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Weakly Progressive: Disproportionate Higher Education Attendance and the Structure of Income Taxes*

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Abstract

This paper studies the effect of income tax progressivity on the disproportionate usage of publicly funded higher education. We develop a rational choice model showing that more progressive tax systems increase poorer households' net fiscal benefit, making their children more likely to attend university. The model also shows that weakly progressive tax systems can determine a "perverse redistribution", in which poorer households subsidize the higher education for richer households. With this model, we develop three empirically testable hypotheses, where (i) countries with higher levels of progressivity have higher enrollment rate in higher education; (ii) the parental income gradient in children's higher education attendance is lower in countries with more progressive tax systems; and (iii) countries with more progressive tax systems have a lower perverse redistribution in higher education. The model also analyzes the role of local progressivity in higher education choice and redistribution. We provide empirical validation for our model's conclusions across European-OECD countries.

Keywords: Public Higher Education, Progressive Income Tax, University Choice, Inequality
JEL Codes: I23, H41, H31, H24

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1 Introduction

Public universities are institutions that create new knowledge, provide educational and professional training, and open doors to better career opportunities for their students. The public aspect of universities has a critical social relevance – with public higher education systems, governments offer every citizen equal access to university education, thereby reducing economic inequality and improving social mobility. The significant role of public education generally and its ability to shape society long-term was first captured and modeled by Solon (2004). Public universities are, thus, essential in the pursuit of a more equitable society and their different funding methods have received particular attention from researchers and policymakers both in Europe (Eurydice, 2020) and in the U.S. (Dynarski and Scott-Clayton, 2013).

Governments finance their expenditures, including public higher education, through taxes, such as on incomes and profits. Progressive income taxes are most frequently used, as tax progressivity aims to reduce the tax incidence for people with a lower ability to pay. This redistributes economic resources from richer to poorer households. However, even if the higher education system is public and financed through progressive taxes, households bear some private cost if they want to enroll their child in university, such as tuition fees or additional expenditures necessary for a student to get a university degree. These private costs can represent a financial constraint for poorer households who may decide not to send their children to higher education.

One relevant societal and political problem of financing public higher education via progressive income taxes is that economies can end up in a perverse equilibrium in which the poor subsidize the higher education of the rich (Diris and Ooghe, 2018). This situation occurs when children from poorer households do not attend higher education: for instance, it has been shown that in Denmark children from richer parents receive higher in-kind transfers from upper-secondary and tertiary education throughout their entire work life (Nielsen Arendt and Christensen, 2022). This disproportional distribution of in-kind transfers in public higher education may be due to poorer households perceiving the cost of higher education (i.e. private cost net of income taxes) as too high compared to the benefit (e.g., higher future income for their children) and decide not to send their children to university, even if higher education is tuition-free. If a large portion of poorer households opts not to send their children to university and their parents still pay taxes to finance higher education, a "perverse redistribution" from poor to rich occurs in higher education. As a result, the redistributive effect of the higher education system is weakened.

In this paper, we develop a theoretical rational choice model of higher education (Becker, 1993) showing that low tax progressivity can increase perverse redistribution in higher education. The model shows that weakly progressive tax systems are associated with lower poorer households' net fiscal benefit from higher education, making their children less likely to attend university; notwithstanding, poorer households continue to pay the fiscal cost of higher education through their income taxes, thereby financing the higher education of the rich.

Our model is motivated by the fact that income tax progressivity declined in European countries over the last 20 years, as shown in the first half of Figure 1. Income tax progressivity is measured at three different points of the income distribution, namely at 67%, 100% and 167% of the average productive worker (APW). The income tax progressivity at 67% of the APW increased, while the progressivity at the 167% of the APW remained almost constant and the progressivity at the 100% of the AWP declined before bouncing back at the same level it was in 2000. Income tax progressivity increased more for poorer individuals, making the overall tax system less progressive in the last 20 years. In other words, European countries experienced an increase in the fiscal cost for the poor greater than the change in the fiscal cost of richer households over the last 20 years.

This increase in the fiscal cost is also confirmed by the second half of Figure 1, which shows the the marginal tax rate for people with an income at 67% of the APW increased more than the marginal tax rate at the average productive worker – which slightly declined–

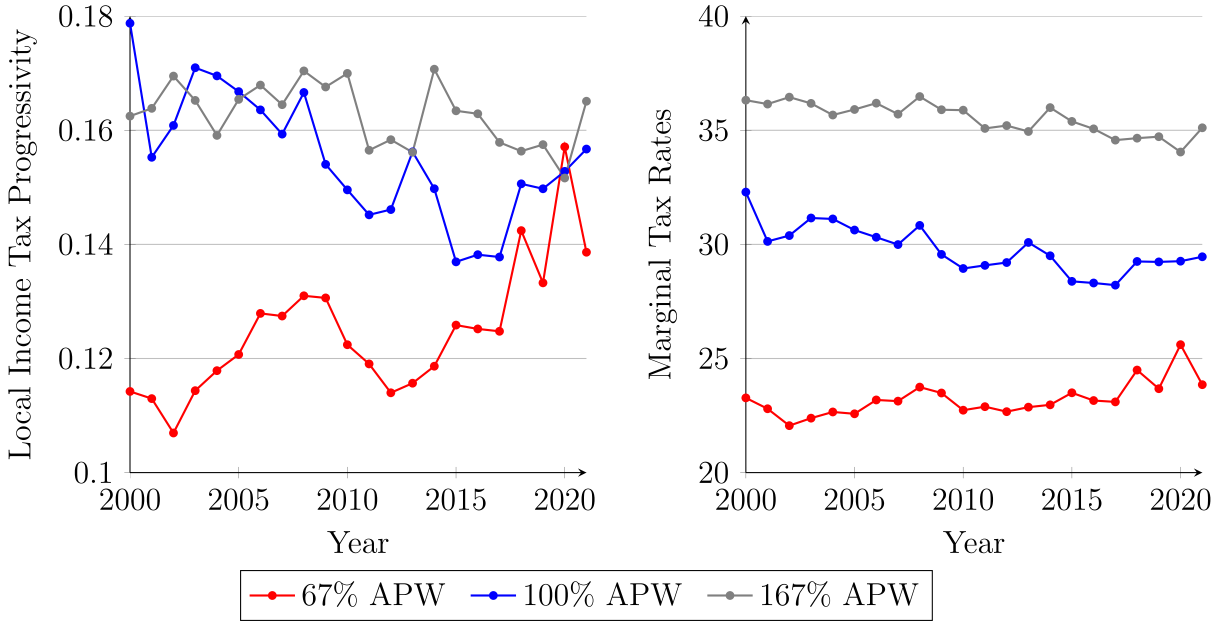

Figure 1: Local Income Tax Progressivity and Marginal Taxe Rates in Europe at different income levels: 2000-2021

Notes: Local tax progressivity and marginal tax rates at 67%, 100% and 167% of the average productive worker (APW) in European countries. Countries are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Slovak Republic, Slovenia, Spain, Sweden, and Switzerland.

and at 167% of the APW, which remained constant between 2000 and 2021.

The model draws three conclusions about the role of tax progressivity on university choice: first, countries with higher levels of progressivity have higher enrollment rates in higher education. Second, the parental income gradient in children's higher education attendance is lower in countries with more progressive tax systems. Third, countries with more progressive tax systems have a lower perverse redistribution in higher education.

We test our model's conclusions empirically for European-OECD countries in the period 2000-2018 using various data sources, such as data from OECD (2022c), the Luxembourg Income Study (LIS), the World Bank (2022) and data from Eurostat (Eurostat, 2022a,b). We choose to focus on European OECD member countries, which allows us to compare developed economies with similarly complex broad-based tax systems and tertiary education systems to isolate the effect of income tax progressivity on our dependent variables of interest.

Our paper offers new insights into the consequences of the design of tax systems on the effectiveness of educational policies and households' university enrollment choices. On the one hand, the model illuminates how greater tax progressivity incentivizes poorer households to send their children to higher education. We show that an increase in progressivity raises the net fiscal benefit vis-á-vis the cost of higher education for poorer households, thereby increasing the probability of sending their children to university. The rise in poorer households' net fiscal benefit can occur either through a reduction in the fiscal cost of financing higher education for the poor or through an increase in the fiscal benefit from higher education without adding any additional cost for the poor. On the other hand, the model suggests that having a progressive tax system is not enough to improve economic opportunities for poorer households in the economy. One conclusion of the theoretical model is that perverse redistribution can still exist if the higher education system is financed through a progressive income tax. We introduce the concept of local progressivity, where the degree of progressivity built into a tax system changes along the income distribution and can thus affect the enrollment rate and the effectiveness of income redistribution along the same distribution. As a result, we show that countries face several possibilities for adjusting the income tax progressivity while seeking to increase university enrollment and reduce perverse redistribution. Lastly, by introducing progressive income taxes to study the perverse redistribution in higher education, our paper contributes to the theoretical literature on the financing methods of public education and educational choices (Epple and Romano, 1996; Glomm and Ravikumar, 1998; Tanaka, 2003; Glomm et al., 2011).

The remainder of the paper is structured as follows: Section 2 provides the general set-up of the theoretical model. Section 3 shows how tax progressivity affects the decision to attend university and the perverse redistribution. Section 4 formulates three hypotheses based on the theoretical model. Sections 5 and 6 discuss the different data and empirically test our hypotheses. Section 7 concludes.

2 The Basic Model

2.1 The economy and the general framework

There is a continuum of households whose mass is normalized to 1 in the economy, where each household consists of one parent and one child. Parents are endowed with an income y, which is continuously distributed with a c.d.f. $F(y)$ that is strictly increasing in y and twice continuously differentiable and a p.d.f $f(y) > 0$ defined over a continuous support $[\underline{y}, \bar{y}] \subset \mathbb{R}_{++}$, whereby $\mathbb{R}_{++} = \{x \in \mathbb{R} \mid x > 0\}$. We assume that the minimum income in the economy is strictly greater than 0, so that each parent can afford at least some level of consumption. This is equivalent to ensuring a lump-sum transfer for everyone in the economy which guarantees a minimum consumption level.[1] In the economy, there exists only a public university system E – without a private option – that is free to the student and entirely financed through a progressive income tax. Additionally, the government allocates a portion of total tax revenues, G, for other public spending targets.

At the beginning of Period 1, a parent pays taxes and the household jointly decides if the child will attend university. In our model, higher education requires some private cost from the household. This private cost increases the probability of the child successfully completing higher education. Thus, parents can choose to pay the additional cost of higher education to increase the probability of their child obtaining higher expected future income or can choose not to bear the additional cost of higher education such that their child will get a lower expected income in the future.

