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A Theory of Perverse Redistribution in Higher Education and Income Tax Progressivity in Europe

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A Theory of Perverse Redistribution in Higher Education and Income Tax Progressivity in Europe*

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Abstract

This paper studies the effect of income tax progressivity on the disproportionate use of publicly funded higher education. We show that more progressive tax systems increase low-income households' net fiscal benefit of higher education, making their children more likely to attend university. To increase the university enrollment of children from low-income households, the "degree" of income tax progressivity must increase along the income distribution. "Weakly progressive" tax systems can determine a *perverse redistribution* equilibrium, in which poorer households subsidize the higher education for richer households.

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

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The Online Appendix to this paper can be found here: https://sites.google.com/site/nmstrecker/GS-OA

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1 Introduction

In Europe, governments finance public higher education systems through taxes, particularly income taxes.[1,2] Progressive income taxes are the most frequently used form of income taxes – reducing the tax incidence for individuals with a lower ability to pay, thereby redistributing the economic burden from high-income to low-income households. However, financing public higher education via income taxes can lead higher education to become a regressive form of public expenditure (e.g., OECD, 2020). If higher education is difficult to access for many children from lower-income households despite their parents paying income taxes, lower-income households end up subsidizing the higher education of higher-income households (e.g., Fernandez and Rogerson, 1995). This leads to a regressive redistribution of resources that is termed as "perverse redistribution" (Diris and Ooghe, 2018, p. 278).[3]

In this paper, we develop a rational choice model of public higher education attendance that shows that less progressive income tax systems are associated with larger perverse redistribution in higher education. The model offers three key insights about the relationship between income tax progressivity and households' decision to send their children to higher education: (i) higher levels of income tax progressivity led to higher enrollment rates in higher education; (ii) more progressive income tax systems reduce lower-income households' net fiscal cost of higher education, thereby increasing the probability of lower-income households sending their children to higher education; (iii) more progressive tax systems at the top of the income distribution led to lower perverse redistribution in higher education because the

[1] In this paper, we will use university education and higher education, and tertiary education interchangeably. By this we mean all education undertaken after the completion of secondary school.

[2] Since 2000, total public expenditures in higher education increased by about 15% among European countries before stabilizing after 2013. Apart from the UK and Ireland, European universities receive most of their funding from government funding (Lepori, 2019), which can define the quality of the higher education system (e.g., see Lahmandi-Ayed, Lasram and Laussel (2021) for a theoretical analysis). The UK and Ireland draw on private contributions such as tuition fees, in addition to government supports.

[3] For instance, in Denmark, where the education system is predominantly public, children from high-income families receive larger per capita public investments through upper-secondary and higher education than children from low-income families who are less likely to attend university (Nielsen and Christensen, 2022). Similarly, Bonneau and Grobon (2022) show that, in France, which finances its education system through public funds – children from high-income families receive approximately twice the amount of public spending on higher education than children from low-income families.

likelihood of attending higher education for a child from a lower-income family is higher when the tax system is more progressive at the top of the income distribution.

Our paper contributes to two distinct research areas. First, we contribute to the economic theory linking the financing methods of public education and educational choices. One strand of this literature focuses on how different financing schemes affect university participation (e.g., Del Rey and Racionero, 2010). A second strand builds on political economy models where citizens vote on a *flat tax rate* on income to finance public education after deciding whether to attend public education.[4] Unlike previous models, our paper sheds light on how income tax progressivity affects households' decision to send their children to university. We show that, in a universal public higher education system,[5] an increase in progressivity raises the net fiscal benefit vis-á-vis the cost of higher education for lower-income households, thereby increasing the probability of sending their children to higher education. The rise in lower-income households' net fiscal benefit can occur in two ways: (i) a reduction in the fiscal cost of financing higher education for low-income households without changing the quality of education or (ii) an increase in the fiscal benefit from higher education without adding any additional fiscal cost for the lower-income households, i.e. financing higher education through higher taxes on high-income households.[6]

Our theoretical results also complement the theoretical works by Nielsen and Sørensen (1997) and Alstadsæter (2002), who show that labor income tax progressivity reduces human capital investments in favor of financial investments, such that tax progressivity reduces the return to human capital. Particularly, as noted in Alstadsæter (2002), when education

[4]This strand of literature is large and includes decisions about attending private versus public education versus not attending education at all and going directly into the labor market. For examples of this work, see Epple and Romano (1996), Fernandez and Rogerson (1995), Glomm and Ravikumar (1998), Tanaka (2003), or Gutiérrez and Tanaka (2009). Glomm, Ravikumar and Schiopu (2011) offers a comprehensive literature review of the political economy of higher education.

[5]Starting from the second half of the 20^{th} century, OECD countries moved from higher education as the prerogative of the "elite" to "universal" higher education systems (see Marginson, 2016; OECD, 2020). Trow (1973) defined a universal higher education system as one where more than 50 percent of an age cohort access higher education.

[6]To some extent, our paper also contributes to the literature studying how income taxes and the design of an income tax system – specifically, income tax progressivity – affects people's preferences and decision (see, e.g., Doerrenberg and Peichl, 2013; Beramendi and Rehm, 2016; Casarico and Sommacal, 2018).

itself has a consumption value.[7] In contrast, we build a theoretical model in which more progressive income taxes can increase the total higher education enrollment in countries with "universal" public higher education. However, a progressive income tax system is not enough to ensure higher participation in higher education. Our model highlights that, in order to increase the total university enrollment, the "degree" of income tax progressivity must increase along the income distribution. In recent years, the degree of tax progressivity has gained particular prominence in the academic and public policy debate. For instance, the EU Tax Observatory documents that for countries such as France, Netherlands, and the US, the income tax systems are regressive at the top of the income distribution (Alstadsæter, Godar, Latitude, Nicolaides and Zucman, 2023). Similarly, Guzzardi, Palagi, Roventini and Santoro (2023) show that the Italian income tax system is regressive for individuals with income above the 95% percentile of the income distribution. In this paper, we show that if a country has a progressive tax system but the degree of progressivity declines with household income or is not large enough compared to the bottom of the income distribution, then perverse redistribution in higher education occurs.

Secondly, this paper builds on and contributes to the literature on human capital investments (see Becker, 1993) and the choice of attending higher education. Previous models in this literature assume that public education – in contrast to private alternatives – does not involve private costs (see, e.g., Epple and Romano, 1996; Glomm and Ravikumar, 1998). At face value, this assumption can capture the main difference between private and public higher education; however, some public goods still require "costly access", deterring some households from participating in them.[8] In this paper, we show that including the private costs of participating in public higher education can highlight the role of the design of the tax system in the decision to attend higher education. To this end, we assume that even if higher edu-

[7] Alstadsæter (2002) describes the "consumption value of education" as the set of non-monetary values attributed to the decision to attend education. See also Alstadsæter, Kolm and Larsen (2008).

[8] We co-opt the term "public goods with costly access" from Cremer and Laffont (2003). While Cremer and Laffont (2003) mainly refer to "information goods" as an example of public goods with "costly access", the problem of participation costs can be easily extended to higher education, even in the context of a universal public higher education system.

cation is publicly financed and universal, – with no private option available –, parents must still make private investments to support their children's education if they choose to send them to university. In the context of higher education, these additional parental investments cover expenses such as private tutoring, living near the university or in neighborhoods with better amenities, and managing the higher general costs of living. Such investments directly or indirectly contribute to improved children's academic performance (e.g., Psacharopoulos and Papakonstantinou, 2005; Hamilton, 2013; Kobus, Van Ommeren and Rietveld, 2015; Hardt, Nagler and Rincke, 2023) and increase their probability of attending and completing higher education (e.g., Frenette, 2006; Spiess and Wrohlich, 2010). However, they also represent a clear financial constraint, particularly for lower-income households. For instance, lower-income households may choose not to send their children to university if they perceive that, even with their investment, the probability of graduation – and, consequently, their children's future income prospects – are too low. Our model shows that if tax progressivity increases, the cost of maintaining or increasing the quality of higher education shifts from low-income to high-income households, increasing the participation of low-income individuals and reducing perverse redistribution in higher education. This result can occur in two ways: (i) taxes of low-income households decrease, thereby increasing their disposable income or (ii) because high-income households sustain the costs of public higher education through higher taxes.

Through various extensions of the basic model we introduce and discuss the implications of different ways of financing higher education: (i) tuition fees, (ii) income-contingent, means-tested, public grants, and (iii) income-contingent, publicly subsidized loans. For all the extensions, the role of income tax progressivity does not change. However, we discuss the limitations of tax progressivity in reducing perverse redistribution when tuition fees are in place if a government does not also implement income-contingent, means-tested, public grants or publicly subsidized loans.

The remainder of the paper is structured as follows: Section 2 presents stylized facts on income tax progressivity and education enrollment rates across European OECD countries that underpin this paper. Section 3 provides the general set-up of the theoretical model before Section 4 shows how tax progressivity affects the decision to attend higher education and the perverse redistribution. Section 5 presents the extensions of the basic model before 6 concludes.

2 Stylized facts across Europe

Over the last 20 years, two major trends emerged in European OECD countries: a decline in personal income tax progressivity and an increase in the gross enrollment rate in higher education. In fact, both trends have been observed worldwide since the 1990s (Schofer and Meyer, 2005; Strecker, 2017).

We next present stylized facts on the development of tax progressivity, education, and the relationship between the two, focussing on European OECD countries that took part in the Bologna Process. This allows us to compare countries with similar economies and university systems.[9]

2.1 Tax progressivity

The left-hand panel of Figure 1 shows the decline of personal income tax progressivity in European OECD countries since 2000. Income tax progressivity is measured at three different points along the income distribution, namely at 67%, 100% and 167% of the average production worker's wage (APW),[10] taxed as a single male without dependents. The income tax progressivity at 67% of the APW increased, the progressivity at the 167% of the APW remained largely constant, and the progressivity at the 100% of the AWP declined before

[9]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*.

