he can only change the parameter τ given the status quo system. However,

⁷However, we do allow the social planner to use tax revenues to finance the public good.

this assumption simplifies the regulator's decision while still allowing for non-linearity in income taxation.

For a given price of the public good p_y , the government's budget constraint shows how much revenue needs to be additionally generated by means of income taxation. Together with a specified income tax scheme we can back out the parameter τ . Thus, we can rewrite the income taxation parameter τ as a function of price p_y ⁸.

Maximizing the social welfare function with respect to the budget constraint yields an optimality condition which determines prices set by the utility.

$$\frac{\partial W}{\partial p_y} = \sum_i w_i \left(\frac{\partial v}{\partial p_y} - \lambda_i \frac{\partial t}{\partial \tau} \frac{\partial \tau}{\partial p_y} \right), \quad (5)$$

where λ_i represents the marginal utility of income. Hence, in the optimum, a marginal decrease in household utility resulting from an increase in the price of the public good equals the marginal benefit of a reduction in direct taxation. This marginal benefit $\lambda_i \frac{\partial t}{\partial \tau} \frac{\partial \tau}{\partial p_y}$ is the product of the marginal utility of income (λ_i), the effect of the direct taxation parameter τ on individual tax payments ($\frac{\partial t}{\partial \tau}$) and lastly the effect of a price change on τ ($\frac{\partial \tau}{\partial p_y}$).

Since setting the optimal public utility price as well as the specified direct taxation scheme implicitly determines the parameter τ , we can compute $\frac{\partial \tau}{\partial p_y}$ by the implicit function theorem:

$$\begin{aligned} \frac{\partial \tau}{\partial p_y} &= - \frac{\sum y_i + (p^y - \frac{\partial C(\sum y_i)}{\partial \sum y_i}) \frac{\partial \sum y_i}{\partial p_y}}{\frac{\partial \sum_i t_i}{\partial t_i} + (p_y - \frac{\partial C(\sum y_i)}{\partial \sum y_i}) \frac{\partial \sum y_i}{\partial \tau}} \\ &\approx - \frac{\sum y_i + (p^y - \frac{\partial C(\sum y)}{\partial \sum y_i}) \frac{\partial \sum y_i}{\partial p_y}}{\frac{\partial t_i}{\partial \tau}}, \end{aligned} \quad (6)$$

where the effect of income taxation on energy demand is assumed to be of second order magnitude (such that $\frac{\partial \sum y_i}{\partial \tau} \approx 0$).

⁸See Munk (1977) or the structural model for more details

Plugging this expression into the FOC and using Roy's identity $\frac{\partial u_i}{\partial p_y} = -\lambda_i y_i$ yields:

$$-\sum w_i \lambda_i y_i + \sum w_i \lambda_i \left(\frac{\frac{\partial t_i}{\partial \tau}}{\frac{\partial \sum t_i}{\partial \tau}} \right) \left[\left(p_y - \frac{\partial C(\sum y_i)}{\partial \sum y_i} \right) \frac{\partial \sum y_i}{\partial p_y} + \sum y_i \right] = 0$$

$$\frac{p_y - \frac{\partial C(\sum y)}{\partial \sum y_i}}{p_y} = \left(1 - \frac{R_y}{R_\tau} \right) \frac{1}{E_{yy}}, \quad (7)$$

where we define as in Munk (1977) $R_y = \sum_i w_i \lambda_i \frac{y_i}{\sum y_i}$ as the distribution parameter for the public good and $R_\tau = \sum w_i \lambda_i \left(\frac{\frac{\partial t_i}{\partial \tau}}{\frac{\partial \sum t_i}{\partial \tau}} \right)$ the distribution parameter of income taxation. E_{yy} is an expression for the price elasticity of the public good $\frac{\partial \sum y_i}{\partial p_y} \frac{p_y}{\sum y_i}$. R_y is large if individuals with a high social weight consume a large share of the public good y . This corresponds to the case of basic goods. Then again, for luxury goods R_y is expected to be rather low. The size of R_τ depends on the types of households that mainly bear the costs of an increase in direct taxation. On the one hand, if an increase in direct taxation mainly increases tax payments for individuals with a high welfare weight R_τ is large. On the other hand, if high income households with a low welfare weight bear most of the effects of an increase in τ , R_τ will be low.