If a child attends university, the household must pay a private subsidy s for the duration of the child's studies. Any additional unit in s is an investment in the future human capital of the child. This assumption allows richer families to afford greater investments in their children's education, which leads to a higher probability of their child graduating. These additional parental costs and investments could cover private tutoring, housing closer to

[1] While this transfer can be added to the model, it would unnecessarily complicate the model without substantially changing the results.

campus and in neighborhoods with greater amenities, and higher general costs of living, which ensures better university results by, either directly or indirectly, increasing the time that can be devoted to learning.

A child's expected future post-graduation income is a function of educational quality, which depends on the amount of public funding directed into the university system, $E > 0$; however, obtaining a university degree is still subject to uncertainty. If a child attends university, they will graduate with a probability $p(s) \in [0, 1)$ or fail to graduate with a probability $1 - p(s)$. The probability of graduating cannot take value 1, so that a child is never 100% certain to graduate, and is a strictly increasing and concave function of parental investments, s, such that $p'(s) > 0$ and $p''(s) < 0$. Moreover, we assume that $p(0) = 0$ and that $p'(0) = \infty$. If parents consider sending their child to higher education, they cannot expect any return without some investment in education.[2] In this context, the private investment in a child's education and government expenditures in public higher education are complements. We assume that without some private support, a child cannot attend and successfully complete higher education, as there are costs that complement attending higher education that households must bear.[3] If a child does not attend university or fails to graduate, they receive the future income of someone with a upper-secondary school (high school) diploma, $w > 0$, such that $0 < w < E$. This assumption aligns with the fact that those with higher education have, on average, higher incomes.

2.2 Utility maximization problem

We assume that parents' utility function is weakly additively separable into the parents' consumption utility, $u(c)$, and the expected income utility of their child, $v(y^c)$. We as-

[2]The probability of graduating can also take into account skills and knowledge acquired prior to going to higher education, such that $p(s, a(y))$, where $a(y)$ captures the skills accumulated by child until the achievement of high school diploma and positively depends on the economic status of their parents, such that $a'(y) \geq 0$.

[3]We relax these restrictions in Online Appendix C where we explore the possibility of means-tested grants (applied in nearly all European countries) or means-tested subsidized loans (such as the German or U.K. system).

sume that parents cannot observe future tax rates; however, they can observe their children's human capital. Thus, parents only explicitly care about their expected children's pre-tax income, which is a function of their children's human capital. The utility function $u(c)$ is continuous, twice differentiable, strictly increasing ($u'(c) > 0$), and strictly concave ($u''(c) < 0$) in parental consumption c. Moreover, we assume that parents cannot favor their children's education over their own consumption if that implies parental consumption equal to 0 ($u'(0) = \infty$). Similarly, the utility function for children, $v(y^c)$, is continuous, twice differentiable, strictly increasing, and strictly concave in children's future income, y^c.

A parent makes the choice that maximizes their utility depending on whether or not they send their child to university. Namely, they maximize between V^e and V^w, $\max\{V^e, V^w\}$. The two functions are the present discounted indirect utility from sending their child to university, V^e, and the present discounted indirect utility from having their child entering the work force without university graduation, V^w.

If a parent decides to send their child to university, they maximize $u(c) + \delta[p(s)v(E) + (1 - p(s))v(w)]$ subject to the budget constraint $c + s \leq d_k(y)$, where $d_k(y) > 0$ is the post-tax income of a household in income class k, which is continuously differentiable and strictly increasing in y, while $\delta \in (0, 1)$ is the discount factor for the child's future utility. As result, parents obtain the indirect utility V^e (see Appendix A for a detailed derivation):

$$V^e = u(d_k(y) - s^*) + \delta[p(s^*)v(E) + (1 - p(s^*))v(w)], \tag{1}$$

whereby $s^* = s(d_k(y)) > 0$ is the optimal parental subsidy.

If a parent decides not to send their child to university, they cease investing in their child's education and, thus, maximize $u(c) + \delta v(w)$ subject to the budget constraint $c \leq d_k(y)$ to obtain the indirect utility V^w,

$$V^w = u(d_k(y)) + \delta v(w). \tag{2}$$

The indifferent utility in (1) shows that, if a parent chooses to send their child to university, they have to invest an optimal amount of subsidy given their net income, $s(d_k(y))$ to maximize the probability $p(s(d_k(y))) \in (0,1)$ of their child graduating and obtaining the higher future income. On the other hand, (2) shows that, if a parent does not send their child to university, parents will consume their entire income and their child will receive income $w > 0$ going forward. The differences between the indirect utility functions (1) and (2) define the opportunity cost that parents face in their decision.

2.3 Educational system and government budget constraint

Income earners in the economy pay income taxes in order to finance the public education system, E, and other public goods, G. The public education system of one cohort is financed only through the taxes paid by their parents at the beginning of Period 1. The timing of the events implies that those children who decide not to attend university do not finance the public education system for children of the same cohort who did decide to attend university. The tax system is piece-wise continuously differentiable function, where tax rates increase with income. Hence, we modify the classical linear piece-wise tax function, in line with D'Antoni (1999), so that the tax function is non-linearly increasing to the right of each income bracket. This small modification allows the function to be continuously differentiable in its domain and to identify the different income brackets B and tax rates $\mathbf{t}$. For simplicity, we assume that the tax system consists of 2 income brackets $B = \{\widehat{y}_0, \widehat{y}_1\}$ and 3 different income classes $\bar{K} = \{0, 1, 2\}$. We will refer to the income classes as poor, middle class, and rich going forward. We define the poor as the income class that includes the minimum income $\underline{y}$, the middle class as the class that includes the average income $y_a = \int_{\underline{y}}^{\bar{y}} y f(y) dy$ and the rich as the income class, which includes the maximum income $\bar{y}$. We also assume that different marginal tax rates are associated with each income class, such that $\mathbf{t} = \{t_0, t_1, t_2\}$. Thus, the tax liability of a parent depends on their respective income class and follows the tax function in (3):

$$T_i(y) = \begin{cases} 0 & \underline{y} \leq y \leq \widehat{y}_0 \\ t_1(y - \widehat{y}_0) + \tau_1(y)(t_0 - t_1) & \widehat{y}_0 < y < \widehat{y}_0 + \epsilon \\ t_1(y - \widehat{y}_0) + \tau_1(\widehat{y}_0 + \epsilon)(t_0 - t_1) & \widehat{y}_0 + \epsilon \leq y \leq \widehat{y}_1 \\ t_1(\widehat{y}_1 - \widehat{y}_0) + t_2(y - \widehat{y}_1) + \tau_1(\widehat{y}_0 + \epsilon)(t_0 - t_1) + \tau_2(y)(t_1 - t_2) & \widehat{y}_1 < y < \widehat{y}_1 + \epsilon \\ t_1(\widehat{y}_1 - \widehat{y}_0) + t_2(y - \widehat{y}_1) + \tau_1(\widehat{y}_0 + \epsilon)(t_0 - t_1) + \tau_2(\widehat{y}_1 + \epsilon)(t_1 - t_2) & y \geq \widehat{y}_1 + \epsilon \end{cases} \quad (3)$$

where ϵ is strictly greater than zero and very small, $t_0 = 0$ is the tax rate for incomes below the zero-tax threshold, $\widehat{y}_0$, and the term $\tau_k(y)(t_{k-1} - t_k) < 0$ is a tax credit function associated with income class k. The tax liability function (3) is increasing and progressive if $t_k > t_{k-1}$ for every $k \in \bar{K}$, whereby $t_k \in [0, 1)$ and if each $\tau_k(y)$ in $\boldsymbol{\tau} = \{\tau_0(y), \tau_1(y), \tau_2(y)\}$ has the following properties:

T1) Each $\tau_k(y)$ is an increasing, continuously differentiable function, such that $0 \leq \tau_k'(y) < 1$ in $(\widehat{y}_{k-1}, \bar{y}]$ (i.e. $\tau_k(y)$ is a contraction mapping);

T2) $\tau_0(y) = 0$ if $y < \widehat{y}_0$ and $\tau_k(\widehat{y}_{k-1}) = 0$ for each $k \in \bar{K}$;

T3) for $k > 0$, $\lim_{y \to \widehat{y}_k} \tau_k'(y) = 1$ and $\lim_{y \to \widehat{y}_k + \epsilon} \tau_k'(y) = 0$.

The progressivity comes from the fact that $t_{k+1} > t_k$. Under this condition, the marginal tax rate is strictly increasing in income for any $t_k > 0$. Because of properties T1-T3 and because $t_k > t_{k-1}$ for every $k \in \bar{K}$, it follows that the tax system is also *strongly incentive preserving* (Fei, 1981; Eichhorn et al., 1984), meaning that the ranking of tax-payers according to their pre-tax and post-tax incomes is the same (see Appendix B for further discussion of the tax function).

Figure 2 illustrates the tax revenue and tax rate functions obtained at different levels of income.

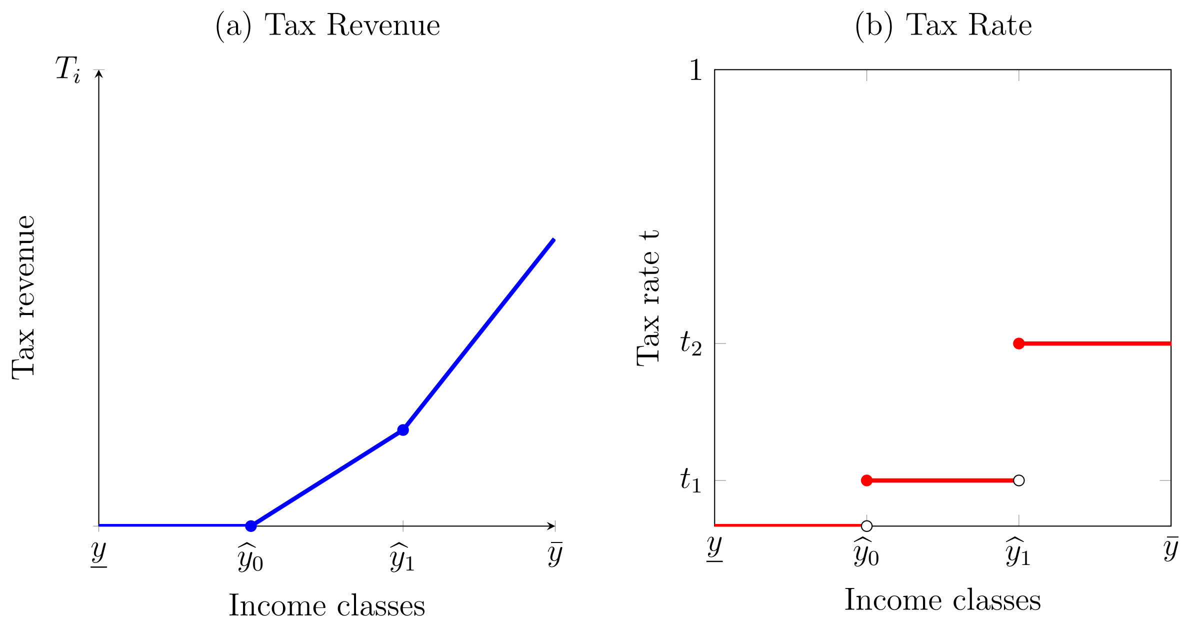

Figure 2: Income tax revenue and rates

Notes: (a) Tax revenue given the level of income and the income classes. The blue dots represent the function in the right-neighbor $(y_k, y_k + \epsilon)$. (b) Progressive tax rates per income classes. The red (white) dots mean that the tax rate is (is not) applied to the income class.