[10]The average production worker earns the average income of a full-time production worker in the manufacturing sector of the respective country: `https://stats.oecd.org/oecdstat_metadata/ShowMetadata.ashx?Dataset=CSP6&Coords=[SUB].[TAXAPW]&Lang`.

bouncing back to its initial level. Income tax progressivity increased more for poorer individuals, making the overall tax system less progressive since 2000. In other words, European OECD countries experienced an increase in the fiscal cost for low-income households greater than the change in the fiscal cost of high-income households.

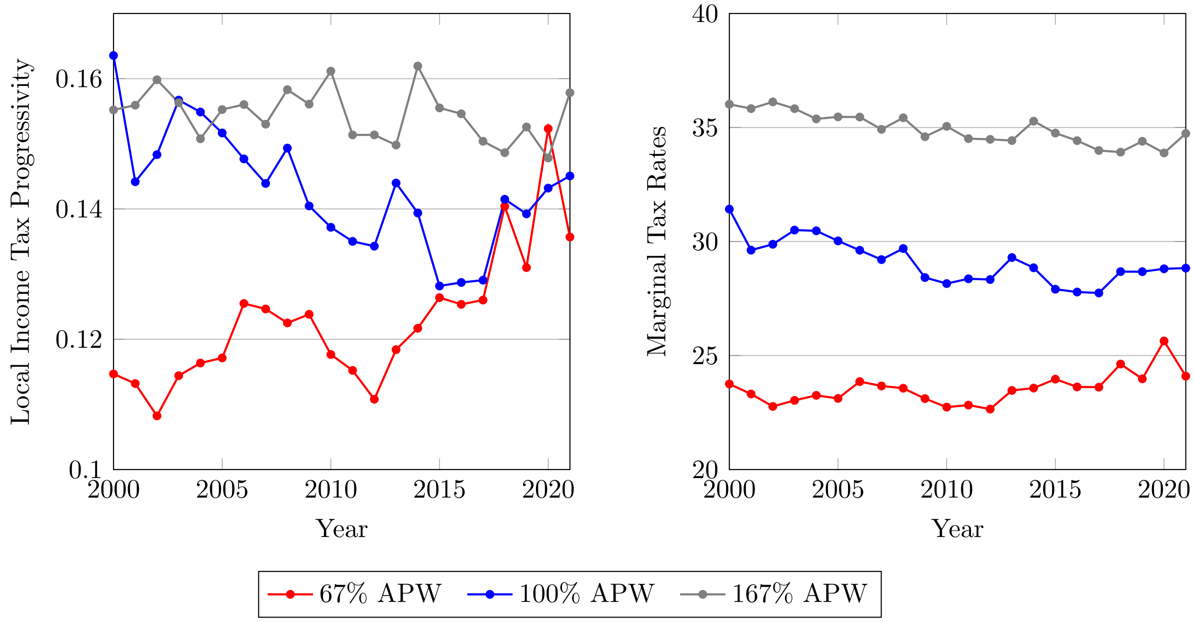

Figure 1: Local Income Tax Progressivity and Marginal Tax Rates in Europe at different income levels: 2000-2021

Notes: Local tax progressivity (left) and marginal tax rates (right) at 67%, 100%, and 167% of the average production worker (APW) in European countries. Tax progressivity calculated following Arnold (2008) and Rieth et al. (2016). Tax progressivity is higher when closer to 1. Countries are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, United Kingdom, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, and Switzerland. Authors' calculations using data from OECD Tax Database (OECD, 2022c)

This increase in the fiscal cost is also confirmed by the right-hand panel of Figure 1, which presents that the marginal tax rate at 67% of the APW increased while the marginal tax rates at 100% and 167% of the APW declined slightly since 2000.

Given the differential developments in progressivity and tax rates across the income distribution, even de facto progressive tax systems may be considered "weakly progressive". This may be the case when it features increasing marginal tax rates across the income distribution but still imposes a disproportionately heavier financial burden on individuals with lower incomes compared to those with higher incomes. This occurs, for instance, when the top marginal tax rate is not high enough or if the income distribution exhibits a long right tail. In such cases, high-income households end up with a smaller tax burden relative to their income, resulting in a lower average tax rates and lower tax progressivity than households in the middle or left-tail of the distribution.

2.2 Higher education

The second trend is the expansion of higher education systems in European OECD countries. The transition from *elite* to universal higher education systems has been well documented by Trow (1973) and became increasingly common across OECD countries (Marginson, 2016; OECD, 2020).

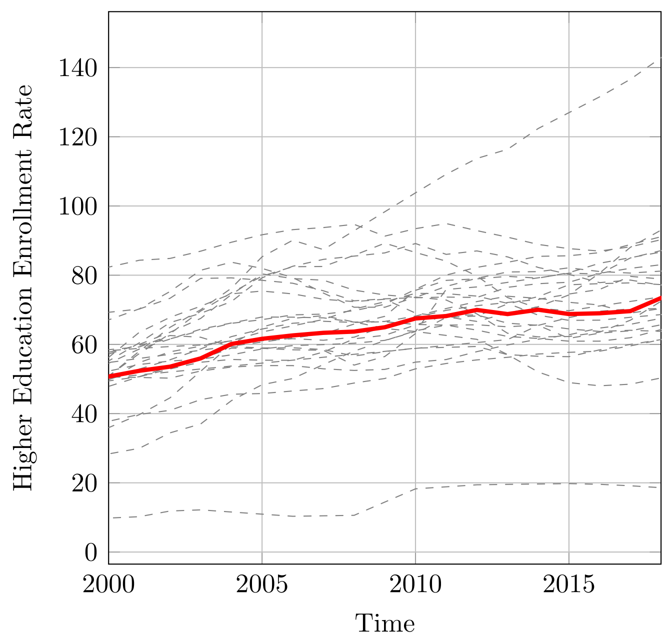

Figure 2: Gross enrollment rate in higher education in European countries between 2000 and 2019

Notes: Data on gross enrollment rate in higher education from World Bank (2022). The gross enrollment ratio for higher education is calculated by dividing the number of individuals enrolled in higher education (regardless of age) by the population of the age cohort that officially corresponds to higher education and multiplying by 100. Thus, numbers can exceed 100. Red line plots simple European OECD average.

Figure 2 shows the gross enrollment trends in higher education in European OECD countries between 2000 and 2019. The European OECD average (red line) highlights that, for European countries, enrollment rates in higher education increased since 2000. However, the trends in Figure 2 could hide the possible disproportionate use of higher education across income classes in Europe. For instance, empirical evidence shows that the rise in higher education enrollment and graduation rates in the UK between the 1970s and 1990s were very unevenly distributed, with students from more affluent families being more likely to participate in higher education (Blanden and Machin, 2004).

2.3 Tax progressivity on education

Combining the insights on income tax progressivity and higher education enrollment, aggregate enrollment is positively correlated with tax progressivity. The simple linear regressions represented in the binned scatter plots in Figure 3 capture the results in Columns 1 and 4 in Table 3 in Appendix H.

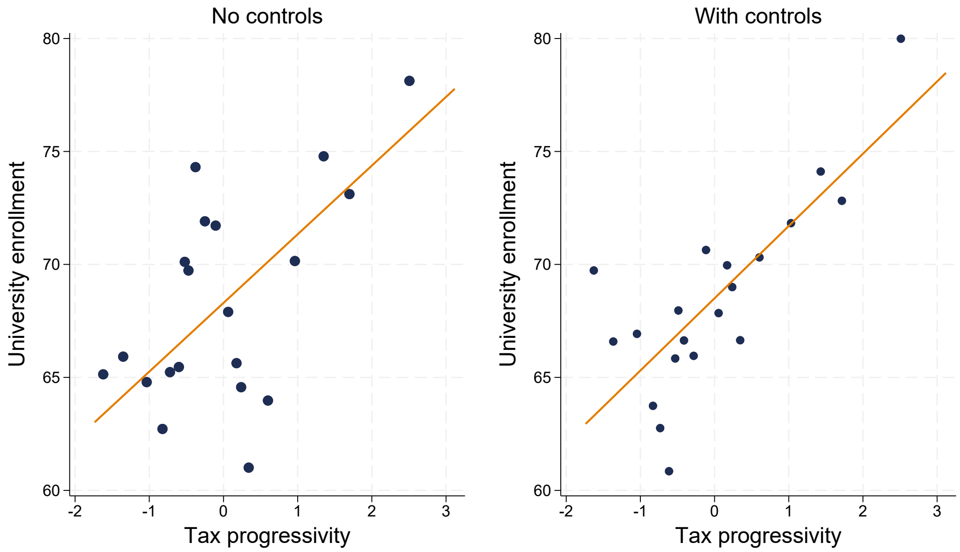

Figure 3: University enrollment and tax progressivity

Notes: Binned scatter plots for the years 2000-2018 based on results in Table 3. The left-hand figure only accounts for tax progressivity, Column 1. The right-hand figure includes a set of additional controls in Column 4. $p - value < 0.05$. We calculated the optimal number of bins by applying the integrated mean square error-optimal number of bins (Cattaneo et al., 2024).

Initial regressions of education on tax progressivity (left) and a whole additional set of country-level control variables (right)[11] indicate that as lagged local tax progressivity at 100% APW increases so does gross enrollment in higher education. The coefficients on local tax progressivity range from 3.04 to 3.2 from the least to the most restrictive estimations. A breakdown across different specifications is available in Table 3 in Appendix H.

Using to microdata from the Luxembourg Income Study, we highlight how individual households' uptake of higher education relates to tax progressivity and parental income. Full results for these microdata-based estimations are available in Table 4 in Appendix H. Households with children between 17 to 19 years of age (the approximate ages where European upper secondary school graduates transition into higher education) demonstrate

[11]The control variables include country-level lagged higher education expenditures as a percentage of GDP, natural log of gross national income per capita, general government expenditure, Reynolds-Smolensky index, the average annual unemployment rate, the annual inflation rate, the long-term interest rate, and the percentage of people living in urban area.

a negative parental income gradient – negative coefficients in Column 1 in Table 1.