Equation (7) determines how the social planner optimally sets the price of the public good. The left hand side of equation (7) represents the markup of prices over marginal costs $\frac{\partial C(\sum y_i)}{\partial \sum y_i}$. The resulting markup is a function of the price elasticity of the public good as well as the distribution parameters of both the public good and income taxation. The sign of the markup is solely determined by the relative size of R_y and R_τ . If $R_y/R_\tau < 1$ it is optimal to set a price for the public good above marginal costs. Thus, the markup is positive if high weighted individuals consume a small share of the good provided by the public utility while they bear a relatively large share of direct taxation. On the other hand the price of the good under consideration should be set below marginal cost if $R_y/R_\tau > 1$. That is, a good mainly consumed by high weighted individuals should be subsidized (as long as they do not bear a sufficiently large share of income taxation).

Two additional implications follow. First, the higher the absolute value of the price elasticity of the good provided by the utility, the lower the optimal markup. Second, prices should only equal marginal costs if $R_y/R_\tau = 1$.

3.1 Structural Model of Energy Grid Pricing

In the following we present our basic model for the residential electricity market. Customers choose between consumption of electricity y_i and an outside good x_i . We specify the following log-linear utility function:

$$u(y_i, z_i, x_i, \theta) = x_i + \frac{\alpha - 1}{\alpha} y_i^{\frac{\alpha}{\alpha-1}} z_i^{\frac{\gamma}{1-\alpha}} \theta_i^{\frac{1}{1-\alpha}}, \quad (8)$$

where θ_i is a taste parameter for electricity consumption specific to customer i .

We set the private good x_i as numeraire. Thus, the optimization problem of each household yields the following demand function (defining $\alpha - 1 = \beta$):

$$y_i = p_y^\beta z_i^\gamma \theta_i \quad (9)$$

Using this specification, the optimality condition in equation (7) now reads⁹¹⁰:

$$\frac{p_y - \frac{\partial C(y)}{\partial y_i}}{p_y} = \left(1 - \frac{\sum w_i \frac{z_i^\gamma \theta_i}{\sum z_i^\gamma \theta_i}}{\sum w_i \left(\frac{\frac{\partial t_i}{\partial \tau}}{\frac{\partial \sum t_i}{\partial \tau}} \right)} \right) \frac{1}{-\beta} \quad (10)$$

Total costs of the energy utility $C(y)$ include two components: The variable cost of energy production and the fixed cost of the transmission and distribution infrastructure. We specify the following cost function of the energy utility:

$$C(\sum y_i) = \sum y_i c_i + F \quad (11)$$

where c_i is the generation cost of one unit of electricity and F are the fixed infrastructure costs. Most energy providers offer two part tariffs to their residential customers. That is, customers pay a variable energy price but also yearly fixed fees f_i . Fixed tariff elements usually do not suffice to cover fixed transmission costs. Hence, energy utilities finance

⁹Note that we have $\lambda_i = 1$ in this case.

¹⁰The main question we address in this paper is whether the regulator should draw on one (income taxation) or two (income and public utility pricing) instruments for efficiency and redistribution. While we do allow the regulator to subsidize the public good through a negative markup, we do not refer to this subsidy as a second tax instrument. Rather it reinforces the results under which income taxation is to be preferred.

part of these fixed costs by levying a markup on the energy price, i.e. a volumetric grid charge, which in our framework corresponds to $\frac{p_y - \frac{\partial C(y)}{\partial y_i}}{p_y}$. Thus, the markup resembles a commodity tax to finance infrastructure costs and can be considered an alternative to financing these costs via fixed fees or income taxes. Since f_i is equivalent to a head tax we treat it as part of t_i in the model.

To estimate an expression for the redistributive preferences of the regulator based on our data, we need to derive an expression for $\frac{\frac{\partial t_i}{\partial \tau}}{\frac{\partial \sum_i t_i}{\partial \tau}}$. τ is a single parameter that fully describes the tax payment for each household as a function of income.

We assign τ to be the total average tax rate, that is the average tax revenue generated by one unit of income:

$$\tau = \frac{\sum_i t_i}{\sum_i z_i} \quad (12)$$

$$\Rightarrow \frac{\partial \sum_i \sum_i t_i}{\partial \tau} = \sum_i z_i \quad (13)$$

Let us assume the social planner starts with a certain share of tax revenue from each household, i.e. $t_i^0 = s_i \cdot \sum_i t_i^0$. If the *share* of total tax revenue derived from each household is independent of the level of taxation, we can derive the following condition:

$$\frac{\partial t_i}{\partial \tau} = s_i \cdot \sum_i z_i \quad (14)$$

where we can calculate s_i from our tax data.