The balanced government budget constraint is thus:

$$E + G = T, \tag{4}$$

whereby T is the total government tax revenue raised, $E = T\alpha$ is the amount (quality) of per-household higher education, while $G = T(1-\alpha)$ is the amount of per-household public spending that is not directed to public education and does not directly affect the utility function of households in their educational choice; thus, G includes, for instance, the spending towards the public health system, national defence, or other social protections.[4] The parameter $\alpha \in (0,1)$ represents how much of total tax revenue (or total expenditure) attends education. For instance, α can be interpreted as the percentage of tax revenue that

[4] G could also be a set of other public goods that affect the utility function of a parent (i.e. $u(c,G)$) and that the utilities of private goods and public goods are on average independent (i.e. $u''_{cG} = 0$). This independence assumption was first applied by Aaron and McGuire (1970) and does not change the results of the model because G would remain the same, whether the child attends university or not.

a country spends on higher public education. We assume that public spending is strictly greater than zero.

In (4), the number of households does not affect the quality of the public goods available, thereby implying no congestion effect. We exclude a congestion effect at the level of public spending G, as it represents a large set of different public goods that are available to all households, with some households partaking in some public goods more than others and ruling out an overall congestion effect. For the provision of higher public education E, we exclude the congestion effect for two main reasons: (i) ambiguous empirical findings in the literature on the congestion effect in higher education and (ii) the capacity of governments to absorb the excess demand for higher education in a universal higher education system, which is the case of the European, high-income countries we are considering (see Online Appendix B for an in-detail discussion).

2.4 University choice

In order to understand how progressivity can affect the decision of attending university, we next focus on the conditions under which parents decide to send their children to university. First, we show the existence of an unique indifference pre-tax income threshold over the income support $[\underline{y}, \bar{y}]$, under a progressive income tax scheme $\{\mathbf{t}, \boldsymbol{\tau}\}$:

Lemma 1 *Given a continuous income distribution with C.D.F $F(y)$ and with p.d.f $f(y)$ over a continuous support of $[\underline{y}, \bar{y}] \subset \mathbb{R}_{++}$, and given a progressive tax scheme $\{\mathbf{t}, \boldsymbol{\tau}\}$, there exists an unique threshold $\widetilde{y} \in [\underline{y}, \bar{y}]$ such that $V^w(d_k(y)) \geq V^e(d_k(y))$ if and only if $y \leq \widetilde{y}$.*

Proof. See Appendix C.1 ■

Lemma 1 illustrates a simple result – for a given distribution of incomes and a given tax scheme, there exists a unique pre-tax income threshold such that parents above the threshold have a higher utility from sending their children to tertiary education, while parents below that threshold derive a greater utility from not investing in their child's tertiary education.

Thus, for a given income distribution with C.D.F $F(y)$, we can split the population into two sub-samples: (i) the mass of households with $y > \widetilde{y}$, who decide to send their children to university, $N^e = \mathbf{P}(V^w < V^e) = \mathbf{P}(y > \widetilde{y}) = 1 - F(\widetilde{y})$, where $\mathbf{P}$ is the probability of sending one's child into tertiary education for a given income. (ii) the mass of households with $y \leq \widetilde{y}$, who decide not to send their children to tertiary education, $N^w = \mathbf{P}(V^w \geq V^e) = \mathbf{P}(y \leq \widetilde{y}) = F(\widetilde{y})$. Figure 3 illustrates these two masses along the income distribution.

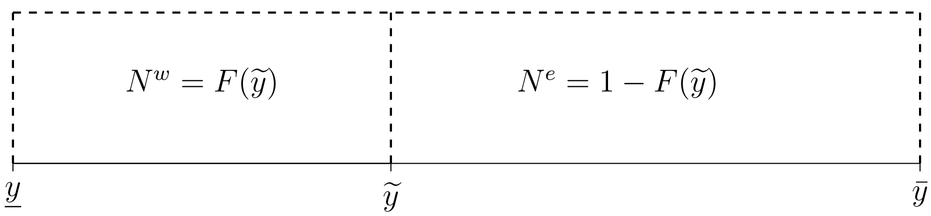

Figure 3: Working population and population in university

Notes: The graph shows that the portion of population with income $y \leq \widetilde{y}$ represent the working population N^w. The portion of population with income $y > \widetilde{y}$ represents the population in university N^e.

We are interested in studying how the threshold $\widetilde{y}$, and thereby the decision of attending university, changes when different parameters in the economy change. If the threshold is negatively or positively related to certain factors, the threshold will move to the left or right, respectively as those factors increase. Lemma 2 explains the relationship between $\widetilde{y}$ and different structural parameters.

Lemma 2 *The threshold $\widetilde{y}$ is increasing in the expected income of individuals that do not graduate, w (i.e. $\frac{\partial \widetilde{y}}{\partial w} > 0$). The threshold $\widetilde{y}$ is decreasing in the share of tax revenue directed to higher public education, α (i.e. $\frac{\partial \widetilde{y}}{\partial \alpha} < 0$).*

Proof. See Appendix C.2 ■

These results have simple economic explanations: if the salary of people without a university degree w increases, then the opportunity cost of sending a child to university is lower and poorer households will prefer not to pay any additional private cost (the subsidy s) for an investment with an uncertain return. On the other hand, if the government increases the share of tax revenue directed to the public higher education, the quality of education – and thereby future post-university incomes – increases, and more households will be incentivized to send their children to university.

2.5 Perverse redistribution

We define perverse redistribution as the fiscal phenomenon where poorer households sustain the fiscal cost of a public good without being able to partake in the benefit of it. In other words, perverse redistribution occurs if poorer households' taxes go towards funding a public good, which is more intensively used by the rich, due to the additional cost and opportunity cost of accessing the public good. In higher education, this perverse redistribution happens because poorer households pay for a public higher education system with their taxes but do not send their children into tertiary education. Henceforth, because the model only has three income classes, to study the effect of progressivity on perverse redistribution, we will consider the case where, for a given structure of a tax system, the indifferent threshold is $\widetilde{y} < \widehat{y}_1$ and households in the richest income class strongly prefer to send their children to higher education.

If $\widehat{y}_0 < \widetilde{y} < \widehat{y}_1$, the population consists of three groups:

(i) The portion of households that finances public higher education through their taxes and decides to send their child to university, denoted N^e, such that $N^e = 1 - F(\widetilde{y})$.

(ii) The portion of households that finances public higher education through their income taxes but who do not send their children to university (we will shorthand these households the middle class), denoted N^w, such that $N^w = F(\widetilde{y}) - F(\widehat{y}_0)$. The mass of this population also represents the size of the perverse redistribution.[5]

(iii) The portion of households that do not send their children to university and who are

[5] N^w households are poorer than N^e households and do not send their children to higher education; however, due to their tax payments greater than zero, they do contribute to the financing of higher education of more affluent families' children; thus, the higher N^w is, the greater the perverse redistribution.

not financing higher education because they are to the left of the no-tax threshold, denoted N_0^w, such that $N_0^w = F(\widehat{y}_0)$.

Figure 4 shows the three groups for a given income distribution over the support $[\underline{y}, \bar{y}]$:

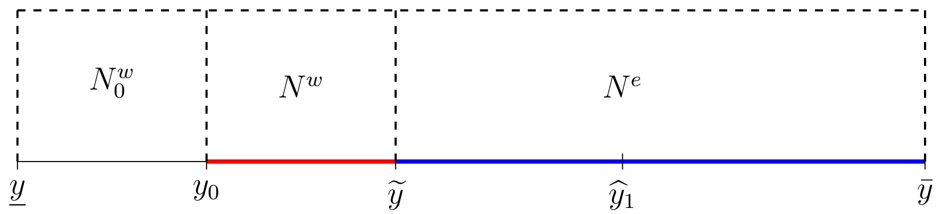

Figure 4: Perverse redistribution

Notes: The graph shows that the poorest part of the population (black line) N_0^w does not attend university, but does not subsidizes it. People in the middle N^w (red line) do not attend university and subsidize university for richer households. Richer households N^e (blue line) send their chi to university and pay for it.

If $\widehat{y}_0 \geq \widetilde{y}$, then $N^w = 0$ and there are only two groups of households, namely N_0^w and N^e. In this case, there is no perverse redistribution because poorer households do not send their children to university and do not pay for it, while those attending university are richer households and are paying higher taxes to finance public higher education.

3 Progressive taxation

Considering our empirical question, we want to study the effect of income tax progressivity on higher education choice and estimate the level of perverse redistribution built into how we finance public higher education. In line with Doerrenberg and Peichl (2013), we model an increase in progressivity as a positive change in the tax rate of the rich (t_2), while the tax rates on the middle class (t_1) and the poor (t_0) remain constant.[6]

We consider this definition of progressivity sufficiently detailed to theoretically analyse how changes in progressivity can affect households' educational choices and perverse redis-

[6]By increasing the number of the income classes to $k > 3$, an increase in progressivity would correspond to a positive change in the tax rate of any of the income classes above the indifference threshold, while the other tax rates remain unchanged.

tribution. We acknowledge that, in reality, an increase in progressivity can occur through a simultaneous non-proportional variation in more than one tax rate without changing the overall public investment in education. However, within this definition, we can disentangle the overall shift of the fiscal cost across income classes as a result of an increase in educational spending through a change in progressivity.[7]

As described in Lemma 2, an increase in the total level of public higher education funding moves the indifference threshold to the left; however, an increase in tax progressivity may be targeted to finance other public spending targets rather than higher education. Some countries may have highly progressive tax schemes but only direct a limited amount towards public tertiary education. On the other hand, countries may have relatively low levels of progressivity but funnel a higher share of funding towards public tertiary education.

To disentangle the effect of income tax progressivity on higher education choice from changes in spending targets, we consider α to be the size of an educational policy; thus, we assume that α is a continuous differentiable function of the total tax revenue, such that $\alpha(T) : T \to (0, 1)$. If spending in higher education increases along with income tax progressivity, then $\partial\alpha(T)/\partial t_2 > 0$; if spending in higher education does not change, then $\partial\alpha(T)/\partial t_2 = 0$; and if spending in higher education decreases along with income tax progressivity, then $\partial\alpha(T)/\partial t_2 < 0$. Henceforth, we will consider all the three cases. Empirically, among advanced economies with similar higher education systems, income tax progressivity is not significantly correlated with higher educational spending, even after controlling for different macroeconomic variables. This result implies that we empirically observe $\partial\alpha(T)/\partial t_2 = 0$.