Households in the first few quintile have a lower probability of sending a child to higher education relative to the highest income quintile. Columns 2-4 illustrate marginal effects

Table 1: Regression: Parental income gradient and tax progressivity

		Average marginal effects		
	Prob. attending university	Tax progressivity 67% APW	Tax progressivity 100% APW	Tax progressivity 167% APW
Variables	(1)	(2)	(3)	(4)
Parental Income Quintile$_1$	-0.103***	-0.044**	-0.007	0.088***
	(0.015)	(0.017)	(0.021)	(0.026)
Parental Income Quintile$_2$	-0.093***	-0.034**	0.002	0.044*
	(0.012)	(0.015)	(0.017)	(0.023)
Parental Income Quintile$_3$	-0.075***	-0.010	-0.003	0.013
	(0.011)	(0.015)	(0.017)	(0.023)
Parental Income Quintile$_4$	-0.037***	-0.021	-0.010	0.014
	(0.010)	(0.014)	(0.015)	(0.023)
Countries	17	17	17	17
Obs.	44,332	44,332	44,332	44,332
Adj. R-squared	0.380	0.380	0.380	0.380

Notes: The table shows the parental income gradient in higher education interacted with three measures of progressivity (67%, 100% and 167% of the APW). Country-, year- and cohort-fixed effects, and country-cohort interaction capturing linear trends for specific cohorts included. Household-level clustered standard errors in parentheses. ***, **, and * indicate levels of statistical significance at 1, 5, and 10 percent, respectively.

of the differential relationship between the parental income gradient in attending higher education and tax progressivity. On the one hand, the marginal effects in Column 4 show that an increase in tax progressivity at the top of the income distribution (167% APW) is correlated with a reduction in the negative parental income gradient for poorer households. On the other hand, Column 2 shows that a reduction in the parental income gradient for poorer households increases the probability of poorer households sending their children into higher education, even if those households are paying income taxes – reducing perverse redistribution in higher education. These correlations also indicate that as tax progressivity increases at the bottom of the income distribution, the parental income gradient appears more negative for households in the lower quintiles.

Overall these correlations indicate that an increase in tax progressivity could increase perverse redistribution and reduce the university enrollment of individuals from poorer households, if the increase in progressivity occurs in the poorest income classes.

However, while tax progressivity is correlated with individual household choice over higher education attendance, there is no clear relationship between aggregate higher education spending and tax progressivity (at various income levels) among European countries. We present stylized regressions in Table 2.

Table 2: Regression: Higher Education Spending (% GDP) and income tax progressivity

Variables	(1)	(2)	(3)
$\pi_{67\%APW,t}$	-0.005		
	(0.024)		
$\pi_{100\%APW,t}$		0.009	
		(0.021)	
$\pi_{167\%APW,t}$			-0.019
			(0.029)
Constant	0.956***	0.954***	0.956***
	(0.077)	(0.077)	(0.077)
Countries	25	25	25
Observations	467	467	467
Adj. R-squared	0.896	0.896	0.896

Notes: Columns (1)-(3) report the spending in higher education (% GDP) and the degree of income tax progressivity at 67%, 100% and 167% of the average productive worker, respectively. Local tax progressivity measures after standardizing around the mean. Country-level clustered bootstrap standard errors (1000 replications) 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.

We next formulate a theoretical model to integrate these stylized facts.

3 Theoretical Setting

Based on the stylized facts above, we formulate a theoretical model for the relationship between the choice to attend higher education and tax progressivity. We first establish the setting for our baseline model.

3.1 The economy

The economy consists of a continuum of households whose mass is normalized to 1, 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 $[\underline{y}, \overline{y}] \subset \mathbb{R}_{++}$. 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.[12] In the economy, there exists only a public university system – without a private option – that is tuition-free to students and entirely financed through a progressive income tax, thereby receiving a portion of total tax revenues, E. Additionally, the government allocates a portion of total tax revenues, G, to other public spending targets.

At the beginning of Period 1, a parent pays taxes and decides if 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, in which case 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. These additional parental costs and investments could cover private tutoring, housing closer to 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.[13]

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

[13]For instance, Hardt et al. (2023) show that online tutoring in higher education can increase the amount

Furthermore, a child's expected post-graduation income stream (or wage) development is a strictly increasing function of educational quality, which positively depends on the amount of public funding directed into the university system. Thus, if a child earns a university degree, they will get a future income stream equal to $\overline{w}(E)$, such that $\overline{w}(E) : \mathbb{R}_{++} \to \mathbb{R}_{++}$ and $\overline{w}'(E) > 0$; However, obtaining a university degree is still subject to uncertainty. If a child attends university, they will graduate with a probability $p(s)$, such that $p(s) : \mathbb{R}_{+} \to [0, 1)$, 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 $p''(s) < 0$. The strong concavity assumption captures the diminishing returns of monetary parental investments on the probability of a child's university graduation.[14] Moreover, we assume that $p(0) = 0$ and that $p'(0) = \infty$. If parents consider sending their child into higher education, they cannot expect any increased returns without some investment in education.[15] In this context, the private parental investment in a child's education and government expenditures in public

of accumulated credits by almost one-third and the GPA by about one grade level. Private tutoring also represents a large portion of private households' university costs (Psacharopoulos and Papakonstantinou, 2005). Empirical evidence has also shown a negative impact of distance on various outcomes in higher education, such as students' grades (Kobus et al., 2015) or the probability of attending university (Frenette, 2006; Spiess and Wrohlich, 2010). The effect of distance on university participation is also heterogeneous across social classes with a (larger) negative effect for people from low-income families (Spiess and Wrohlich, 2010; Cullinan, Flannery, Walsh and McCoy, 2013).

[14] The assumption of diminishing returns to monetary parental investments in human capital accumulation is widely accepted in economic theory (see, for instance, Becker, Kominers, Murphy and Spenkuch, 2018) and empirical research has shown that monetary parental investments made during higher education exhibit diminishing returns on the likelihood of their children's university graduation (Hamilton, 2013). The strong concavity assumption can also be relaxed, such that $p''(s) \leq 0$, without changing the results of the model. In this case, it is possible also to relax the assumption $p(s) \in [0, 1)$ by introducing a private educational investment threshold, $\widehat{s}$, such that $p(s) = 1$ for any $s \geq \widehat{s}$. However, this assumption seems unrealistic to us as it would exclude other unpredictable external factors that could affect the probability of graduating, which we implicitly capture by assuming $p(s) < 1$ for each $s \geq 0$.

[15] The probability of graduating from higher education could also be an increasing function of skills and knowledge acquired prior to enrollment. The work of Kosse, Deckers, Pinger, Schildberg-Hörisch and Falk (2020) and Falk, Kosse, Pinger, Schildberg-Hörisch and Deckers (2021), among others, shows that children from higher socioeconomic status (SES) families tend to have higher cognitive and non-cognitive skills, which in our model would make them more likely to enroll in university. Thus, the probability function would become: $p(s, a(y))$, where $a(y)$ captures the skills accumulated by a child graduating secondary school and positively depends on the economic status of their parents, such that $a'(y) \geq 0$. Interestingly, Ichino, Rustichini and Zanella (2024) show that the expansion of higher education in the UK resulted in the admission of students from high SES and lower levels of intelligence, which may suggest that skills are not the major determinant in the decision to attend university.

higher education are complements. We assume that without some private support, a child cannot attend and successfully complete higher education, as there are necessary costs that complement attending higher education that households must bear. We will relax these restrictions in the extensions to this baseline model. If a child does not attend university or fails to graduate, they receive the future income stream of someone with completed upper-secondary school education, $\underline{w} > 0$, such that $0 < \underline{w} < \overline{w}(E)$ for any $E > 0$.[16] This assumption aligns with the fact that those with higher education have, on average, higher incomes. Indeed, one can interpret $\overline{w}(E) - \underline{w} > 0$ as the long-run income (or wage) premium between university and secondary-school graduates.

In this model, there is no congestion effect on public goods, meaning that the mass of households consuming the available public goods does not affect the quality of those public goods. We exclude a congestion effect at the level of public spending G, as G represents a large set of different public goods available to all households, with some households partaking in some public goods more than others and ruling out an overall congestion effect. Regarding the quality of higher public education, E, we exclude the congestion effect for several reasons: (i) ambiguous empirical findings in the literature on the congestion effect in higher education;[17] (ii) ambiguous empirical findings on the effect of higher education expansion on the higher education wage premium, which might depend on the quality of the accumulated human capital or the general equilibrium effects on skill prices;[18] (iii) the capacity of gov-

[16]Note that we always assume $E > 0$. We do not consider the case in which $E = 0$, which would occur if a government cannot or does not finance a public higher education system, as we explain in subsection 3.3. This scenario is unrealistic for European or developed countries. Moreover, if $E = 0$, a private higher education option likely emerges as a unique option; However, this scenario goes beyond the purpose of this paper.

[17]While a number of empirical findings point to a negative effect of class size in higher education outcomes, (Kokkelenberg, Dillon and Christy, 2008; De Giorgi, Pellizzari and Woolston, 2012; Kara, Tonin and Vlassopoulos, 2021, e.g.,), others find no effect, (e.g., Kennedy and Siegfried, 1997; Cho, Baek and Cho, 2015; Bettinger, Doss, Loeb, Rogers and Taylor, 2017). Another strand of this literature finds mixed or heterogeneous results depending on the type of university course (Cheng, 2011; De Paola, Ponzo and Scoppa, 2013; Kara et al., 2021).