Last, we need to specify a functional form for our welfare weight. Assuming that $w_i = z_i^\delta / \sum_i z_i^\delta$ we can express our optimality condition as:

$$\frac{p_y - \frac{\partial C(y)}{\partial y_i}}{p_y} = \left(1 - \frac{\sum_i z_i^\delta \frac{z_i^\gamma \theta_i}{\sum_i z_i^\gamma \theta_i}}{\sum_i z_i^\delta \left(\frac{s_i \cdot z_i}{\sum_i z_i} \right)} \right) \frac{1}{-\beta} \quad (15)$$

4 Estimation and Results

Using our detailed income and energy consumption data we can directly estimate all parameters of equation (15).

By taking logs of the demand equation (9) we can express energy demand as:

$$\ln(y_i) = \beta \ln(p_y) + \gamma \ln(z_i) + \ln(\theta_i) + \epsilon_i \quad (16)$$

We can further decompose the taste parameter $\ln(\theta_i)$ into a constant (α), a household fixed effect (ν_i) and a set of household specific controls $x'_i \xi$:

$$\ln(y_i) = \alpha + \beta \ln(p_y) + \gamma \ln(z_i) + \nu_i + x'_i \xi + \epsilon_i \quad (17)$$

Assuming that $\epsilon_i \sim iidN(0, 1)$, we can estimate the parameters by a linear household fixed effect model.¹¹ Given the panel structure of our data, we also include year dummies.

Table 2 presents the results of our regression. As we can see from Table 2, the energy price elasticity β is negative and highly significant and amounts to -0.2. All other coefficients display the expected signs and significant at least at the 10 per cent level.

¹¹Note that the time subscript is neglected for simplicity.

Table 2: ESTIMATED COEFFICIENT

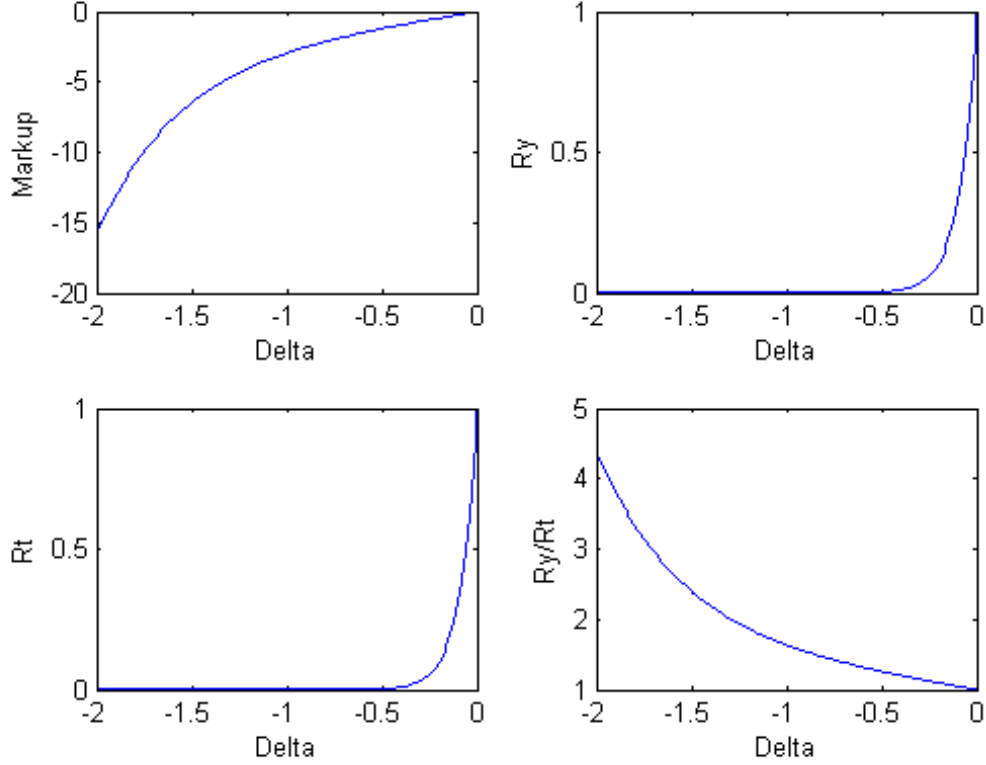
	Energy Consumption
	(1)
Price	-.206 (.014)***
Income	.009 (.002)***
Homeowner	.019 (.006)***
Householdsize	.053 (.002)***
Electheatwater	.290 (.072)***
ConstuctionPeriod	-.021 (.010)**
NumbRooms	.238 (.155)
AppartmentSurface	.237 (.141)*
NumbObs	515586
R^2	.963
Household FE	yes
Year FE	yes

Note: Significance levels: *** 0.01, ** 0.05, * 0.1. Standard errors in parentheses. Log of total yearly energy consumption is used as dependent variable. Price, Income, AppartmentSurface variables are in logs. See also Feger, Pavanini, and Radulescu (2017)

Plugging our estimated coefficients into equation (15) we can directly calculate the optimal markup $\mu = \frac{p_y - \frac{\partial C(y)}{\partial y_i}}{p_y}$ as a function of the welfare weight parameter δ .