To study the effect of progressivity on perverse redistribution in education, we consider two cases in the following subsections. Section 3.1 considers an increase in progressivity when the indifference threshold $\widetilde{y}$ is above the no-tax threshold, $\widehat{y}_0$, while Section 3.2 considers an increase in progressivity when the indifference threshold $\widetilde{y}$ is below the no-tax threshold, $\widehat{y}_0$.

[7] In Online Appendix C, we provide an alternative definition of an increase in progressivity that captures the shift of the fiscal cost from the middle class and poor to the rich, without changing the level of educational spending and results remain unchanged.

Section 3.3 presents the concept of local progressivity in the context of perverse redistribution.

3.1 Increase in progressivity if $\widehat{y_0} < \widetilde{y} < \widehat{y_1}$

If we assume that the income of the indifferent household is such that $\widehat{y_0} < \widetilde{y} < \widehat{y_1}$, we can set the difference between the two indirect utility functions of the indifferent household equal to 0.

$$\Delta(\widetilde{y}) = V^w(d_1(\widetilde{y})) - V^e(d_1(\widetilde{y})) = 0 \tag{5}$$

An increase in progressivity consists of an increase in the tax rate t_2. Totally differentiating the difference between the two utility functions and applying the envelope theorem, we get

$$\frac{\mathrm{d}\widetilde{y}}{\mathrm{d}t_2} = -\frac{1}{D}\left[\underbrace{\frac{\partial[u(d_1(\widetilde{y})) - u(d_1(\widetilde{y}) - s)]}{\partial t_2}}_{\text{Marginal fiscal cost=0}} \underbrace{- \delta p(s) v'(E)\left(\underbrace{\alpha\frac{\partial T}{\partial t_2}}_{\text{Tax Revenue }>0} + \underbrace{T\frac{\partial \alpha}{\partial t_2}}_{\text{H.E. funding}}\right)}_{\text{Marginal fiscal benefit }\lesseqgtr 0}\right], \tag{6}$$

where $D = \partial\Delta(\widetilde{y})/\partial\widetilde{y} < 0$ and $\alpha[\partial T/\partial t_2] > 0$.

Proof. See Appendix D ■

The sign of (6) depends on the direction of the policy $\alpha(T)$. If $\partial\alpha/\partial t_2 \geq 0$, then funding for public tertiary education increases in response to rising progressivity. The increase in public funding can be due to a change in spending targets (i.e. $\partial\alpha/\partial t_2 > 0$) or in response to rising total tax revenues, without changing the share of public spending on public higher education (i.e. $\partial\alpha/\partial t_2 = 0$). Under these circumstances, a more progressive tax schedule is negatively related to the income of the indifferent households (i.e. $\partial\widetilde{y}/\partial t_2 < 0$). An increase in progressivity then reduces the income level at which households are indifferent between sending their child to university or not. After an increase in progressivity, the marginal fiscal cost for greater quality public tertiary education paid by households in the poor and middle income classes is equal to zero because their tax rates remained constant. On the other hand, the marginal fiscal benefit from higher quality education is strictly positive for everyone in the economy; thus, the net marginal fiscal benefit is strictly positive for all poor and middle income households. With a more progressive tax scheme, the indifferent households have a fiscal benefit greater than their fiscal cost. An increase in progressivity increases the opportunity cost of sending a child to university, incentivizing formerly indifferent households to send their children into higher education.

If $\partial\alpha/\partial t_2 < 0$, the result is ambiguous. The increase in tax revenue may be offset by a decrease in the overall funding share going towards public higher education, such that $\alpha\frac{\partial T}{\partial t_2} + T\frac{\partial \alpha}{\partial t_2} > 0$. The sign of (6) would then be positive and the increase in progressivity will have a negative effect on the educational choice of the poorer. However, (6) will be smaller than if an increase in progressivity coincides with an increase in educational funding α, $\partial\alpha/\partial t_2 \geq 0$. If the negative change in higher education funding is smaller than the increase in total tax revenue, $\alpha\frac{\partial T}{\partial t_2} + T\frac{\partial \alpha}{\partial t_2} < 0$, then (6) will be negative.

The effect of an increase in progressivity can also be analysed by focusing on how the masses of the three population subgroups change. Consider an initial distribution that splits the population into its three subgroups: N_0^w, N^w, and N^e. As shown in (6), an increase in progressivity consists of an increase in t_2 and implies $\partial\widetilde{y}/\partial t_2 < 0$. Therefore, the effect of an increase in progressivity on the partition of the population when $\partial\alpha/\partial t_2 \geq 0$ follows

$$\frac{\partial N^w}{\partial t_2} = \frac{\partial \widetilde{y}}{\partial t_2} f(\widetilde{y}) < 0, \tag{7}$$

$$\frac{\partial N^e}{\partial t_2} = -\frac{\partial \widetilde{y}}{\partial t_2} f(\widetilde{y}) > 0, \tag{8}$$

$$\frac{\partial N_0^w}{\partial t_2} = 0, \tag{9}$$

(7) shows that a more progressive tax scheme reduces the mass of households who con-

tribute to the financing of the public higher public education system but do not send their children into higher education. In other words, a more progressive tax system reduces the perverse redistribution in the economy. By extension, a more progressive tax system increases in the number of households sending their children to university, as shown by (8), while the mass of N_0^w remains unchanged unless the new threshold $\widetilde{y}$ moves below $\widehat{y}_0$. Figure 5 portrays this effect.

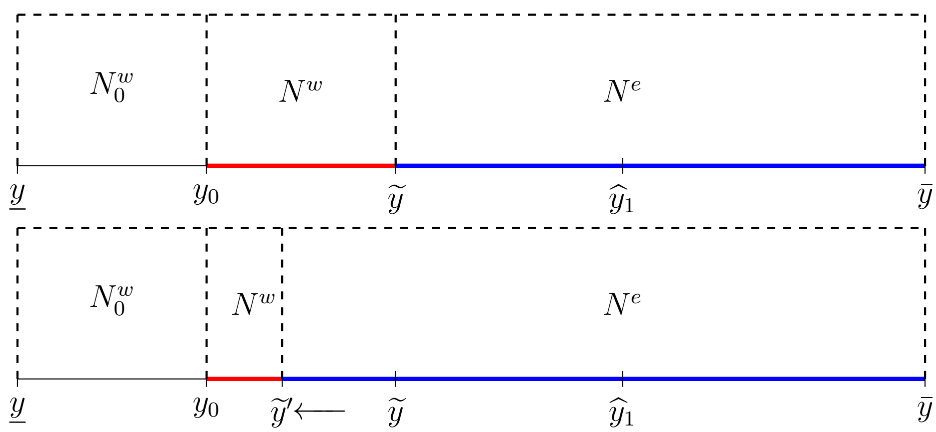

Figure 5: Perverse redistribution after an increase in progressivity

Notes: The graph shows that an increase in progressivity increases the number of people going to university (area above the blue line) and reduces the perverse redistribution (area above the red line).

Figure 5 illustrates the dynamics of perverse redistribution (the area above the red line) as the income tax becomes more progressive with respect to the indifferent household. As the tax rate t_2 increases, the threshold $\widetilde{y}$ shifts to the left of the support $[\underline{y}, \bar{y}]$, following (6). As $\widetilde{y}$ shifts left, poorer households prefer to send their children to university and, thus, perverse redistribution shrinks.

When $\partial\alpha/\partial t_2 < 0$, the signs of the derivatives (7) and (8) may be different – if the increase in total tax revenue is smaller than the reduction of funding going to tertiary education, the sign in the derivatives (7) and (8) reverse. Instead, if the increase in total tax revenue is larger than the reduction in the funding share α, then the sign of the derivatives (7) and (8) remain the same, while the size of the effect will be smaller than when $\partial\alpha/\partial t_2 \geq 0$.

Proposition 1 *If $\widehat{y}_0 < \widetilde{y} < \widehat{y}_1$, it is possible to reduce perverse redistribution by increasing the progressivity through an increase of the tax rate t_2 if and only if the amount of funding directed to tertiary education α does not decrease more than the increase in total tax revenue.*

3.2 Increase in progressivity if $\widetilde{y} \leq \widehat{y}_0$

When $\partial\alpha/\partial t_2 \geq 0$ and $\widetilde{y} \leq \widehat{y}_0$, then $N^w = 0$. The economy will then only consist of two groups of households, namely N_0^w and N^e and there will be no perverse redistribution, because the poorer households who do not send their children to university do not contribute to its financing, and among those sending their children to attend university, richer households pay more for the available public tertiary education. Thus, an increase in progressivity will increase the number of people going to university and the number of poorer households who do not pay taxes but who decide to attend higher education.

$$\frac{\partial N^e}{\partial t_2} = -\frac{\partial \widetilde{y}}{\partial t_2} f(\widetilde{y}) > 0, \tag{10}$$

$$\frac{\partial N_0^w}{\partial t_2} = \frac{\partial \widetilde{y}}{\partial t_2} f(\widetilde{y}) < 0, \tag{11}$$

$$\frac{\partial N^w}{\partial t_2} = 0, \tag{12}$$

If $\partial\alpha/\partial t_2 < 0$, the sign of the derivatives (10) and (11) may reverse if and only if the increase in total tax revenue is smaller than the reduction of funding going to tertiary education, $\alpha\frac{\partial T}{\partial t_2} + T\frac{\partial \alpha}{\partial t_2} > 0$.

Proposition 2 *If $\widetilde{y} \leq \widehat{y}_0$, the tax system is sufficiently progressive and there is no perverse redistribution. An increase in progressivity then increases the number of poorer household opting for their child to attend university if and only if the amount of funding directed to tertiary education does not decrease more than the increase in total tax revenue.*

In Online Appendix C we introduce further plausible extensions to the baseline model.[8]

3.3 Local Progressivity

The analysis so far has focused on the relationship between perverse redistribution and the general progressivity of the income taxes in an economy; however, both the model and the empirical implications consider progressivity as the difference in marginal tax rates between the different households in the three income groups, particularly between the indifferent and the richer households. This form of progressivity can be captured in the *local progressivity* measure.

The local progressivity measure, π_k, as applied by Arnold (2008) and Rieth et al. (2016), captures the progressivity in each income class k:

$$\pi_k = \frac{t_k - a_k}{1 - a_k}, \tag{13}$$

where $t_k \in [0, 1)$ is the marginal tax rate of a household in income class k and $a_k \in [0, 1)$ is the average tax rate of that same household in income class k defined as the total tax paid by a household divided by the household' total income, $a_k = T_k(y, \mathbf{t})/$y. The progressivity measure in (13) is increasing in the marginal tax rate t_k and decreasing in the average rate a_k. If $\pi_k > 0$, the tax is progressive for a household in income class k, while the tax is regressive if $\pi^k < 0$. Finally, if $\pi_k = 0$, the marginal and average tax rate coincide and the tax is proportional.