[18]While Carneiro and Lee (2011); Bianchi (2020) and Ichino et al. (2024), among others, find a negative effect of higher education expansion due to lower quality accumulation of human capital or skill price general equilibrium effects, Walker and Zhu (2008) and Blundell, Green and Jin (2022) find no effect, and Katz and Murphy (1992); Carneiro, Liu and Salvanes (2023), and Westphal, Kamhöfer and Schmitz (2022) find a positive effect.

ernments 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. In the theoretical literature, the universality of a public education system is captured by fixing the congestion effect, namely the mass, N, of users congesting the public good, at $N = 1$ (e.g., see Glomm et al. (2011)), which illustrates the general idea that universal access does not limit the size of institutions (Trow, 1973); (iv) households might be myopic regarding the congestion effect (see, for instance, Glomm et al. (2011)) and might not consider the expansion of higher education in their decision to attend it, thereby considering N as fixed. If a congestion effect exists, myopic agents would explain the growing enrollment in higher education in European and OECD countries (Marginson, 2016; OECD, 2020).[19]

3.2 Utility maximization problem

We assume that the household's utility function is weakly additively separable into the parent's consumption utility, $u(c)$, and the expected income utility of the child, which is linear in their future income. The utility function, $u(c) : \mathbb{R}_+ \to \mathbb{R}$, is continuous, twice differentiable, strictly increasing ($u'(c) > 0$), and strictly concave ($u''(c) < 0$) in parental consumption, c. Moreover, we assume that the household cannot favor the child's education over parental consumption if that implies parental consumption equals 0 ($u'(0) = \infty$). We also assume that the household cannot observe future tax rates; they can, however, observe the child's human capital. Thus, the household only explicitly cares about the child's expected pre-tax income, which is a function of the child's human capital. While the assumption that households and parents consider the children's future human capital or pre-tax income is already widely used in the education choice literature,[20] there are a number of reasons to justify this assumption: (i) The empirical evidence shows that expected gross market wage or gross return to schooling are predictors of university enrollment (e.g., see Attanasio and Kaufmann,

[19] See Online Appendix C for a detailed discussion and descriptive empirical evidence about points (i)-(iv).

[20] Examples are Epple and Romano (1996), Fernandez and Rogerson (1995) or De Donder and Martinez-Mora (2017). See Glomm et al. (2011) for a comprehensive literature review.

2014; Schweri and Hartog, 2017); (ii) post-tax income depends on many factors (e.g., having children, marital status, industry, etc.) and an individual will form their expectations based on incomplete information;[21] and (iii) considering the pre-tax future income incorporates the preference for higher education, which is associated with lower income volatility and higher returns to education, factoring in the lower unemployment risk, while any redistributive effect of the tax system would not be considered.[22]

The household makes the choice that maximizes their utility depending on whether or not they send the 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 the child to university, V^e, and having the child entering the work force without a university degree, V^w, respectively.

If a household decides to send the child to university, they maximize the utility function as follows:

$$\begin{aligned} \max_{c,s} \quad & u(c) + \delta\left[p(s)\cdot\overline{w}(E) + (1-p(s))\cdot\underline{w}\right] \\ \text{s.t.} \quad & c + s \leq d_k(y), \end{aligned} \tag{1}$$

whereby $d_k(y) : [\underline{y}, \overline{y}] \to \mathbb{R}_{++}$ 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, the household obtains the indirect utility V^e (see Appendix A for a detailed derivation):

$$V^e = u(d_k(y) - s^*) + \delta\left[p(s^*)\cdot\overline{w}(E) + (1-p(s^*))\cdot\underline{w}\right], \tag{2}$$

such that $s^* > 0$ is the optimal parental subsidy.

[21] For instance, Klößner and Pfeifer (2019) show that the effect of tax progressivity on expected future gross salaries is underestimated.

[22] In other words, agents consider the intrinsic labor market advantages of completing higher education, irrespective of the tax and benefits system in which they live. See, for instance, Delaney and Devereux (2019) for the effect of higher education on lower income volatility and Delaney (2019) for an estimation of the returns to education, accounting for the unemployment risk.

If a household decides not to send their child to university, the parent ceases to invest in their child's education and, thus, maximizes the utility function as follows:

$$\begin{aligned} \max_{c} \quad & u(c) + \delta \underline{w} \\ \text{s.t.} \quad & c \leq d_k(y), \end{aligned} \tag{3}$$

whereby they obtain the indirect utility V^w:

$$V^w = u(d_k(y)) + \delta \underline{w}. \tag{4}$$

The indirect utility in (2) shows that, if a household chooses to send their child to university, they have to invest an optimal amount of subsidy given parental net income to maximize the probability $p(s) \in (0, 1)$ of the child graduating and obtaining the child's higher future income. On the other hand, (4) shows that, if a household does not send the child to university, it will consume the entire parental income and the child will receive a income $\underline{w} > 0$ going forward. The differences between the indirect utility functions (2) and (4) define the opportunity cost that the household faces in that decision.

3.3 Educational system and government budget constraint

Income earners in the economy pay income taxes in order to finance the public education system and other public goods. 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 events implies that households whose children decide not to attend university do not finance the public education system for children of the same cohort who did decide to attend university. To make the tax function more mathematically tractable, we modify the classical linear piece-wise tax function, in line with D'Antoni (1999), such that the tax function in the model is non-linearly increasing to the right of each income threshold. This small modification smooths the function around the income thresholds, making the function continuously differentiable in its domain. As a consequence, the function allows us to identify the different income thresholds B and tax rates $\mathbf{t}$, thereby allowing us to study the effect of changes in the different tax rates. For simplicity, we assume that the tax system consists of only two tax thresholds $B = \{\widehat{y}_0, \widehat{y}_1\}$ and three different income classes $\overline{K} = \{0, 1, 2\}$. 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 incomes between the income thresholds $\widehat{y}_0$ and $\widehat{y}_1$ and the rich as the income class which includes the maximum income $\overline{y}$. 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 individual tax function $T_i(y) : [\underline{y}, \overline{y}] \to \mathbb{R}_+$ defined in (5):

$$T_i(y) = \begin{cases} 0 & \underline{y} \leq y \leq \widehat{y}_0 \\ t_1(y - \widehat{y}_0) + \tau_1(y)(t_0 - t_1) & \widehat{y}_0 < y < \widehat{y}_0 + \epsilon \\ t_1(y - \widehat{y}_0) + \tau_1(\widehat{y}_0 + \epsilon)(t_0 - t_1) & \widehat{y}_0 + \epsilon \leq y \leq \widehat{y}_1 \\ t_1(\widehat{y}_1 - \widehat{y}_0) + t_2(y - \widehat{y}_1) + \tau_1(\widehat{y}_0 + \epsilon)(t_0 - t_1) + \tau_2(y)(t_1 - t_2) & \widehat{y}_1 < y < \widehat{y}_1 + \epsilon \\ t_1(\widehat{y}_1 - \widehat{y}_0) + t_2(y - \widehat{y}_1) + \tau_1(\widehat{y}_0 + \epsilon)(t_0 - t_1) + \tau_2(\widehat{y}_1 + \epsilon)(t_1 - t_2) & y \geq \widehat{y}_1 + \epsilon \end{cases} \tag{5}$$

where $\epsilon > 0$ and very small, $t_0 = 0$ is the tax rate for incomes below the zero-tax threshold, $\widehat{y}_0$, and the term $\tau_k(y)(t_{k-1} - t_k) \leq 0$ is a tax credit function associated with income class k. The tax liability function (5) is increasing and progressive if $t_k > t_{k-1}$ for every $k \in \overline{K}$, 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 function $\tau_k(y) \geq 0$ is an increasing, continuously differentiable function, such that $0 \leq \tau_k'(y) < 1$ in $(\widehat{y}_{k-1}, \overline{y}]$ (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 $k \in \overline{K}$;

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

T4) for $y > \widehat{y}_{k-1}$, $y - \widehat{y}_{k-1} > \tau_k(\widehat{y}_{k-1} + \epsilon)$.

Tax progressivity arises from $t_{k+1} > t_k$. Under this condition, the marginal tax rate is strictly increasing in income for any $t_k > 0$. Because of properties T1-T4 and because $t_k > t_{k-1}$ for every $k \in \overline{K}$, it follows that the tax system is also *strongly incentive preserving* (e.g., see Fei, 1981; Eichhorn, Funke and Richter, 1984), such that the ranking of tax payers according to their pre-tax and post-tax incomes is constant (see Online Appendix D for further discussion of the tax function). Moreover, property T4 guarantees that any marginal tax credit never exceeds the marginal tax revenue. Figure 4 illustrates the tax revenue and tax rate functions obtained at different levels of income.

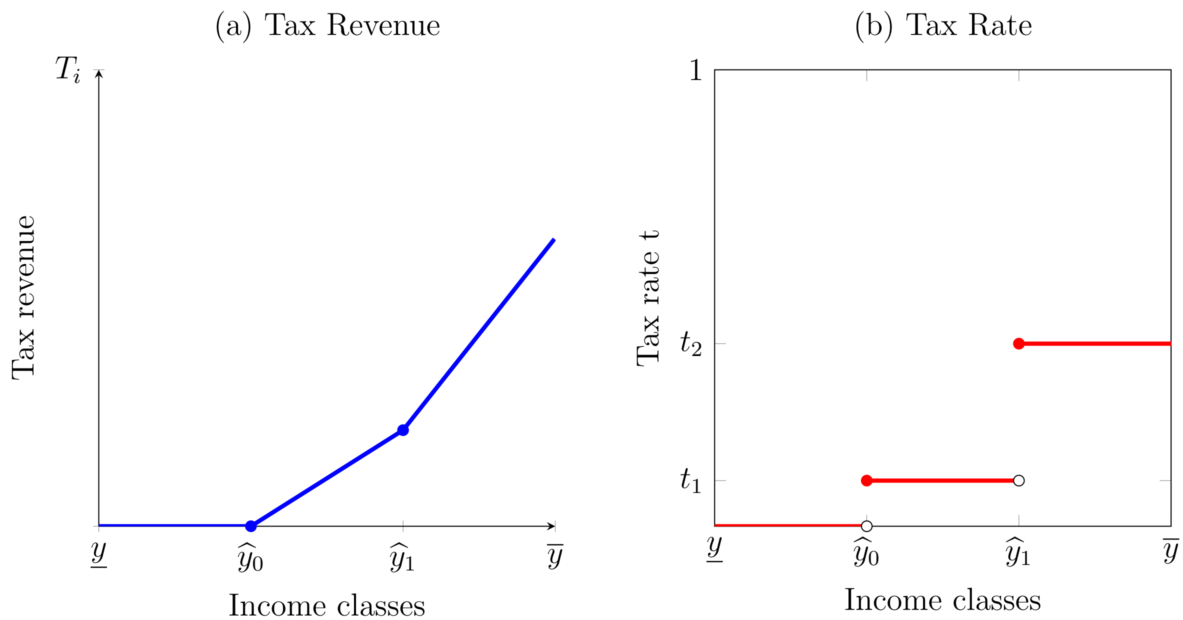

Figure 4: Income tax revenue and rates

Notes: (a) Tax revenue given the level of income and the income classes. The blue dots represent the function in the right-neighbor pairs $(y_k, y_k + \epsilon)$. (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:

$$E + G = T, \tag{6}$$

whereby $T = \int_{\underline{y}}^{\overline{y}} T_i(y)f(y)dy > 0$ is the total government tax revenue raised, which is also equal to total government expenditures. $E = T\alpha$ is the amount tax revenue then redirected towards or spent on higher education, whereas $G = T(1-\alpha)$ is the amount of tax revenue for public spending that spent on other policy objectives, which do 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.[23] The parameter $\alpha \in (0, 1)$ represents the portion of total tax revenue (or total expenditure) that is directed towards public higher education. We assume that the percentage of tax revenue in higher education is strictly greater than zero, such that $E > 0$. This assumption is consistent with the expenditure patterns in European OECD countries in Section 2, and holds in other countries around the globe.