Figure 3 shows the results of this exercise. With a negative δ , i.e. a higher welfare weight on poorer households, the optimal markup is always negative. In other words, the regulator should subsidize energy consumption by increasing direct taxation. Intuitively, the result follows from the fact that low income households in our data only bear a small share of income taxation while the difference in energy consumption is less nuanced. Thus, in this scenario, the optimal government policy draws solely on income taxation for raising revenue and subsidizes energy consumption. We should note once again that this result crucially depends on the assumption that the share of the tax payments does not change relative to the status quo.

Figure 3: Optimal Markup for Different Income Weights



Notes: The figure shows the evolution of the optimal markup and the underlying distributional parameters according to the optimality condition (15) and a specified δ . The parameter δ is chosen negatively in this illustration which corresponds to giving more welfare weight to lower income households.

We can also back out the underlying δ of the current markup present in our data. In 2013 the largest energy provider BKW imposed a markup of approximately 43% on the energy price to finance the energy infrastructure. This is equivalent to $\delta = 0.19$ according to our previous calculation. Thus, the current policy would imply the government puts a larger welfare weight on high income households.

5 Extensions

5.1 Labor Reaction

In the basic model we assume that labor income is fixed. Thereby, we do not allow direct income taxation to distort the individual's labor choice. One simple way to introduce such a reaction is by defining income z_i a function of τ . This slightly alters both the individual's and the government's budget constraints (1) and (4) respectively:

$$p_x x_i + p_y y_i \leq z_i(\tau) - t(z_i(\tau), \tau) + g \quad (18)$$

$$\sum_i [p_y y_i + t(z_i(\tau), \tau)] \geq C \left(\sum_i y_i \right) + gN, \quad (19)$$

The modified optimality condition now reads:

$$\frac{\partial W}{\partial p_y} = \sum_i w_i \left[\frac{\partial u}{\partial p_i} - \lambda_i \left(\left(\frac{\partial t}{\partial z_i} - 1 \right) \frac{\partial z_i}{\partial \tau} + \frac{\partial t}{\partial \tau} \right) \frac{\partial \tau}{\partial p_y} \right], \quad (20)$$

with

$$\frac{\partial \tau}{\partial p_y} \approx - \frac{\sum y_i + (p^y - \frac{\partial C(y)}{\partial y_i}) \frac{\partial \sum y_i}{\partial p^y}}{\frac{\partial \sum_i t_i}{\partial \tau} + \sum_i \frac{\partial t_i}{\partial z_i} \frac{\partial z_i}{\partial \tau}}, \quad (21)$$

which leads to the new expression for R_y :

$$R_\tau = \sum w_i \lambda_i \left(\frac{\frac{\partial t}{\partial \tau_i} + \overbrace{\left(\frac{\partial t}{\partial z_i} - 1 \right) \frac{\partial z_i}{\partial \tau}}^{>0}}{\underbrace{\frac{\partial \sum t_i}{\partial \tau} + \sum_i \frac{\partial t_i}{\partial z_i} \frac{\partial z_i}{\partial \tau}}_{<0}} \right) \quad (22)$$

This expression shows that ceteris paribus R_τ increases if we allow for a income reaction of the agent. Thus, the optimal markup increases.