If we consider the local progressivities of our model's three income classes, we observe that $\pi_0 = 0$ even if $t_1 > t_2$ and the overall tax scheme is progressive. Moreover, depending on the difference between the marginal tax rate and the average tax rate, richer households

[8] These extensions address (i) the greater familial-social pressure to attend university and complete it successfully faced by children of richer households; (ii) the addition of public means-tested grants or (iii) publicly-funded loans; (iv) and increases in progressivity that stem from a reduction of the tax rate for poorer households, while keeping the overall quality of education constant. While extensions (ii)-(iv) bring some extra discussion of the concept of perverse redistribution, they do not change the general validity of the model.

may have a lower local progressivity than households around the indifference threshold.

$$t_1 - a_1 > t_2 - a_2 \implies \pi_1 > \pi_2 \tag{14}$$

To understand how local progressivity factors into the household university choice and perverse redistribution, we explore the following example. The indifferent household lies above y_0 and thus pays a positive t_1 and a_1. An increase in t_1 then increases π_1, but reduces π_2 because $\partial a_2/\partial t_1 > 0$ and $\partial \pi^2/\partial a_2 < 0$. The effect of an increase in t_1 has, therefore, an ambiguous effect on the university choice of the indifferent household, as their marginal fiscal cost is now positive:

$$\frac{\mathrm{d}\widetilde{y}}{\mathrm{d}t_1} = \left[-\frac{1}{D}\right] \left[\underbrace{\frac{\partial[u(d_1(\widetilde{y})) - u(d_1(\widetilde{y}) - s)]}{\partial t_1}}_{\text{Marginal fiscal cost} > 0} - \underbrace{\delta p(s) v'(E) \left(\alpha \frac{\partial T}{\partial t_1} + T \frac{\partial \alpha}{\partial t_1} \right)}_{\text{Marginal fiscal benefit } > 0} \right] \tag{15}$$

An increase in local progressivity for the indifferent household could then have no or even negative effect on higher education choice and perverse redistribution, depending on whether their marginal fiscal cost exceeds the marginal fiscal benefit. If the income class of the indifferent household bears the cost of raising more revenue (meaning only t_1 is increased, while t_0 and, most importantly, t_2 remain constant), π_1 rises, π_2 will decrease.

Proposition 3 *If $\widehat{y}_0 < \widetilde{y} < \widehat{y}_1$, an increase in local progressivity π_1 will either maintain or move the indifference threshold $\widetilde{y}$ to the right, $\frac{\partial \widetilde{y}}{\partial t_1} \geq 0$, if the marginal fiscal cost exceeds the marginal fiscal benefit.*

Conceptually, local progressivity implies that the degree of progressivity of a tax system changes along the income distribution and can thus affect the enrollment rate along the same distribution. This affects overall perverse redistribution in higher education. When countries seek to increase university enrollment and reduce perverse redistribution, countries face several scenarios for adjusting the income tax progressivity, as long as the marginal fiscal benefit of the indifferent household exceeds their marginal fiscal cost.

4 Hypotheses

Before connecting the model to the data, we clarify the hypotheses stemming from the theoretical framework:

Hypothesis 1 *For a similar share of resources spent on public higher education, countries with higher levels of progressivity have a higher enrollment rate in higher education.*

Hypothesis 2 *For a similar share of resources spent on public higher education, parent-income gradient in children's higher education attendance is lower in countries with more progressive tax systems.*

Hypotheses 1 and 2 stem from Propositions 1 and 2. If the progressivity is sufficiently high, the fiscal cost of the public education system will be smaller than the fiscal benefit for a larger share of the poorest households. Thus, a highly progressive tax system can induce higher enrollment rates in public higher education, expanding access for poorer households.

Hypothesis 3 *For a similar share of resources spent on public higher education, countries with more progressive tax systems, have lower perverse redistribution in public higher education.*

Hypothesis 3 stems from Propositions 1 and 3. Countries with a more progressive tax system can reduce the opportunity cost of going to university. If the tax system is increasing in progressivity, more poorer households will opt to send their children to university and the redistributive effect of progressive taxation will be from richer to poorer households. If the tax system is not progressive enough, fewer poorer households will opt to send their children to university and perverse redistribution from poorer to richer households takes place.

5 Data

For our analysis, we focus on European OECD countries that took part in the Bologna Process. Starting in 1999 with the Bologna Declaration, the Bologna Process consisted of a series of agreements between European countries intended to make the higher educational systems in Europe comparable, to engage in common reforms, and to create a *European Higher Education Area*. This allows us to compare countries with similar economies and university systems, allowing to better isolate the effect of income tax progressivity.

For our analysis we use several different data sources. We rely on (i) household-level microdata from the Luxembourg Income Study (LIS) to gain information on household incomes and education choices across a large panel of countries and years, (ii) a detailed set of income tax calculators from OECD (2022c) to identify local tax progressivities at different points along the income distribution and households above the zero-tax threshold y_0, (iii) data on tertiary education enrollment from World Bank (2022), (iv) data from tertiary educational spending from Eurostat (2022b) and (v) various macroeconomic variables from World Bank (2022), (OECD, 2022a), and (Eurostat, 2022a). We discuss the respective sources and choices in detail below.

5.1 Household microdata

The LIS database provides harmonized household microdata on incomes, labor choices, and demographic characteristics for about 50 countries across the globe spanning over five decades. We use all available European OECD country-year samples between 2000 and 2018, which contain information about a household's children and their higher education attendance, as well as total parental income, 22 countries in all.[9] We use this LIS microdata to estimate the parental income gradient in children higher education choices.

In our analysis, we define a child's parents as the head of the household (HoH) and their

[9]The countries are Austria, Belgium, Czechia, Denmark, Estonia, Finland, France, Hungary, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Slovak Republic, Slovenia, Spain, Sweden, and Switzerland.

partner, if any; thus, parental income is the sum of the income of the HoH and their partner. In this way, we exclude the income of other household members, such as grandparents' pensions or siblings' incomes, which are unlikely to finance the higher education of a child. We exclude households for which either the HoH's or their partner's income is missing, rather than imposing a lower total parental income. Student-workers are also excluded by the sample as they might reduce or do not ask for financial help to their parents.

Because we do not have information about permanent parental income, we only consider children between the ages of 17-19. Those ages correspond to the approximate ages at which students choose whether or not to attend university in Europe. A child attending higher education is defined as a child who reports upper-secondary education as their highest level of completed education and whose current employment status is reported as in education. While this means that we include both those in tertiary education and advanced non-tertiary (generally, post-secondary) education, this inclusions is nevertheless necessary as the data specify neither the current type of education nor the type of upper-secondary school that has been completed.[10]

5.2 Income taxes

We use data on income taxes from the OECD Tax Database (OECD, 2022c), which provides the marginal and average personal income tax rates for all OECD countries at different point along the income distribution: namely, 67%, 100%, and 167% of the average production worker's wage. We use these data to calculate the local tax progressivity measures at the different income estimates, denoting them $\pi_{67\%APW}$, $\pi_{100\%APW}$, and $\pi_{167\%APW}$. We include the local tax progressivity measures after standardizing around the mean.

[10]Our analysis further excludes children whose employment status is reported as disabled, homemakers, or retired, or who report an age gap to the HoH under 14 years.

5.3 Country-level data

Using the LIS microdata, we have 199 country-year observations, and while we can adjust the regression weights within the microdata, the corresponding country-year panel would be highly unbalanced. Thus, we turn to information from cross-country sources to compile a more balanced country-year sample to supplement our empirical evidence.

We take the gross enrollment rate in tertiary education, $GrEnroll$, the unemployment rate, $Unemp$, the inflation rate, $Infl$, gross national income per capita, $GNIpc$, the percentage of people living in urban area, $UrbanPop$, and the gross graduation rate from first degree programs (at ISCED 6 and 7), $GrGrad$ from World Bank (2022). We rely on Eurostat for data on tertiary education expenditures as a percentage of GDP, $TertEdExp$ (Eurostat, 2022b) and the employment rate of individuals with upper secondary and post-secondary (non-tertiary) education, $SecEdEmpl$ (Eurostat, 2022a). We also include countries' long-term interest rate, $Interest$, from OECD (2022a) and general government spending, $GovtExp$, from OECD (2022b).

To be able to hold the overall level of redistribution built into the tax and welfare system, plausibly considered a measure of overall progressivity, constant, we estimate the Reynolds-Smolensky index, $RSIndex$, based on the market and disposable income Gini coefficients from the Standardized World Income Inequality Database (SWIID), see Solt (2020). The Reynolds-Smolensky index was proposed by Reynolds and Smolensky (1977) as the difference between the pre-tax (or market) Gini coefficient and the post-tax (or disposable) Gini coefficient.

For the aggregate estimations below, we are able to include 20 countries – losing a few observations due to data availability.[11]

[11] We include the following countries in the aggregate estimations: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Slovak Republic, Slovenia, Spain, Sweden, and Switzerland. The UK is excluded because of missing data on tertiary education expenditure in Eurostat (2022b).

6 Empirical Evidence

6.1 Higher education enrollment and income tax progressivity

We begin our empirical validations by estimating the relationship between the enrollment rate in higher education and tax progressivity. The theoretical model establishes that countries with higher levels of tax progressivity have a higher enrollment rate in higher education after controlling for the total amount of higher educational spending (Hypothesis 1). We empirically validate if the enrollment rate in higher education is indeed positively correlated with the income tax progressivity in an unbalanced sample of 20 European OECD countries between 2000 and 2018.

To study the effect of progressivity on the enrollment rate in higher education, we regress the gross enrollment rate in tertiary education on the local progressivity measure. We follow the previous literature on tax progressivity with aggregate data (Arnold, 2008; Rieth et al., 2016) in considering the average production worker's wage (OECD, 2022c). We estimate the following

$$GrEnroll_{c,t} = \beta_0 + \beta_1 \pi_{100\%APW,c,t-1} + \gamma' X_{c,t-1} + \theta_c + \theta_t + \epsilon_{c,t}, \tag{16}$$

where $\pi_{100\%APW,c,t-1}$ is the local progressivity measure at the average productive wage of country c in the year $t-1$, $X_{c,t-1}$ includes a set of aggregate and macroeconomic variables in the year $t-1$. θ_c and θ_t summarize the country- and year-fixed effects. In our model, we use lagged explanatory variables to account for a delayed reaction in the enrollment rate. In this way, we also mitigate the possibility of reverse causality.