3.4 Higher education choice

In order to understand how progressivity interacts with the decision of to attend higher education, we next focus on the conditions under which a household decides to send the child to university. First, we show the existence of a unique indifference pre-tax income threshold over the income support $[\underline{y}, \overline{y}]$, under a progressive income tax scheme $\{\mathbf{t}, \boldsymbol{\tau}\}$:

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

Proof. See Appendix D.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 households above the threshold have a higher utility from sending their children to higher education, while

[23] G could also be a set of other public goods that explicitly or implicitly affect the utility function of a household (i.e., $u(c, G)$), where the utilities of private 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 irrespective of a child's university attendance.

households below that threshold derive a greater utility from not investing in their children's higher 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 higher education, $N^e = \mathbf{P}(V^w < V^e) = \mathbf{P}(y > \widetilde{y}) = 1 - F(\widetilde{y})$, where $\mathbf{P}$ is that probability of sending the child to higher education for a given income. (ii) the mass of households with $y \leq \widetilde{y}$, who decide not to send their children to higher education, $N^w = \mathbf{P}(V^w \geq V^e) = \mathbf{P}(y \leq \widetilde{y}) = F(\widetilde{y})$. Figure 5 illustrates these two masses along the income distribution.

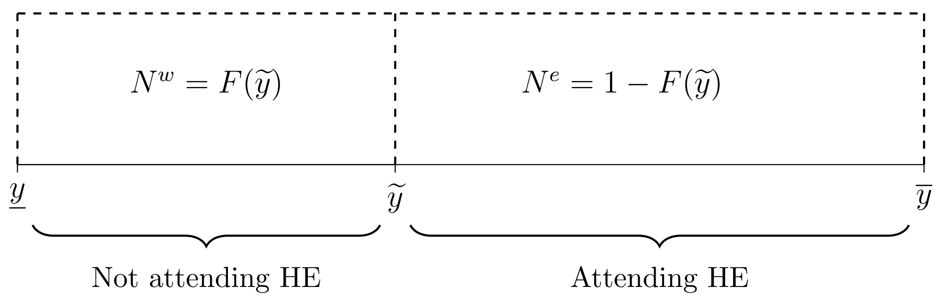

Figure 5: Distribution of households by income and higher education attendance

We are interested in how the threshold $\widetilde{y}$, and, thus, the decision of attending higher education, changes when different parameters in the economy, such as α or $\underline{w}$, change. If the threshold is negatively or positively related to certain factors, such as the expected income of individuals that do not graduate from higher education, $\underline{w}$, or the share of revenue directed towards higher public education, α, the threshold will move to the left or right, respectively, as those factors increase. Lemma 2 clarifies the relationship between $\widetilde{y}$ and the different structural parameters.

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

Proof. See Appendix D.2 ■

These results have simple economic explanations: if the income of workers without a university degree, $\underline{w}$, increases, then the opportunity cost of sending a child to higher education is lower and poorer households will prefer not to bear the additional private cost (the subsidy s) for an investment with uncertain returns. On the other hand, if the government increases the share of tax revenue directed to public higher education, the quality of education – and thus the post-university incomes and wage premia – increases and more households will be incentivized to send their children to higher education.

4 A model of perverse redistribution

As previously explained, perverse redistribution arises when poorer households sustain the fiscal cost of a public good without partaking in its benefits. 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 fiscal and opportunity costs of accessing said public good. In higher education, this perverse redistribution arises because poorer households may be paying positive taxes but cannot bear the additional required costs of higher education.

We next explore the effect of progressivity on perverse redistribution in the baseline setting. For a given tax system, the indifference threshold is located below the highest income class, $\widetilde{y} < \widehat{y}_1$, and households in the richest income class strongly prefer to send their children into higher education.

If $\widehat{y}_0 < \widetilde{y} < \widehat{y}_1$, the population is separable into three groups:

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

(ii) The mass of households that finance public higher education through their income taxes but who do not send their children to university (we will shorthand these households as 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 extent of perverse redistribution.[24]

(iii) The mass of households that do not send their children to university and who do not finance higher education because they are to the left of the zero-tax threshold, denoted N_0^w, such that $N_0^w = F(\widehat{y}_0)$.

Figure 6 illustrates the three groups for a given income distribution over the support $[\underline{y}, \overline{y}]$:

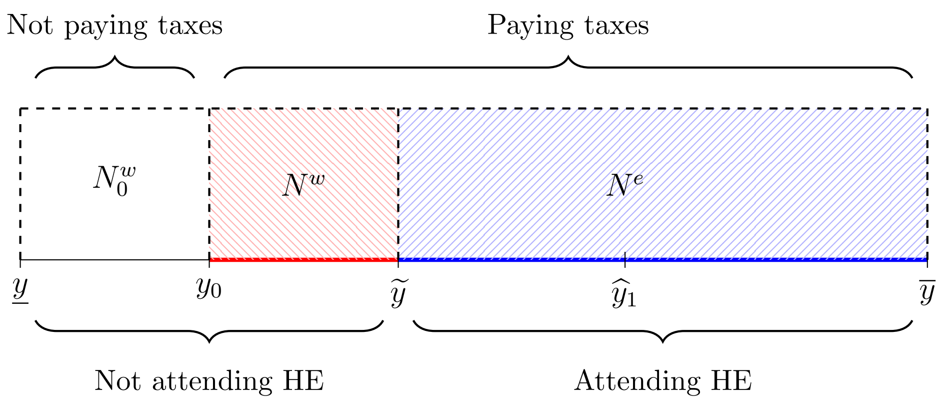

Figure 6: Perverse redistribution

If $\widehat{y}_0 \geq \widetilde{y}$, then $N^w = 0$ and three groups of household collapse into two, 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 taxes to finance public higher education.

4.1 Changes in progressive taxation

We next want to understand the effect of income tax progressivity on higher education choice and consider the inherent level of perverse redistribution in a tax-financed public higher education system. In line with Doerrenberg and Peichl (2013), we model an increase

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

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.[25]

While this definition of progressivity abstracts away from the complexities of real-world tax systems, it is sufficiently detailed to theoretically analyze how changes in progressivity can affect households' educational choices and perverse redistribution. In reality, an increase in progressivity can occur through a simultaneous non-proportional variation in more than one tax rate without changing the overall tax collections and thus spending on 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.[26]

As described in Lemma 2, an increase in the total level of public higher education funding moves the indifference threshold to the left. However, as is frequently the case, an increase in tax progressivity may be required 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 higher education. On the other hand, countries may have relatively low levels of progressivity but funnel a higher share of funding into public higher education.

To disentangle the effect of income tax progressivity on the choice to attend higher education from changes in spending targets, we consider α to be the size of an educational policy defining the portion of total tax revenue spent on higher education; thus, we assume that α is a continuously differentiable function of the total tax revenue, such that $\alpha(T) : T \to (0, 1)$. There are three possible relationships between education spending and tax progressivity, $\partial\alpha(T)/\partial t_2$.

i. $\partial\alpha(T)/\partial t_2 > 0$: spending on higher education increases as income tax progressivity

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

[26] In Online Appendix D and in Section 4.3, we provide and discuss 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. The results remain unchanged.

increases.

ii. $\partial\alpha(T)/\partial t_2 < 0$: spending in higher education decreases along with income tax progressivity.

iii. $\partial\alpha(T)/\partial t_2 = 0$: spending in higher education does not change with tax progressivity.

As seen in Section 2, among advanced economies with similar higher education systems, income tax progressivity is not significantly correlated with higher educational spending, consistent with the last possibility, $\partial\alpha(T)/\partial t_2 = 0$. We will consider all three possibilities going forward.

To explore the effect of progressivity on perverse redistribution in education, we focus on two cases. First, we consider an increase in progressivity when the indifference threshold $\widetilde{y}$ is above the no-tax threshold, $\widehat{y}_0$. Second, we consider an increase in progressivity when the indifference threshold $\widetilde{y}$ is below the no-tax threshold, $\widehat{y}_0$.

4.1.1 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.

$$\Delta(\widetilde{y}) = V^w(d_1(\widetilde{y})) - V^e(d_1(\widetilde{y})) = 0 \tag{7}$$

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

$$\frac{\mathrm{d}\widetilde{y}}{\mathrm{d}t_2} = \frac{\overbrace{\delta p(s^*)\overline{w}'(E)\left(\alpha\frac{\partial T}{\partial t_2} + T\frac{\partial \alpha}{\partial t_2}\right)}^{\text{Marginal fiscal benefit } \lesseqgtr 0} - \overbrace{\frac{\partial \Delta(u)}{\partial t_2}}^{\substack{\text{Marginal fiscal} \\ \text{cost=0}}}}{D} \lesseqgtr 0, \tag{8}$$

where $D = \partial\Delta(y)/\partial y < 0$, $\Delta(u) = u(d_1(\widetilde{y})) - u(d_1(\widetilde{y}) - s^*)$ and $\alpha[\partial T/\partial t_2] > 0$.