5.2 Welfare Weights as Function of Consumption

Up to now we considered welfare weights to be a function of income. Instead, the regulator might also set these weights as a function of consumption. Such a scheme would imply energy conservation goals on part of the regulator, that is energy efficient households receive a higher welfare weight in policy considerations. Hence, we define the welfare weight to take the form:

$$w_i = y_i^\delta / \sum_i y_i^\delta$$

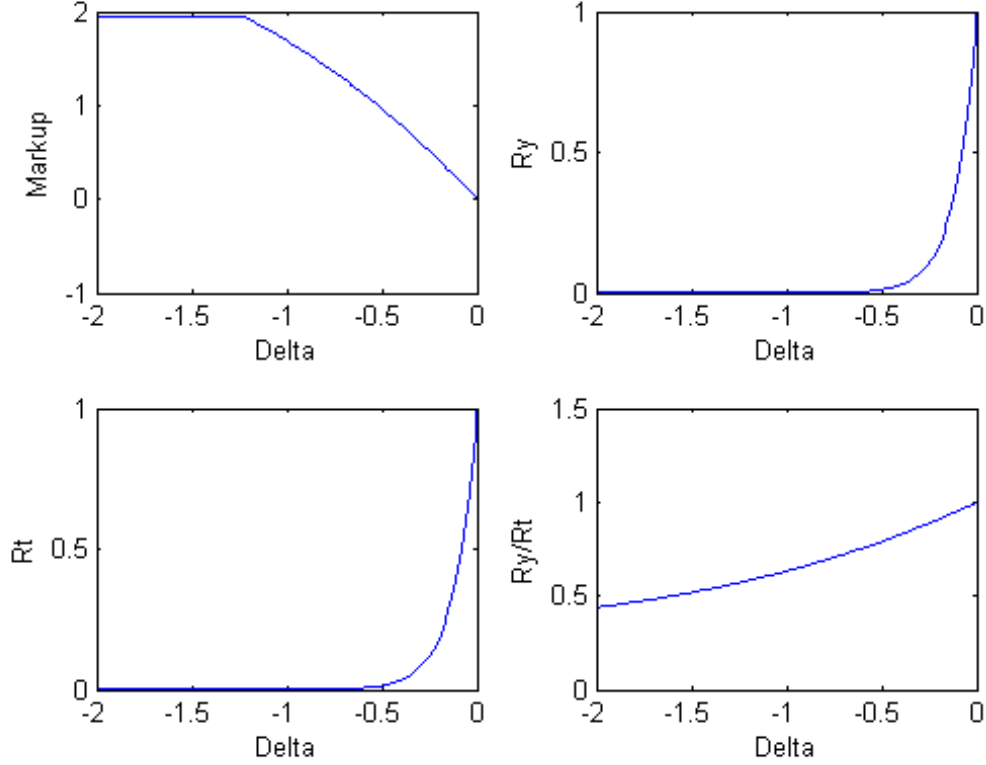
which modifies the optimal mark up equation as follows:¹²

$$\frac{p_y - \frac{\partial C(y)}{\partial y_i}}{p_y} = \left(1 - \frac{\sum y_i^\delta \frac{z_i^\gamma \theta_i}{\sum z_i^\gamma \theta_i}}{\sum y_i^\delta \left(\frac{s_i \cdot z_i}{\sum_i z_i} \right)} \right) \frac{1}{-\beta} \quad (23)$$

Figure 4 shows the simulated result based on this new condition. Not surprisingly, with a welfare weight increasing with energy efficiency optimal markups become positive. The markup's upper bound of 1.96 is ascribed to the fact that we do not allow the regulator to finance other governmental expenditures through the public good. At this markup, the energy grid is fully self-financed.

¹²Note that a price change does not alter the consumption weight as $w_i = \frac{y_i^\delta}{\sum_i y_i^\delta} = \frac{z_i^\gamma \theta_i}{\sum z_i^\gamma \theta_i}$ and thus $\frac{\partial w_i}{\partial p_y} = 0$.

Figure 4: Optimal Markup for Different Energy Consumption Weights



Notes: The figure shows the evolution of the optimal markup and the underlying distributional parameters according to the optimality condition (23) and a specified δ . The parameter δ is chosen negatively in this illustration which corresponds to giving more welfare weight to lower electricity consumption households.

We can again recover the underlying δ from the current markup of 43% in our data. Using a consumption based welfare weight now leads to $\delta = -0.201$. Thus, the positive markup in our data could be explained by energy efficiency considerations. The regulator attaches a low weight to high consumption households to e.g. combat the negative externalities of energy use.