Table 1 presents the results of the effect of progressivity on the gross enrollment rate in higher education. The most basic specification in Column (1) shows that an increase in the lagged local progressivity is positively correlated with the enrollment rate in higher education and highly statistically significant. This relationship remains consistent and statistically significant across all other specifications. Columns (2)-(6) expand the specification to control for lagged tertiary education spending, which has no significant relationship on

Table 1: REGRESSION: GROSS ENROLLMENT IN TERTIARY EDUCATION AND PROGRESSIVITY

	Gross enrollment in higher education					
Variables	(1)	(2)	(3)	(4)	(5)	(6)
$\pi_{100\%APW,t-1}$	3.039***	2.880**	2.938***	3.199**	2.386*	2.884**
	(1.030)	(1.088)	(1.025)	(1.186)	(1.349)	(1.010)
$TertEdExp_{t-1}$		12.632	11.887	11.472	11.670*	10.773
		(9.128)	(7.117)	(7.101)	(5.963)	(6.755)
$ln(GNIpc)_{t-1}$			11.031	12.657*	1.967	12.543
			(6.821)	(6.649)	(7.296)	(7.321)
$GovtExp_{t-1}$			−0.299	−0.299	−0.127	−0.296
			(0.192)	(0.188)	(0.185)	(0.184)
$RSIndex_{t-1}$			1.830	4.715	89.482	22.305
			(56.903)	(57.015)	(65.009)	(54.225)
$Unemp_{t-1}$			2.273***	2.245***	1.930***	1.765*
			(0.640)	(0.649)	(0.593)	(0.882)
$Infl_{t-1}$			0.104	0.074	0.054	0.066
			(0.263)	(0.277)	(0.286)	(0.262)
$Interest_{t-1}$			−0.108	−0.118	−0.088	−0.096
			(0.282)	(0.292)	(0.310)	(0.269)
$UrbanPop_{t-1}$				0.582		
				(0.689)		
$GrGrad_{t-1}$					0.252	
					(0.153)	
$SecEdEmpl_{t-1}$						−0.463
						(0.526)
$Constant$	59.091***	50.376***	−48.683	−95.663	50.715	−23.064
	(4.116)	(6.885)	(77.213)	(81.447)	(80.880)	(70.878)
Countries	20	20	20	20	20	20
Observations	314	309	296	296	258	296
R-squared	0.859	0.875	0.925	0.926	0.923	0.926

Notes: Country-level clustered standard errors in parentheses. ***, **, and * indicate levels of statistical significance at 1, 5, and 10 percent, respectively. For brevity, the country- and year-fixed effects are suppressed.

gross enrollment. Columns (3)-(6) include a set of lagged macroeconomic factors that affect the university enrollment, such as the log of GNI per capita, general government expenditures, the Reynolds-Smolensky index, the unemployment rate, the inflation rate, and the real interest rate. Of those, only the lagged unemployment rate has a consistently positive and significant relationship to the gross enrollment rate – a finding strongly in line with the literature, enrollment increases when the economy slows down.

Columns (4)-(6) expand to include lagged proxies for different parameters from the theoretical model. Column (4) includes the lagged share of the urban population to account for the ease of access to tertiary education and the additional cost s that is required to attend; however, the result is not statistically significant. Column (5) includes the lagged gross graduation rate, p in the model, and presents a positive but insignificant relationship. However, it must be noted that we lose 38 country-year observations due to the lack of data. Column (6) includes the lagged employment rate of individuals with upper secondary and post-secondary (non-tertiary) education as a proxy for the base wage w, resulting in a statistically insignificant relationship.[12]

6.2 Parental income gradient, local progressivity, and perverse redistribution

Hypothesis 2 states that countries with higher income progressivity have a lower parental income gradient in higher education attendance, while Hypothesis 3 states that countries with higher income progressivity have lower perverse redistribution. To verify, we begin by illustrating the existence of a negative parental income gradient and that tax progressivity can have a positive or negative effect on this gradient, depending on the position of a house-

[12]We conduct several robustness checks to ensure the stability of these results. Estimations using the local progressivity index at 67% or 167% of the average production wage, respectively, are statistically insignificant. As these estimations use aggregate country-level data and we do not have information about the income distribution for those households making the enrollment decision or the interaction between the local progressivity measure and incomes at different points of the income distribution. The results are also robust to using lagged GDP per capita rather than lagged GNI per capita.

hold along the income distribution. To make results easier to interpret, we include parental incomes using income quintile dummy variables and interact these quintile indicators with the local progressivity measure. Pooling all available LIS microdata samples and adjusting the sampling weights, we estimate the following linear probability model:

$$\begin{aligned} Pr(HEd=1)_{i,c,t} &= a_0 + \alpha' PIQ_{i,c,t} + \beta' \pi_{\%APW,c,t-1} + \gamma' PIQ_{i,c,t} \times \pi_{\%APW,c,t-1} \\ &\quad + \eta' X_{c,t-1} + \zeta' Z_{i,c,t} + \theta_c + \theta_t + \theta_{cohort} + \theta_c * cohort_{i,c,t} + \epsilon_{i,c,t}, \end{aligned} \tag{17}$$

where $Pr(HEd=1)_{i,c,t}$ is the binary indicator variable equal to 1 if a child in household i in country c in year t attends higher education, $PIQ_{i,c,t}$ is the set of dummy variables representing the income quintile, excluding the highest quintile, to which household i belongs, $\pi_{\%APW,c,t-1}$ is a vector of progressivity measures computed at the 67%, 100% and 167% of the average production wage in country c at time $t-1$, $X_{c,t-1}$ a set of one-year-lagged macroeconomic variables (i.e. government general spending, government redistributive capacity, government spending in tertiary education), $Z_{c,t-1}$ a set of individual control variables (i.e. number of households members without labor income, household type, head of household' and partner's years of education and dummies for living in a rural area, gender and individual immigrant status), θ_c , θ_t and θ_{cohort} are the country-, year- and cohort-fixed effects, while $\theta_c * cohort_{i,c,t}$ is the country-cohort interaction capturing linear trends for specific cohorts.[13]

Table 2 presents the results of (17) using measures of local tax progressivity at different multiples of the average productive wage. Consistent with the model's predictions, the correlation between the probability of a household's child attending higher education and the income quintiles, with respect to the richest quintile PIQ_5, is negative and highly statistically significant. As incomes increase from the first to the fourth quintile, the correlation becomes more negative, meaning that the probability of sending a child to higher education compared to the highest quintile decreases.

[13]We include the following countries in the pooled microdata estimations: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Slovak Republic, Slovenia, Spain, Sweden, and Switzerland.

Table 2: Regression: Parental income gradient and tax progressivity

Variables	Probability of university attendance (1)	(2)	(3)
PIQ_1	−0.191***	−0.191***	−0.103***
	(0.009)	(0.009)	(0.015)
PIQ_2	−0.154***	−0.151***	−0.093***
	(0.008)	(0.008)	(0.012)
PIQ_3	−0.131***	−0.130***	−0.075***
	(0.008)	(0.008)	(0.011)
PIQ_4	−0.079***	−0.077***	−0.037***
	(0.008)	(0.008)	(0.010)
$\pi_{67\%APW,t-1}$	−0.008	−0.009	−0.022
	(0.012)	(0.013)	(0.014)
$\pi_{100\%APW,t-1}$	−0.001	−0.013	0.006
	(0.014)	(0.014)	(0.014)
$\pi_{167\%APW,t-1}$	−0.030**	−0.032**	−0.010
	(0.014)	(0.014)	(0.022)
Constant	−23.729**	−58.493***	−75.678***
	(9.417)	(11.860)	(14.176)
$PIQ \times \pi_{\%APW,t-1}$	✓	✓	✓
Aggregate Controls		✓	✓
Individual Controls			✓
Year FE	✓	✓	✓
Country FE	✓	✓	✓
Cohort FE	✓	✓	✓
Country-Cohort FE	✓	✓	✓
Countries	22	22	17
Obs.	70,877	68,489	44,332
Adj. R-squared	0.340	0.346	0.380

Household-level clustered standard errors in parentheses. ***, **, and * indicate levels of statistical significance at 1, 5, and 10 percent, respectively.

These results are robust also by controlling by aggregate and individual controls, even if the sample size reduces and we loose 5 countries due to data availability.[14] Table 2 also shows that the effect of progressivity is negative and statistically significant only at 167% APW; however, when we control for individual control variables, this effect becomes statistically insignificant.

Given the large number of interactions included in (17), we must calculate the marginal effect of the interactions between tax progressivity and income quintiles, $PIQ \times \pi_{\%APW,t-1}$, on the probability of going to higher education by income quintiles to test Hypotheses 2 and 3. We present these marginal effects in Table 3. Recall that the reference category is the highest income quintile, PIQ_5.

Exploring the estimates of the local tax progressivity and the parental income quintiles, in Block A (based on Table 2, first column), Column (1) illustrates that, without additional controls, an increase in the local progressivity at 67% of APW is negatively and significantly correlated with the probability of a household sending their child into higher education for the lowest quintiles, PIQ_1 and PIQ_2. This is consistent with the model, where higher progressivity at the bottom of the income distribution implies that the poorer households bear more of the cost of the increase in progressivity. If households do not value the marginal benefit of a better quality tertiary education higher than the marginal fiscal cost, they will be less likely to send their children to higher education. Column (2) shows that the interaction effect at 100% of APW is statistically insignificant for everyone. We interpret this result as the marginal benefit and the marginal cost offsetting each other, in line with the model predictions in (15) and Proposition 3. Column (3), in line with (6) and Proposition 2 in the model, shows that an increase in local progressivity at 167% of APW increases first household-quintile's propensity to send their children to university, but the effect is dampened significantly in the third quintile, PIQ_3.

Block B presents the marginal effects when we include aggregate controls in (17) (based

[14]Those countries are Estonia, Finland, Hungary, Netherlands, Slovenia, Sweden

Table 3: Marginal Effect: Parental income quintiles and local progressivity

	Marginal Effects		
	$\pi_{\%APW,67}$ (1)	$\pi_{\%APW,100}$ (2)	$\pi_{\%APW,167}$ (3)
A		*No Controls*	
PIQ_1	−0.028**	−0.015	0.029*
	(0.013)	(0.016)	(0.015)
PIQ_2	−0.025**	0.009	−0.004
	(0.012)	(0.015)	(0.014)
PIQ_3	−0.008	0.013	−0.024*
	(0.012)	(0.014)	(0.013)
PIQ_4	−0.014	−0.004	−0.009
	(0.012)	(0.015)	(0.014)
B		*Aggregate Controls*	
PIQ_1	−0.029**	−0.028*	0.028*
	(0.013)	(0.016)	(0.015)
PIQ_2	−0.026**	−0.003	−0.007
	(0.013)	(0.015)	(0.015)
PIQ_3	−0.010	0.001	−0.026*
	(0.013)	(0.014)	(0.014)
PIQ_4	−0.016	−0.017	−0.011
	(0.013)	(0.015)	(0.014)
C		*Aggregate + Individual Controls*	
PIQ_1	−0.044**	−0.007	0.088***
	(0.017)	(0.021)	(0.026)
PIQ_2	−0.034**	0.002	0.044*
	(0.015)	(0.017)	(0.023)
PIQ_3	−0.010	−0.003	0.013
	(0.015)	(0.017)	(0.023)
PIQ_4	−0.021	−0.010	0.014
	(0.014)	(0.015)	(0.023)

Household-level clustered standard errors in parentheses. ***, **, and * indicate levels of statistical significance at 1, 5, and 10 percent, respectively.

on Table 2, second column). The aggregate controls include lagged general governmental spending and lagged government spending in tertiary education. As before, we include the lagged Reynolds-Smolensky index to take into account the effective overall redistributive capacity of the tax and redistribution system. Block B presents similar results to Block A, in terms of sign, statistical significance, and size of the effect. The only difference is that the probability of sending children to higher education for households belonging to the lowest quintile is negative and statistically significant at 10% level when governments increase the progressivity at 100% of APW. However, this effect not robust to the inclusion of additional controls.