Proof. See Appendix E ■

Derivative (8) represents the response of the threshold to a change in income tax progressivity. Its sign depends on the direction of the policy α. As previously mentioned, if $\partial\alpha/\partial t_2 \geq 0$, then funding for public higher education increases in response to rising progressivity. This encompasses two of our previous possibilities – an increase in public funding can be due to a change in spending targets (i.e., $\partial\alpha/\partial t_2 > 0$) or an overall increase in total tax revenues, without a change in 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 higher education or not. After an increase in progressivity, the marginal fiscal cost for higher quality public higher 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 system, 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 (8) would then be positive and the increase in progressivity will have a negative effect on the educational choice of the middle class. However, (8) will be smaller compared to when 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 (8) will be negative.

The effect of an increase in progressivity can also be analyzed by focusing on how the masses of the three population subgroups change. Consider the initial distribution that split the population into its three subgroups: N_0^w, N^w, and N^e. An increase in progressivity (i.e., an increase in t_2) which does not affect α, $\partial\alpha/\partial t_2 \geq 0$, implies $\partial\widetilde{y}/\partial t_2 < 0$. This will affect the partition of the three subgroups as follows:

$$\frac{\partial N^w}{\partial t_2} = \frac{\partial \widetilde{y}}{\partial t_2} f(\widetilde{y}) < 0, \tag{9}$$

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

$$\frac{\partial N_0^w}{\partial t_2} = 0. \tag{11}$$

Derivative (9) shows that a more progressive tax scheme reduces the mass of households who contribute 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 extent of perverse redistribution in the economy. By extension, a more progressive tax system increases in the number of households sending their children to higher education, as shown by Derivative (10), while the mass of N_0^w remains unchanged unless the new threshold $\widetilde{y}$ moves below $\widehat{y}_0$. Figure 7 portrays this effect.

Figure 7 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 $[\underline{y}, \overline{y}]$, following (8). As $\widetilde{y}$ shifts left, poorer households prefer to send their children to higher education and, thus, perverse redistribution is reduced.

When $\partial\alpha/\partial t_2 < 0$, the signs of the Derivatives (9) and (10) may be different – if the increase in total tax revenue is smaller than the reduction of funding going to higher education, the sign in the Derivatives (9) and (10) reverse. Instead, if the increase in total tax revenue

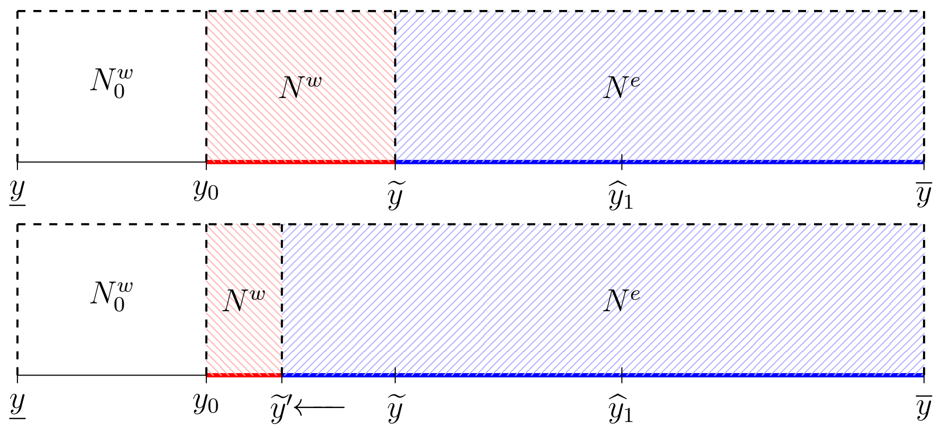

Figure 7: Perverse redistribution after an increase in progressivity

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

is larger than the reduction in the funding share α, then the sign of the Derivatives (9) and (10) 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 higher education α does not decrease more than the increase in total tax revenue.*

Proposition 1 suggests that a more progressive tax system can mitigate perverse redistribution in higher education. However, achieving this outcome relies on the government avoiding significant reductions in the funding allocated to higher education. Simply put, if the government does not invest enough public resources in the quality of the higher education system, the reduction of perverse redistribution becomes unattainable. This is because lower-income households may be less inclined to invest in their children's higher education if attending and graduating from higher education does not guarantee a large enough return on their children's future income.

4.1.2 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 $N^w = 0$. In this case, the economy will only consist of two groups of households, namely the poorer households who do not pay taxes and do not send their children to university, N_0^w, and the richer households who pay taxes and send their children to university, N^e. As a consequence, there is no perverse redistribution – households who do not send their children to university also do not contribute to its financing and those that are sending their children to attend university are the only ones financing public higher education. Thus, an increase in progressivity will strictly increase the number of people going to university by incentivizing households that do not pay taxes to nevertheless invest the addition cost of university attendance and send their children into higher education.

$$\frac{\partial N^e}{\partial t_2} = -\frac{\partial \widetilde{y}}{\partial t_2} f(\widetilde{y}) > 0, \tag{12}$$

$$\frac{\partial N_0^w}{\partial t_2} = \frac{\partial \widetilde{y}}{\partial t_2} f(\widetilde{y}) < 0, \tag{13}$$

$$\frac{\partial N^w}{\partial t_2} = 0, \tag{14}$$

If $\partial\alpha/\partial t_2 < 0$, the sign of the Derivatives (12) and (13) may reverse if and only if the increase in total tax revenue is smaller than the reduction of funding going to higher 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 households opting for their child to attend higher education if and only if the amount of funding directed to higher education does not decrease more than the increase in total tax revenue.*

4.2 Local progressivity

Our model so far has analyzed the relationship between perverse redistribution and an increase in the tax rate of the richest income class, which in our very simple tax system served as a proxy for an increase in tax progressivity. However, in Section 2, we show that (i) income tax progressivity varies along the income distribution; (ii) the heterogeneity of income tax progressivity along the income distribution can affect low- and high-income households' decision to send their children to university. We rely on the concept of *local progressivity* to integrate this income-specific progressivity into our model. Analyzing the changes in local progressivity allows us to identify variations in the incentive to consume and invest in higher education along the income distribution. Consequently, it also allows to identify how the design of a progressive tax system can affect perverse redistribution in higher education. Ultimately, this will allow the model to be extendable to more complex tax systems and more complex tax changes.

Consider the progressivity measure, π_k, as applied by Arnold (2008) and Rieth et al. (2016), for each income class k:

$$\pi_k(\mathbf{t}) = \frac{t_k - a_k}{1 - a_k}, \tag{15}$$

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 the household divided by the household's total income, $a_k = T_k(y, \mathbf{t})/y_k$. π_k then measures the local progressivity of the tax system for income class k. It structurally factors in the complexity of the tax system below income class k through a_k.

The local progressivity π_k in (15) increases in the marginal tax rate t_k and decreases 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.

Considering the local progressivities of our model's three income classes, we observe that $\pi_0 = 0$, $\pi_1 > 0$, and $\pi_2 > 0$; Moreover, the overall tax scheme is progressive, as $t_2 > t_1$. However, even if $t_2 > t_1$, depending on the size of the marginal tax rate and the average tax rate along the income distribution, richer households may have lower local progressivity than poorer households if:

$$t_1(1-a_2) - a_1 > t_2(1-a_1) - a_2 \implies \pi_1 > \pi_2, \tag{16}$$

which can occur if the income distribution is particularly right-skewed (i.e., if the right tail is particularly long) and/or the difference $t_2 - t_1 > 0$ is small enough.[27]

To understand how local progressivity factors into the households' choice to invest in their children's higher education and perverse redistribution, we explore the following example. The indifferent household, $\widetilde{y}$, lies in the middle class and thus pays positive t_1 and a_1. An increase in t_1 then increases the progressivity in the middle class, π_1, but reduces the progressivity in the income class of the rich, π_2:

$$\frac{\partial \pi_1(\mathbf{t})}{\partial t_1} = \frac{1}{\left(1 - T_1(y,\mathbf{t})/y\right)^2}\left[1 - \frac{\partial\left[T_1(y,\mathbf{t})/y\right]}{\partial t_1}\right] > 0, \tag{17}$$

$$\frac{\partial \pi_2(\mathbf{t})}{\partial t_1} = -\frac{\partial\left[T_2(y,\mathbf{t})/y\right]}{\partial t_1}\left[\frac{1-t_2}{\left(1 - T_2(y,\mathbf{t})/y\right)^2}\right] < 0 \tag{18}$$

Proof. See Appendix F.1 ■

Derivatives (17) and (18) show that the progressivity gap between the middle class and the rich decreases as the increase in tax revenue is extracted via a greater tax burden for the middle class. These results differ from the pure increase in t_2 analyzed in Section 4.1, where the rich bear the cost of raising more revenue. Indeed, an increase in t_2 does not affect the progressivity of the middle class but increases the progressivity at the top of the income distribution, making the tax system "locally" more progressive:

$$\frac{\partial \pi_1(\mathbf{t})}{\partial t_2} = 0, \tag{19}$$

[27] In reality, higher tax avoidance at the top of the income distribution can further exacerbate the problem of $\pi_1 > \pi_2$.

$$\frac{\partial \pi_2(\mathbf{t})}{\partial t_2} = \frac{1}{\left(1 - T_2(y_i, \mathbf{t})/y_i\right)^2} \left[1 - \frac{T_2(y_i, \mathbf{t})}{y_i} - \frac{\partial \left[T_2(y_i, \mathbf{t})/y_i\right]}{\partial t_2}(1 - t_2)\right] > 0 \qquad (20)$$

Proof. See Appendix F.2 ■

To understand how an increase in the progressivity of the income class affects perverse redistribution in higher education, we consider an increase in t_1. Assuming $\partial\alpha/\partial t_1 = 0$, the effect of an increase in t_1 has an ambiguous effect on the university choice of the indifferent household, as their marginal fiscal cost is positive.

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.*

$$\frac{\mathrm{d}\widetilde{y}}{\mathrm{d}t_1} = \frac{\overbrace{\delta p(s^*)\overline{w}'(E)\left(\alpha \frac{\partial T}{\partial t_1}\right)}^{\text{Marginal fiscal benefit} > 0} - \overbrace{\frac{\partial \Delta(u)}{\partial t_1}}^{\substack{\text{Marginal fiscal} \\ \text{cost}>0}}}{D} \lesseqgtr 0, \qquad (21)$$

whereby $D = \partial\Delta(y)/\partial y < 0$, $\Delta(u) = u(d_1(\widetilde{y})) - u(d_1(\widetilde{y}) - s^*)$ and $\alpha[\partial T/\partial t_2] > 0$.