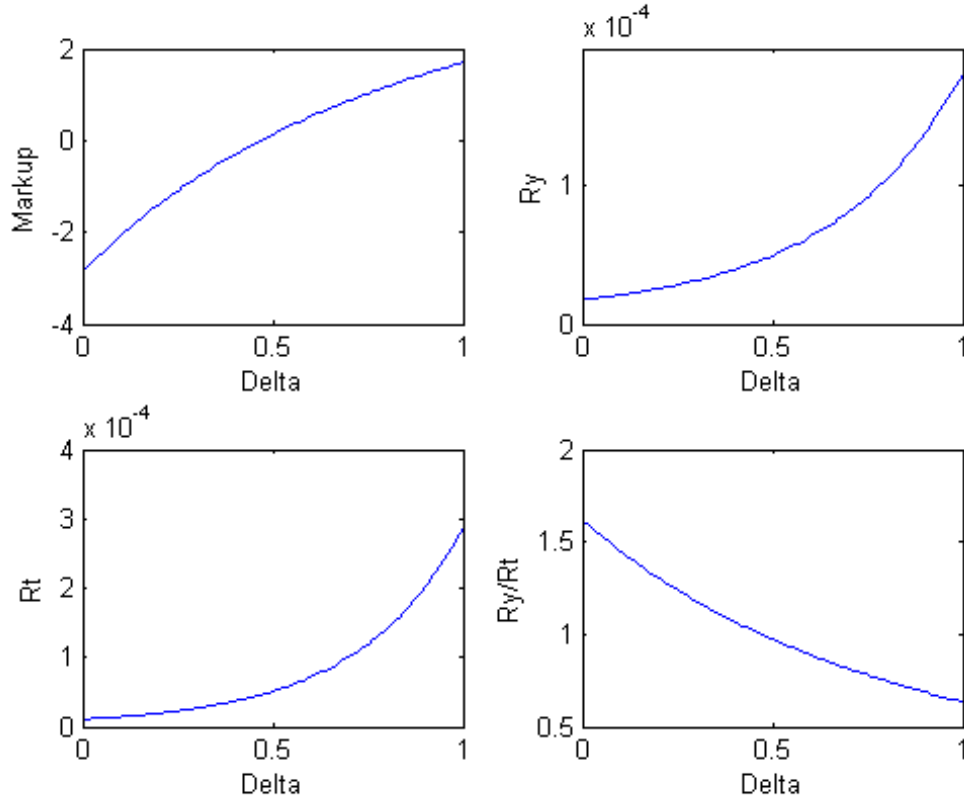
Both a pure income as well as a consumption based welfare weight are extreme scenarios. A more general formulation allows for a combination of both measures. We model

this by assuming the following functional form for the welfare weights:

$$w_i = \frac{1}{y_i^\delta z_i^{1-\delta}} / \frac{1}{\sum_i y_i^\delta z_i^{1-\delta}}$$

where $\delta \in (0,1)$ represents the relative share of consumption in the welfare weight. By increasing δ the regulator puts more weight on energy efficiency while a low δ is associated with a focus on income considerations. Note that for any δ the welfare weight is a decreasing function of income or consumption.

Figure 5: Optimal Markup for Weights Based on Consumption And Income



Notes: The figure shows the evolution of the optimal markup and the underlying distributional parameters according to the optimality condition (23) and a specified δ . The parameter δ corresponds to the share of the consumption measure in the welfare weight and $1 - \delta$ to the share of the income measure.

Figure 5 shows the result for the total range of δ 's. The optimal markup is an increasing function of δ . It is positive for $\delta > 0.5$. With $\delta = 0$ the welfare weight is only a function of income. As shown above, the optimal markup is negative in this case. On the contrary, with $\delta = 1$ the welfare weight is solely based on consumption and the optimal markup is positive. The intermediary cases are a combination of both effects. Allowing for a higher weight of energy consumption implies an increase in the optimal markup. This finding highlights once again the countervailing effects of equity and environmental considerations. Hence, a second tax instrument taking the form of a markup to public utility prices is a useful complement to income taxation if energy conservation goals dominate income redistribution targets. Specifically for Switzerland's markup of 43%, the optimal δ is 0.57. That is, the regulator predominately emphasizes energy conservation targets rather than income redistribution.