In Block C (based on Table 2, third column), we observe the marginal effects when we include both aggregate and individual controls in (17). The individual controls include the number of households members without labor income, household type, the head of household's and their partner's years of education, as well as dummies for living in a rural area, a child's gender, and immigrant status. Results in Block C are similar to the results in Block A and B, confirming the robustness of the statistical model: an increase in the local progressivity at 67% of APW is negatively and significantly correlated with the probability of a household sending their child into higher education for the lowest quintiles, PIQ_1 and PIQ_2. Similar to Block A, the effect of an increase in progressivity at 100% of APW is not statistically correlated with the probability of a household's child attending higher education. Lastly, Column (3) in Block C shows that the progressivity at 167% of APW is positively and significantly (at 1%) correlated with the probability of a household in the first quintile, PIQ_1, and in the second quintile, PIQ_2 (at 10%), sending their children into higher education. Column (3) confirms that the probability of the poorest households sending their children to higher education increases when the local progressivity of richer households is increased, as predicted by the model.

The marginal effects reported in Table 3 represent an empirical validation of Hypothesis 2, as well as for Hypothesis 3. On the one hand, we have shown that local income tax progressivity at the top of the income distribution reduces the parental income gradient for poorer households; on the other hand, if the parental income gradient falls for poorer households, the probability of poorer households not sending their children to higher education, even if they are paying income taxes, decreases. This represents a reduction in the perverse redistribution in tertiary education. The empirical analysis also illustrates that when the local tax progressivity increases at the bottom of the income distribution, the parental income gradient becomes more negative for households in the lower quintiles. As a result, the empirical specification confirms that an increase in local tax progressivity could increase perverse redistribution and reduce the university enrolment of individuals from poorer households, if the increase in progressivity occurs in the poorest income classes, as explained in Section 3.3.

7 Conclusion

This paper develops a theoretical model and conducts an empirical analysis to investigate the disproportional usage of public higher education and how it is affected by progressive income taxes. More precisely, in this study, we focus on how weakly progressive tax systems can negatively affect the decision to attend higher education for poorer families.

The model shows that weakly progressive tax systems reduce poorer households' net fiscal benefit from higher education, making their children less likely to attend university. However, poorer households continue to pay the fiscal cost of higher education through their income taxes, thereby financing the higher education of the rich. The literature has refers to this scenario as perverse redistribution – a redistribution of resources from poorer to more affluent households, in this case via the public financing of higher education.

The model draws three conclusions about the role of tax progressivity on households' tertiary education choice: (i) countries with higher levels of progressivity have higher enrollment rates in higher education; (ii) for a given level of public education spending, the parental income gradient in children's higher education attendance is lower in countries with more progressive tax systems and higher progressivity affects households along the income distribution differently depending on a household's position relative to the indifferent household; (iii) countries with more progressive tax systems have a lower perverse redistribution in higher education. Our empirical analysis uses both aggregate and microdata across European OECD countries and confirms the model's three hypotheses. Additionally, we are able to differentiate the effects of progressivity across the income distribution.

To the best of our knowledge, this is the first paper to study the effect of tax progressivity on the disproportionate usage of higher public education. Our contribution consists in presenting a through theoretical model that illuminates the mechanisms and consequences of tax progressivity on the disproportionate usage of public higher education. Moreover, the model can be extended to accommodate the complex considerations and measures that countries have undertaken to support and finance higher education, such as tuition fees, subsidized loans, government-sponsored grants, just to name a few. Our empirical analysis also makes use of both microdata and aggregate data. While our results provide strong initial results for the presence of perverse redistribution in highly developed, highly educated economies, the findings deserve further analysis, particularly with an eye towards establishing the causal impact of a tax change on the choice to attend university.

We note that this paper's model of a progressive-tax-financed public good with prohibitive additional/opportunity costs and thus unequal usage patterns can be extended to address other essential public goods, such as the non-emergency health system, the non-felony justice system, or even banking and finance. Illuminating the role of tax progressivity can help develop more effective and efficient public policies aimed at reducing economic and social inequalities.

European countries agreed to the Bologna process to, on the one hand, engage in discussions on policy reforms in higher education and, on the other hand, "strive to overcome obstacles to create a European Higher Education Area". While educational outcomes have already become more comparable across countries, access is still limited by any additional cost of attendance, creating scope for perverse redistribution. The goal of a *common* European Higher Education Area must ensure that *common* extends to all able and willing students.

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A Derivation: Maximization problem

The maximization problem when a parent decides not to send their child to university is trivial because the parent consumes all their income. A parent who decides to send their child to university solves the following problem:

$$\max_{c,s} \quad u(c) + \delta[p(s)v(E) + (1 - p(s))v(w)] \qquad \text{s.t.} \quad c + s \leq d_k(y) \tag{A.1}$$

Because the utility function is the sum of strictly increasing and concave functions and because the budget constraint is compact, the budget constraint is binding and we can write the constrained maximization problem as an unconstrained maximization problem:

$$\max_{s} \quad u(d_k(y) - s) + \delta[p(s)v(E) + (1 - p(s))v(w)] \tag{A.2}$$

We compute the FOCs to find the interior optimal solution $s^*(d_k(y))$:

$$-u'(d_k(y) - s^*(d_k(y))) + \delta p'(s^*(d_k(y)))[v(E) - v(w)] = 0, \tag{A.3}$$

The SOCs are negative, thus $s^* > 0$ is a maximum:

$$u''(d_k(y) - s^*) + \delta p''(s^*)[v(E) - v(w)] < 0, \tag{A.4}$$

Using the optimal solution s^*, we obtain the indirect utility:

$$V^e = u(d_k(y) - s^*) + \delta[p(s^*)v(E) + (1 - p(s^*))v(w)]. \tag{A.5}$$

B Continuity and differentiability

The function (3) is a progressive tax liability function because the marginal tax rate $T'(y)$ is strictly increasing in y everywhere in $[\underline{y}, \bar{y}]$. To see it, we write the marginal tax rate function $T_i'(y)$, such that:

$$T_i'(y) = \begin{cases} 0 & \underline{y} \leq y \leq \widehat{y}_0 \\ t_1[1 - \tau_1'(y)] & \widehat{y}_0 < y < \widehat{y}_0 + \epsilon \\ t_1 & \widehat{y}_0 + \epsilon \leq y \leq \widehat{y}_1 \\ t_2[1 - \tau_2'(y)] + \tau_2'(y)t_1 & \widehat{y}_1 < y < \widehat{y}_1 + \epsilon \\ t_2 & y \geq \widehat{y}_1 + \epsilon \end{cases} \tag{B.1}$$

Notice that, as (3) is continuously differentiable in $y \in [\underline{y}, \bar{y}]$, $T_i(\widehat{y}_0) = 0$ with $\tau_1(\widehat{y}_0) = 0$ and as $T_i'(y) > 0$ everywhere, this implies that the total tax revenue for each interval of Eq. (3) is strictly positive:

$$T_{\widehat{y}_0+\epsilon} = \int_{\widehat{y}_0}^{\widehat{y}_0+\epsilon} T_i(y)f(y)dy = t_1 \left[\int_{\widehat{y}_0}^{\widehat{y}_0+\epsilon} (y - \widehat{y}_0)f(y)dy - \int_{\widehat{y}_0}^{\widehat{y}_0+\epsilon} \tau_1(y)f(y)dy\right] > 0, \tag{B.2}$$

Proof. Consider $T_i(y)$ in $(\widehat{y}_0, \widehat{y}_0 + \epsilon)$. Taking the limit $\lim_{y\to\widehat{y}_0} T_{\widehat{y}_0+\epsilon}(y) = \lim_{y\to\widehat{y}_0} t_1(y - \widehat{y}_0) + \tau_1(y)(t_0 - t_1) = 0$ and knowing that $T_i'(y) > 0$, then this means that the area below $t_1(y - \widehat{y}_0)$ is strictly greater then the area below $t_1\tau_1(y)$. Thus, $\left[\int_{\widehat{y}_0}^{\widehat{y}_0+\epsilon}(y - \widehat{y}_0)f(y)dy - \int_{\widehat{y}_0}^{\widehat{y}_0+\epsilon} \tau_1(y)f(y)dy\right] > 0$ and (B.2) is strictly positive. ■

$$T_{\widehat{y}_1} = \int_{\widehat{y}_1+\epsilon}^{\widehat{y}_1} T_i(y)f(y)dy = t_1 \left[\int_{\widehat{y}_0+\epsilon}^{\widehat{y}_1} (y - \widehat{y}_0)f(y)dy - \int_{\widehat{y}_0+\epsilon}^{\widehat{y}_1} \tau_1(y_0 + \epsilon)f(y)dy\right] > 0, \tag{B.3}$$

Proof. Consider $T_i(y)$ in $[\widehat{y}_0 + \epsilon, \widehat{y}_1]$. A consequence of the previous proof is that $\lim_{y\to\widehat{y}_0+\epsilon} T_{\widehat{y}_1}(y) = \lim_{y\to\widehat{y}_0+\epsilon} t_1(y - \widehat{y}_0) + \tau_1(\widehat{y}_0 + \epsilon)(t_0 - t_1) = t_1[\epsilon - \tau_1(\widehat{y}_0 + \epsilon)] > 0$, as