An increase in local progressivity for the indifferent household could then have no or even a negative effect on higher education choice and perverse redistribution, depending on whether their marginal fiscal cost exceeds the marginal fiscal benefit. This occurs because an increase in the progressivity, π_1, implies that the middle-income class – where the indifference threshold is located – bears the cost of raising more tax revenue. In contrast, the progressivity in the income class of the rich, π_2, decreases. Thus, when governments seek to increase university enrollment and reduce perverse redistribution, they face several scenarios to adjust income tax progressivity across the population.

4.3 Changes in local progressivity

The findings in Sections 4.1 and 4.2 highlight that as long as the marginal fiscal benefit of the indifferent household exceeds their marginal fiscal cost, the policymaker is able to "target" the beneficiary of reduced perverse redistribution and the bearer of the cost. The concept of local progressivity is then able to integrate tax changes across all income groups into our analysis of perverse redistribution.

We show above that increasing the degree of tax progressivity at the top of the income distribution can reduce perverse redistribution in higher education. This result occurs because a tax increase for high-income households leads to a better-quality higher education system as the government can reinvest the extra tax revenue in higher education. Here we explore the effect of a tax cut for middle-income households which does not alter the quality of higher education. In other words, we assume that E remains fixed while t_1 decreases.[28]

Assuming the indifferent household is in the affected income group, $\widehat{y}_0 < \widetilde{y} < \widehat{y}_1$, and $\partial\alpha/\partial t_1 = 0$, we formulate the difference between the two indirect utility functions of the indifferent household as $\Delta(d_1(\widetilde{y})) = V^w - V^e = 0$, and apply the implicit function theorem:

$$sgn\left[\frac{\partial\widetilde{y}}{\partial t_1}\right] = sgn\left[-\frac{\frac{\partial\Delta(u)}{\partial t_1}}{D}\right], \tag{22}$$

whereby $D = \partial\Delta(y)/\partial y < 0$ and $\Delta(u) = u(d_1(\widetilde{y})) - u(d_1(\widetilde{y}) - s^*)$.

The derivative (22) is negative if we assume a decrease in t_1. In other words, if we assume a reduction of the marginal fiscal cost of the indifferent household, the difference between the degree of income tax progressivity between the middle class and the rich increases and a larger mass of middle-income households prefers to enroll their children in higher education. The degree of perverse redistribution is thus decreased. Recall Figure 7 for visualization of this reduction in perverse redistribution.

The result in (22) further sheds light on the role of income tax progressivity and perverse redistribution in higher education. When a cut in t_1 occurs while E remains fixed, middle-income households benefit from the reduction in their fiscal cost without facing a reduction in the quality of education. Moreover, when an increase in t_2 implies a better-quality higher

[28] This could occur either because of a simultaneous increase in t_2 or α to compensate the decrease in t_1.

education (i.e., a larger E), middle-income households benefit from an increase in the quality of education without paying the cost. In both cases, the net fiscal benefit of middle-income households is positive and perverse redistribution is reduced.

5 Extensions and further discussion

Here we present three extensions of the baseline model – the introduction of tuition fees, of means-tested public grants, and of publicly subsidized loans.[29]

In all extensions, we assume that $\partial\alpha/\partial t_2 = 0$, which is consistent with previous empirical findings.

5.1 Tuition fees

In the baseline model, we assumed that the additional cost of sending a child into higher education did not include tuition fees. However, in many European countries tuition fees are part of the cost of attending public university. In some countries – such as in Germany or Switzerland – tuition fees represent a negligible amount usually covering administrative and regional fees only. In other countries – such as Italy, Spain, or the UK – tuition fees form a more substantial amount, which the universities can reinvest to enhance the quality of education. When tuition fees are sufficiently large, they create a significant financial barrier and disincentive to enrollment (e.g., Bietenbeck, Leibing, Marcus and Weinhardt, 2023; OECD, 2020). This disincentive is particularly stark for low-income households, who are more likely to suffer the higher costs of education (e.g., see Kelchtermans and Verboven, 2010; Declercq and Verboven, 2015).[30]

[29] A detailed discussion and mathematical proofs of all extensions can be found in the Online Appendix D. Moreover, we introduce further plausible extensions to the baseline model in Online Appendix D. While these further extensions highlight extra discussion of the concept of perverse redistribution, they do not change the general validity of the baseline model.

[30] Declercq and Verboven (2015) study the effect on an increase in tuition fees by 1000$ in Belgium, which reduced the participation rate by around 2 percentage points on average. However, among low-income students participation is reduced by about 3 percentage points. Similarly, Kelchtermans and Verboven (2010) use Finnish data to highlight that a uniform increase in tuition fees can reduce the total participation rate

Building on our baseline model, we set a one-time per-student lump-sum tuition payment, $\phi > 0$, to enroll a child in higher education. We assume that these tuition fees are entirely reinvested in the quality of higher education, such that the future post-graduation income rises to $\overline{w}(E + \phi)$. To isolate the effect of tuition fees on perverse redistribution, we further assume that no forms of financial help – such as means-tested grants or loans – are available.

If the level of pre-tax income, y_ϕ, such that $d_k(y_\phi) = \phi$, lies in the middle class, we can define a new (fourth) population group, that is $N^w_\phi = F(y_\phi) - F(\widehat{y}_0)$. This group N^w_ϕ represents the mass of households who pay taxes but who cannot send their children to university because they have an income below or equal to the tuition fees, ϕ. In contrast to the remaining households in N^w, those in N^w_ϕ cannot afford to send their children to university because the cost of tuition fees exceeds or is equal to their disposable income. Therefore, the mass of perverse redistribution is the sum of N^w_ϕ and N^w, corresponding to the sum of the red and green areas in Figure 8.

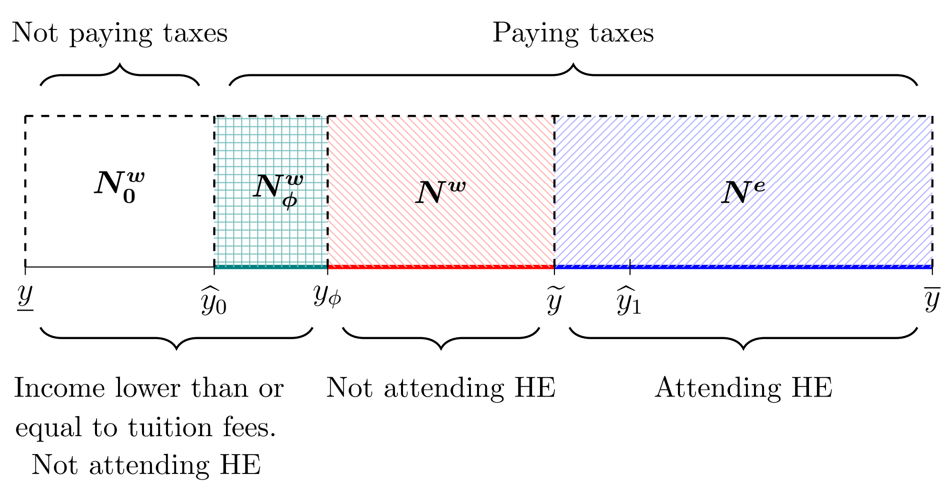

Figure 8: Perverse redistribution with tuition fees

Notes: The graph shows that the poorest part of the population, N^w_0, does not attend university and does not subsidize it. People in the middle N^w_ϕ (green area) do not attend university because their income is lower than the tuition fees but subsidize university for richer households. People in the middle N^w (red area) have an income higher than tuition fees, do not attend university, but do subsidize higher education for richer households. Richer households N^e (blue area) send their children to higher education and pay for it.

in higher education by about 1% for a 1000$ increase to about 7% for a 5000$ increase.

An increase in tax progressivity at the top of the income distribution then shifts the indifference threshold to the left, as in the baseline model:

$$\frac{\mathrm{d}\widetilde{y}}{\mathrm{d}t_2} = \frac{\delta p(s^*)\overline{w}'(E+\phi)\left(\alpha \frac{\partial T}{\partial t_2}\right)}{D} < 0 \tag{23}$$

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

Following an increase in t_2, a larger portion of middle-income households send their children to college and perverse redistribution declines (see Figure 9). Nonetheless, the mass of households with disposable incomes below or equal to the level of tuition fees, ϕ, that are unable to bear the private cost of their children's higher education remains unchanged. Thus, perverse redistribution will not fall below N^w_ϕ, unless $y_\phi \leq \widehat{y}_0$.

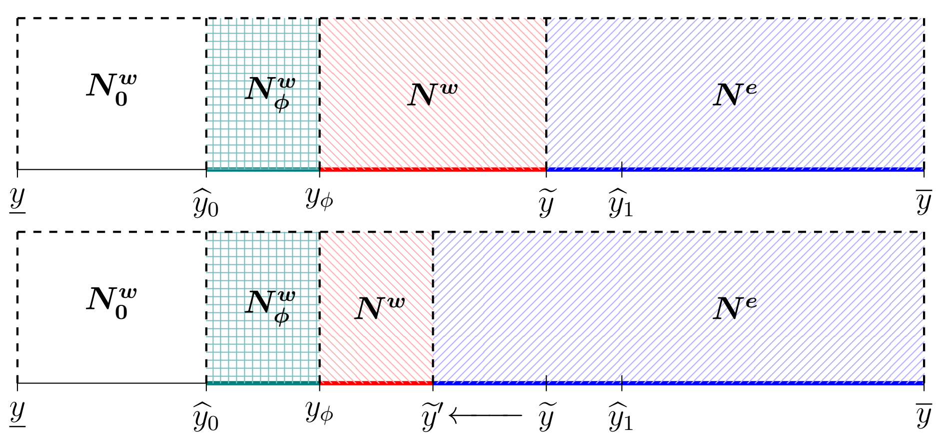

Figure 9: Perverse redistribution after an increase in progressivity

The introduction of tuition fees in the baseline model shows that while tax progressivity can reduce perverse redistribution the reduction is limited if tuition fees create a sufficiently large financial barrier for middle-income households. In fact, if tuition fees are large enough, perverse redistribution will persist even with highly progressive tax systems. If a public university system requires the payment of tuition fees, different forms of financial help may be needed to allow low- and middle-income households to access higher education. See Online Appendix D.2 for a more detailed discussion and mathematical proof.