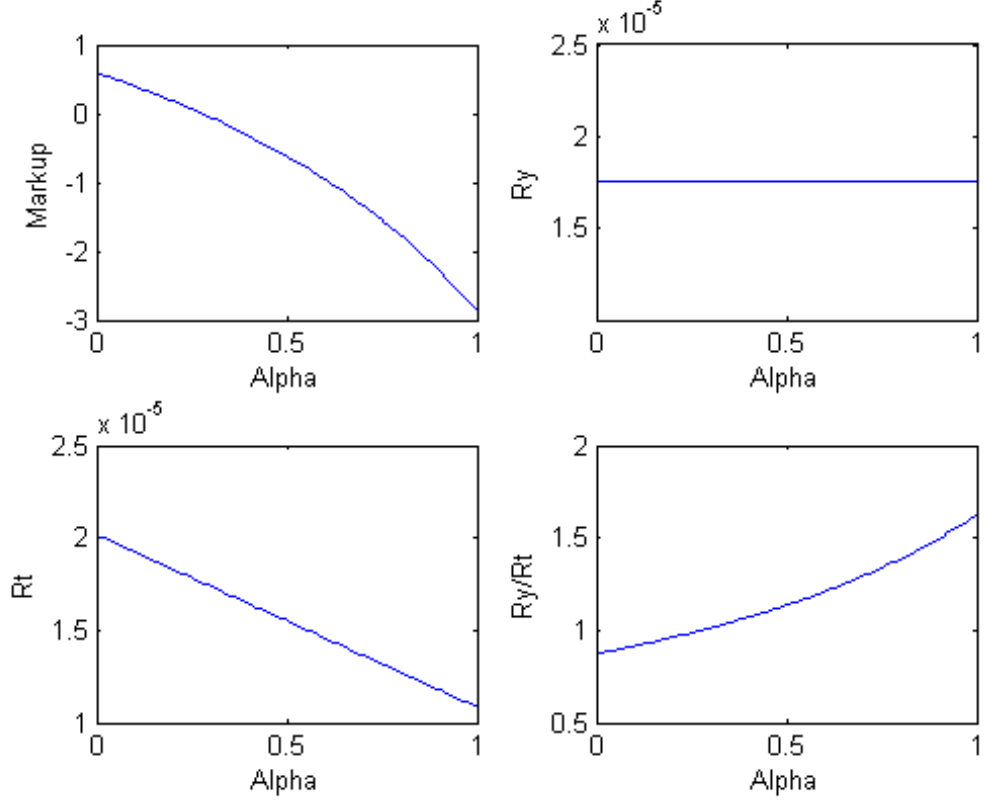
5.3 Effect of Different Taxation Constraints

In our baseline model we assumed that the regulator holds individual tax shares constant when generating additional revenue through income taxation. This assumption is a main driver of our results, as households with a low tax share are affected only to a little extent by a change in the direct tax parameter τ and thus income taxation is an efficient tool for income redistribution. We can relax this assumption and generalize the term $\frac{\partial t_i}{\partial \tau}$ as follows:

$$\frac{\partial t_i}{\partial \tau} = \alpha s_i \cdot \sum_i z_i + (1 - \alpha) \frac{\sum_i z_i}{N} \quad (24)$$

where α is a given parameter and N is the number of households in the sample. The additional term introduced $\frac{\sum_i z_i}{N}$ corresponds to a uniform distribution of the tax burden across households with α being the relative weight of each scenario. The lower α , the higher the share of additional tax revenue financed by a uniform fee. In the extreme case $\alpha = 1$ we are back to our previous results. With $\alpha = 0$ additional tax burden are distributed uniformly among households. Thus, $\alpha = 0$ describes an increase in the head tax, or in our case an increase in the fixed fee f_i .

Figure 6: Optimal Markup for Different Income Tax Schemes



Notes: The figure shows the evolution of the optimal markup and the underlying distributional parameters according to the optimality condition (23) with $w_i = \frac{1}{z_i} / \sum_i \frac{1}{z_i}$ and a specified α . The parameter α corresponds to the share of additional revenue generated by a proportional increase in income tax rates while $1 - \alpha$ relates to an increase in uniform (i.e. lump sum) tax payments.

Figure 6 presents the results of this relaxed assumption for different values of α . Note that we specified $w_i = \frac{1}{z_i} / \sum_i \frac{1}{z_i}$ as the welfare weight set by the regulator. The graph shows that the markup is positive only for very low values of α . Intuitively, this result follows from the redistributive effects of both terms of eq.(24). Relying on uniform taxation redistributes income from low to high income households relative to the status quo. Thus, with a low α a second instrument in the form of a markup on the energy

price is more efficient for redistribution. When $\alpha = 0.28$, an increasing role is assigned to income taxation. In essence, two tax instruments are optimal if direct taxation heavily relies on a lump sum component. In our data the markup amounts to 43% which implies $\alpha = 0.08$. Thus, with an income based welfare weight, the markup is optimal if additional revenue is mainly generated by increasing fixed grid fees.