$\tau_1(y)$ always grows slower than $t_1(y - \widehat{y}_0)$. Because $T_i(y)$ is continuously differentiable and strictly increasing in y, and because $\lim_{y \to \widehat{y}_0 + \epsilon} \tau_1'(y) = 0$, then the area below $t_1(y - \widehat{y}_0)$ must be strictly greater than the area below $\tau_1(\widehat{y}_0 + \epsilon)(t_0 - t_1)$ for each $y \in [\widehat{y}_0 + \epsilon, \widehat{y}_1]$, as $t_1(y - \widehat{y}_0)$ grows faster than $\tau_1(\widehat{y}_0 + \epsilon)(t_0 - t_1)$ and $t_1[\epsilon - \tau_1(\widehat{y}_0 + \epsilon)] > 0$. Thus, $\left[\int_{\widehat{y}_0+\epsilon}^{\widehat{y}_1}(y - \widehat{y}_0) f(y) dy - \int_{\widehat{y}_0+\epsilon}^{\widehat{y}_1} \tau_1(y_0 + \epsilon) f(y) dy\right] > 0$ ■

$$T_{\widehat{y}_1+\epsilon} = \int_{\widehat{y}_1}^{\widehat{y}_1+\epsilon} T_i(y) f(y) dy = t_1 \left[\int_{\widehat{y}_1}^{\widehat{y}_1+\epsilon} (\widehat{y}_1 - \widehat{y}_0) f(y) dy - \int_{\widehat{y}_1}^{\widehat{y}_1+\epsilon} \tau_1(\widehat{y}_0 + \epsilon) f(y) dy\right] + t_2 \left[\int_{\widehat{y}_1}^{\widehat{y}_1+\epsilon} (y - \widehat{y}_1) - \tau_2(y) f(y) dy\right] + t_1 \int_{\widehat{y}_1}^{\widehat{y}_1+\epsilon} \tau_2(y) f(y) dy > 0, \tag{B.4}$$

$$T_{\bar{y}} = \int_{\widehat{y}_1+\epsilon}^{\bar{y}} T_i(y) f(y) dy = t_1 \left[\int_{\widehat{y}_1+\epsilon}^{\bar{y}} (\widehat{y}_1 - \widehat{y}_0) f(y) dy - \int_{\widehat{y}_1+\epsilon}^{\bar{y}} \tau_1(\widehat{y}_0 + \epsilon) f(y) dy\right] + t_2 \left[\int_{\widehat{y}_1+\epsilon}^{\bar{y}} (y - \widehat{y}_1) - \tau_2(\widehat{y}_1 + \epsilon) f(y) dy\right] + t_1 \int_{\widehat{y}_1+\epsilon}^{\bar{y}} \tau_2(\widehat{y}_1 + \epsilon) f(y) dy > 0, \tag{B.5}$$

Proof. The proofs for (B.4) and (B.5) follow the same logic of the proofs for (B.2) and (B.3). ■ (B.2)-(B.5) are strictly increasing in t_1 and Equations (B.4) and (B.5) strictly increasing in t_2. This implies that the total tax revenue equals:

$$T = T_{\widehat{y}_0+\epsilon} + T_{\widehat{y}_1} + T_{\widehat{y}_1+\epsilon} + T_{\bar{y}} > 0, \tag{B.6}$$

such that $\partial T/\partial t_1 > 0$ and $\partial T/\partial t_2 > 0$.

Following (3), we can write disposable income function of an individual i as:

$$d_k(y) = \begin{cases} y & \underline{y} \le y \le \widehat{y}_0 \\ (1-t_1)y + t_1\widehat{y}_0 + \tau_1(y)t_1 & \widehat{y}_0 < y < \widehat{y}_0 + \epsilon \\ (1-t_1)y + t_1\widehat{y}_0 + \tau_1(\widehat{y}_0+\epsilon)t_1 & \widehat{y}_0 + \epsilon \le y \le \widehat{y}_1 \\ (1-t_2)y + t_1\widehat{y}_0 + \tau_1(\widehat{y}_0+\epsilon)t_1 + (t_2-t_1)\widehat{y}_1 + \tau_2(y)(t_2-t_1) & \widehat{y}_1 < y < \widehat{y}_1 + \epsilon \\ (1-t_2)y + t_1\widehat{y}_0 + \tau_1(\widehat{y}_0+\epsilon)t_1 + (t_2-t_1)\widehat{y}_1 + \tau_2(\widehat{y}_1+\epsilon)(t_2-t_1) & y \ge \widehat{y}_1 + \epsilon \end{cases} \tag{B.7}$$

The function (B.7) is continuous, continuously differentiable in y and strictly increasing in y, meaning that the tax system is strongly incentive preserving (Fei, 1981; Eichhorn et al., 1984). Indeed, the first derivative by y of (B.7) is continuous and strictly increasing:

$$d_k'(y) = \begin{cases} 1 & \underline{y} \le y \le \widehat{y}_0 \\ (1-t_1) + \tau_1'(y)t_1 & \widehat{y}_0 < y < \widehat{y}_0 + \epsilon \\ (1-t_1) & \widehat{y}_0 + \epsilon \le y \le \widehat{y}_1 \\ (1-t_2) + \tau_2'(y)(t_2-t_1) & \widehat{y}_1 < y < \widehat{y}_1 + \epsilon \\ (1-t_2) & y \ge \widehat{y}_1 + \epsilon \end{cases} \tag{B.8}$$

C Proof: Lemmas

C.1 Lemma 1

Proof. To prove Lemma 1, we use the intermediate value theorem. For any individual in any income class k, let's define the difference between their two indirect utilities as $\Delta(d_k(y)) = V^w(d_k(y)) - V^e(d_k(y))$:

$$u(d_k(y)) - u(d_k(y) - s^*(d_k(y))) - \delta p(s^*(d_k(y)))[v(E) - v(w)] \tag{C.1}$$

The function (C.1) is continuously differentiable in the pre-tax income y. To simplify the notation, we define the optimal subsidy $s^*(d_k(y))$ as s and its derivative $\frac{\partial s^*(d_k(y))}{\partial d_k(y)}\frac{\partial d_k(y)}{\partial y}$ as $s'd'_k(y)$. Differentiating by y, one gets:

$$\frac{\partial \Delta(d_k(y))}{\partial y} = d'_k(y)[u'(d_k(y)) - (1-s')u'(d_k(y)-s) - \delta p'(s)(v(E)-v(w))] \tag{C.2}$$

whereby $d'_k(y)$ is defined by (B.8).

Rearranging the terms we can rewrite (C.2) as (C.3) and by applying the envelope theorem, we can see that the derivative is strictly negative in income:

$$\frac{\partial \Delta(d_k(y))}{\partial y} = d'_k(y)[u'(d_k(y)) - u'(d_k(y)-s)] < 0, \tag{C.3}$$

The derivative (C.3) is strictly decreasing because: 1) $[u'(d_k(y)) - u'(d_k(y)-s)] < 0$, as $u(\cdot)$ is continuous, strictly increasing and strictly concave; 2) $d'_k(y)$ is strictly increasing in y. Notice that, as $d_k(y)$ is strictly increasing in y and $\Delta(d_k(y))$ is the difference of two continuous differentiable function in $y \in [\underline{y}, \bar{y}]$, then $\Delta(y, \mathbf{t}, \boldsymbol{\tau})$ is continuously differentiable and strictly decreasing in $y \in [\underline{y}, \bar{y}]$, given a progressive tax scheme $\{\mathbf{t}, \boldsymbol{\tau}\}$.

If a threshold in the interval $[\underline{y}, \bar{y}]$ exists, we want to prove that it is unique. For a given progressive income tax scheme $\{\mathbf{t}, \boldsymbol{\tau}\}$, consider the minimum income level $\underline{y} \in [\underline{y}, \bar{y}]$:

If $\Delta(\underline{y}, \mathbf{t}, \boldsymbol{\tau}) \leq 0$, then, because $\Delta(y, \mathbf{t}, \boldsymbol{\tau})$ is continuous and strictly decreasing in y, $\Delta(y, \mathbf{t}, \boldsymbol{\tau}) < 0$ for any $y \in (\underline{y}, \bar{y}]$. Thus, $\Delta(\underline{y}, \mathbf{t}, \boldsymbol{\tau}) = 0$, implying $\underline{y} = \widetilde{y}$. In this case, everyone at least weakly prefers education to work.

If $\Delta(\underline{y}, \mathbf{t}, \boldsymbol{\tau}) > 0$, then we can have either $\Delta(\bar{y}, \mathbf{t}, \boldsymbol{\tau}) \leq 0$ or $\Delta(\bar{y}, \mathbf{t}, \boldsymbol{\tau}) > 0$. If $\Delta(\bar{y}, \mathbf{t}, \boldsymbol{\tau}) \leq 0$, because $\Delta(y, \mathbf{t}, \boldsymbol{\tau})$ is continuous and strictly decreasing in y, by the intermediate value theorem, $\exists! \, \widetilde{y} \in (\underline{y}, \bar{y}]$ such that $\Delta(\widetilde{y}, \mathbf{t}, \boldsymbol{\tau}) = 0$. It follows that if $y \leq \widetilde{y}$, then $V^w \geq V^e$; If $y > \widetilde{y}$, then $V^w < V^e$. If $\Delta(\bar{y}, \mathbf{t}, \boldsymbol{\tau}) > 0$ working is always the best option and there is no indifference threshold in $[\underline{y}, \bar{y}]$. Thus, if a threshold $\widetilde{y} \in [\underline{y}, \bar{y}]$ exists, it must be unique. ■

C.2 Lemma 2

Proof. Let's consider the indifferent individual such that $\Delta(d_k(\widetilde{y})) = V^w(d_k(\widetilde{y})) - V^e(d_k(\widetilde{y})) = 0$. To simplify the notation, we define the optimal subsidy simply as s:

$$u(d_k(\widetilde{y})) - u(d_k(\widetilde{y}) - s) - \delta p(s)[v(E) - v(w)] = 0 \tag{C.4}$$

In order to study how the variables α and w affect the threshold $\widetilde{y}$ we use the implicit function theorem. Let's define the derivative in (C.3) as $D = \partial\Delta(y)/\partial y < 0$. By the implicit function theorem, we can compute the variation of $\widetilde{y}$ given a change in α and w, obtaining the results of Lemma 2:

$$\frac{\mathrm{d}\widetilde{y}}{\mathrm{d}\alpha} = \left[\frac{1}{D}\right][T\delta p(s)v'(E)] < 0, \tag{C.5}$$

$$\frac{\mathrm{d}\widetilde{y}}{\mathrm{d}w} = \left[-\frac{1}{D}\right][v'(w)]\delta p(s) > 0, \tag{C.6}$$

■

D Proof: Progressive taxation

Proof. We obtain Equation (6) by applying the implicit function theorem to the indifferent individual. Let's consider the indifferent individual such that $\Delta(d_1(\widetilde{y})) = V^w - V^e = 0$. To simplify the notation, we define the optimal subsidy simply as s:

$$u(d_k(\widetilde{y})) - u(d_k(\widetilde{y}) - s) - \delta p(s)[v(E) - v(w)] = 0 \tag{D.1}$$

Differentiating by t_2 and applying the implicit function theorem we get:

$$\frac{d\widetilde{y}}{dt_2} = -\left[\frac{\delta p(s)v'(E)}{D}\right]\left[\underbrace{\alpha\frac{\partial T}{\partial t_2}}_{\text{Tax Revenue}} + \underbrace{T\frac{\partial \alpha}{\partial t_2}}_{\text{H.E. funding}}\right] \tag{D.2}$$

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