6 Conclusion

This paper adds to debate following the seminal work of Atkinson-Stiglitz (1976) as to whether the government should rely on one (income taxation) or two instruments (income and commodity taxation) for efficiency and redistribution. We structurally estimate a model of optimal public good pricing and income taxation using an extensive household-level data set for the Swiss canton of Bern. Our empirical model focuses on the residential electricity market. The regulator simultaneously decides on the energy price and the degree of direct taxation maximizing the weighted sum of individual utilities. The resulting optimal energy price markup depends on the electricity consumption share of different household types as well as the distribution of the direct tax burden. The calculations show that with a welfare weight decreasing in level of income, energy price markups should be negative. Intuitively, energy consumption only slightly rises with income while an increase in direct taxation is mainly borne by high income households. We further extend the model to allow for labour supply responses. With income reacting to changes in direct taxation, optimal markups increase compared to the baseline scenario. As an additional extension, we let welfare weights vary with energy consumption instead of income. If the regulator values energy conservation and hence ascribes higher welfare weights to energy efficient households, optimal markups should always be positive. Lastly, we apply our model and find in our data a markup of 43% in the year 2013. Such a value may hint to energy efficiency considerations dominating income based redistribution through the pricing of the good provided by the utility.

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Appendix

Derivation of Price Equation

$$\begin{aligned}
-\sum w_i \lambda_i y_i + \sum w_i \lambda_i \left(\frac{\frac{\partial t_i}{\partial \tau_i}}{\frac{\partial \sum t_i}{\partial \tau_i}} \right) \left[(p_y - mc) \frac{\partial \sum y_i}{\partial p_y} + \sum y_i \right] &= 0 \\
\sum w_i \lambda_i \left(\frac{\frac{\partial t_i}{\partial \tau_i}}{\frac{\partial \sum t_i}{\partial \tau_i}} \right) \left[(p_y - mc) \frac{\partial \sum y_i}{\partial p_y} + \sum y_i \right] &= \sum w_i \lambda_i y_i \\
(p_y - mc) \frac{\partial \sum y_i}{\partial p_y} &= \frac{\sum w_i \lambda_i y_i}{\sum w_i \lambda_i \left(\frac{\frac{\partial t_i}{\partial \tau_i}}{\frac{\partial \sum t_i}{\partial \tau_i}} \right)} - \sum y_i \\
\frac{p_y - mc}{\sum y_i} \frac{\partial \sum y_i}{\partial p_y} &= \frac{\sum w_i \lambda_i \frac{y_i}{\sum y_i}}{\sum w_i \lambda_i \left(\frac{\frac{\partial t_i}{\partial \tau_i}}{\frac{\partial \sum t_i}{\partial \tau_i}} \right)} - 1 \\
\frac{p_y - mc}{p_y} &= - \left(1 - \frac{R_y}{R_\tau} \right) \frac{1}{\frac{p_y}{\sum y_i} \frac{\partial \sum y_i}{\partial p_y}} \\
\frac{p_y - mc}{p_y} &= \left(1 - \frac{R_y}{R_\tau} \right) \frac{1}{E_{yy}}, \tag{25}
\end{aligned}$$

Additional Derivations Structural Model

First order conditions ($p_x = 1$)

$$\begin{aligned}
\lambda_i &= 1 \\
y_i^{\frac{1}{\alpha-1}} z_i^{\frac{\gamma}{1-\alpha}} \theta_i^{\frac{1}{1-\alpha}} &= \lambda_i p_y \\
\Rightarrow y_i &= p_y^{\alpha-1} z_i^\gamma \theta_i = p_y^\beta z_i^\gamma \theta_i
\end{aligned}$$

Demand x_i

$$\begin{aligned}
x_i &= z_i - t(z_i, \tau_i) + g - p_y y_i \\
x_i &= z_i - t(z_i, \tau_i) + g - p_y^\alpha z_i^\gamma \theta_i
\end{aligned}$$

Indirect utility

$$\begin{aligned} v(p_i, z_i) &= z_i - t(z_i, \tau_i) + g - p_y^\alpha z_i^\gamma \theta_i + \frac{\alpha - 1}{\alpha} p^\alpha z_i^\gamma \theta_i \\ &= z_i - t(z_i, \tau_i) + g - p_y^\alpha z_i^\gamma \theta_i + \frac{\alpha - 1}{\alpha} p^\alpha z_i^\gamma \theta_i \end{aligned}$$

Elasticity

$$\begin{aligned} E_{yy} &= \frac{p_y}{\sum y_i} \frac{\partial \sum y_i}{\partial p_y} \\ &= \frac{p_y}{p_y^\beta \sum z_i^\gamma \theta_i} \beta p_y^{\beta-1} \sum z_i^\gamma \theta_i \\ &= \beta \end{aligned}$$