We next discuss the introduction of two forms of financial help: means-tested public grants and publicly subsidized loans.

5.2 Means-Tested Public Grants

Almost all European-OECD countries offer public grants for students, based on students' (and their families') financial situation (Eurydice, 2020). The main characteristic of these means-tested grants is that they are monetary transfers offered on the condition of attending higher education and which do not have to be repaid by the student.[31]

We amend the baseline model by including public means-tested grants for students with parents below an income threshold $\widehat{y}_g < \widehat{y}_0$, such that the probability of succeeding in higher education becomes the result of parental investment and the receipt of the public grant. These means-tested grants are assumed to be targeted towards the poorest income group in the population such that $\widehat{y}_g < \widehat{y}_0$. This is in line with Hatsor and Zilcha (2021), who showed that targeting the poorest households for education subsidies has been shown to reduce the distortions in human capital accumulation.

The government allocates an amount of resources, $E_g = \alpha(1-\pi)T$, to finance the means-tested grants, where $1 - \pi \in (0, 1)$ is the portion of the education spending that goes to financing the means-tested grants. The amount of grant per student is defined by a continuously differentiable function, $g(E_g, y) : \mathbb{R}^2_{++} \to \mathbb{R}_+$, with $g(E_g, y) = 0$ if $y \geq \widehat{y}_g$, which increases in the total amount of resources allocated towards the grants, E_g, and decreases in the student's parental income, y. The financial grant allows eligible students to increase their probability of graduating from higher education even if their parents' economic support is equal to zero, so that $p(g) > 0$.[32] This aligns with findings in Modena, Rettore and Tanzi (2020), among others, which showed that means-tested grants can reduce university dropout and increase the probability of completing a higher education degree.

[31] One generous example is the means-tested public grant in Denmark is the State Educational Grant SU (*Statens Uddannelsesstøtte*). The Danish grants are only available to full-time students in recognized degrees, whose income does not exceed a specific threshold (approximately 30% of the average wage in 2020). Where students live with their parents, the grant considers parental income.

[32] Means-tested grants allow eligible households to choose $s^* = 0$ even if they decide to send their child to higher education, while $p'(0) = \infty$ cannot happen.

The introduction of means-tested grants in the baseline model shows that the households eligible for said grants will always prefer to send their children into higher education as the government subsidy remedies the lack of parental investment. Therefore, the total mass of households opting their children into higher education is composed of the poorest households who do not pay taxes but receive the means-tested grant, N_0^e, and the richest households who send their children into higher education and do pay taxes, N^e. As shown in Figure 10, even in the presence of means-tested grants, perverse redistribution may persist if the indifferent threshold is above the no-tax threshold $\widehat{y}_0$ and richer households are nevertheless more likely to send their children into higher education. However, in the case of means-tested grants, perverse redistribution decreases as a larger mass of poorer households enroll their children in higher education. Moreover, financial aid, such as means-tested grants, can eliminate the perverse redistribution caused by the introduction of tuition fees in Section 5.2 if the means test is set such that $\widehat{y}_g \geq y_\phi$ and the per-capita grant is sufficiently generous. In practice, this scenario reflects publicly financed scholarships and tuition waivers for low-income households.

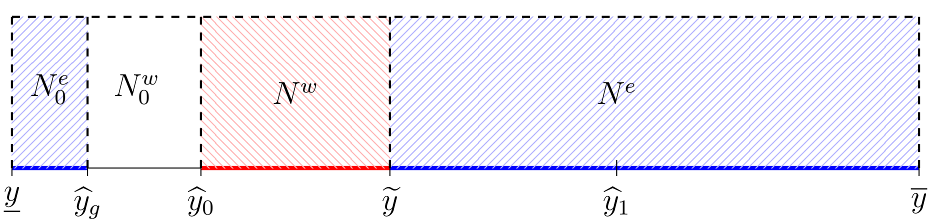

Figure 10: Perverse redistribution with public means-tested grants

Notes: The figure shows that a portion of the poorest part of the population, N_0^e, opts into higher education as they are eligible of public means-tested grants.

See Online Appendix D.3 for a more detailed discussion and proof of the introduction of public means-tested grants.

5.3 Publicly Subsidized Loans

An alternative to public means-tested grants are publicly subsidized student loans – loans that must be repaid, in part or entirety, with reduced or zero interest rates, which can include a parental income test (Eurydice, 2020). This approach to subsidizing students in higher education is less frequently used in Europe than means-tested grants, with the exception of Germany and the UK. The UK student loans are not parental-income contingent and are due to be repaid once the student's (graduate's) income exceeds a minimum threshold. Moreover, UK student loans are charged between 4.3% and 7.3% interest, depending on the loan plan in 2024.The German BAföG (Federal Training Assistance Act) applies a parental income test, awards half of the financial support a grant which does not have to be repaid and the other half as an interest-free loan.[33]

We model publicly subsidized loans as a combination of the loans applied in the UK and Germany. Similar to the public means-tested grants, a publicly subsidized loan is a government subsidy to the student conditional on their university attendance. However, the loan must be repaid from future income. We assume that the amount of resources in education is split into funding going directly to improve the quality of education $E_q = \alpha\pi T$ and funding for publicly subsidised loans $E_l = \alpha(1-\pi)T$, where $1-\pi \in (0,1)$ is the share of resources in higher education invested for student loans. Thus, the amount of per-student public loans is defined by the continuously differentiable function, $l(E_l, y) : \mathbb{R}^2_{++} \to \mathbb{R}_+$, with $l(E_l, y) = 0$ if $y \geq \widehat{y}_l$, which is increasing in the total amount of resources invested by the government, E_l, and decreasing in the student's parental income, y. In other words, we assume that the publicly subsidized loans are income-contingent and decrease with household income. Similar to the means-tested grants, a household is eligible for a publicly subsidized

[33] While Cigno and Luporini (2009) show that student loans are "sub-optimal" for efficiency and redistribution, even if student loans are income-contingent, Eckwert and Zilcha (2014) show that income-contingent student loans can decrease both inequality and underinvestment in human capital. Moreover, Del Rey and Racionero (2010) find that the implementation of income-contingent student loans shifts the optimal level of higher education uptake as long as the direct financial costs and any forgone earnings are covered. Finally, Van Long (2019) demonstrate that income-contingent loans satisfy the efficiency and equity properties if they include a "piecewise-linear repayment schedule".

student loan only if $\widehat{y}_l < \widehat{y}_0$. In contrast to the means-tested grants, the student loan must be repaid conditional to having a future income strictly greater than $\underline{w}$, similar to the loan conditions applied in the UK.[34] If a student graduates, they must repay part of the loan ml with $m \in (0,1]$ at an interest rate $r \in [0,1)$ so that they repay an amount equal to $m(1+r)l$. As before, incomes with a higher education degree are strictly greater than incomes without a degree, even with the loan repayment.

$$\overline{w}(E_q) - m(1+r)l > \underline{w} > 0$$

Similar to the means-tested grant, if a poor individual has access to the loan, then $V^e > V^w$, even if parents invest $s^* = 0$. Thus, results on perverse redistribution are similar to the results in Figure 10 for means-tested public grants and lead to similar implications. We relegate a more complete discussion and mathematical proof of publicly subsidized loans to Online Appendix D.4.

6 Concluding remarks

Starting from stylised facts from Europe, this paper develops a theoretical model to investigate the disproportionate 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 lower-income families. Although these tax systems have increasing marginal tax rates across the income distribution, they also present a disproportionate increase in fiscal cost for those with lower incomes compared to those with higher incomes.

[34]This assumption is similar to other theoretical economic models of higher education finance (e.g., see Del Rey and Racionero, 2010). We do not consider the scenario where loans will still need to be repaid if a student fails to graduate, as is the case in the U.S. or when loans are provided through banks and guaranteed by the state. The effect of such loans would be ambiguous if the student is forced to repay at least part of the loan even when they only earn future income $\underline{w}$. The ambiguity stems from the households' general risk aversion and the significant heterogeneity across Europe repayment requirements.

The model shows that such 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 referred 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 on three empirical realities: (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 at the top of the income distribution; (iii) countries with more progressive tax systems have a lower perverse redistribution in higher education. The baseline model integrates these empirical findings to establish the relationship between parental income, higher education attendance, and taxation.

The thorough 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 subsidized loans or government-sponsored grants, just to name a few.

The baseline 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.

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A Derivation: Maximization problem

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

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

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:

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

We compute the FOCs to find the interior optimal solution, s^*:

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

where $\overline{w}(E) - \underline{w} > 0$ is the wage premium of being a graduate with respect to being a non-graduate. The SOCs computed at s^* are negative, thus $s^* > 0$ is the unique optimal value solving (A.2):

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

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

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

B Household tax liability and total tax revenue

The tax function 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 (5) 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 because of T1–T4, this implies that the total tax revenue for each interval of (5) is positive, such that:

$$T = \int_{\underline{y}}^{\bar{y}} T_i(y) f(y) dy > 0 \tag{B.2}$$

C Disposable income function

Following (5), we can write the disposable income function of an individual household i as:

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

The function (C.1) is continuous, continuously differentiable in y and strictly increasing in y. Indeed, the first derivative by y of (C.1) is continuous and strictly increasing:

$$d_k'(y) = \begin{cases} 1 & \underline{y} \leq y \leq \widehat{y}_0 \\ (1-t_1) + \tau_1'(y)t_1 & \widehat{y}_0 < y < \widehat{y}_0 + \epsilon \\ (1-t_1) & \widehat{y}_0 + \epsilon \leq y \leq \widehat{y}_1 \\ (1-t_2) + \tau_2'(y)(t_2-t_1) & \widehat{y}_1 < y < \widehat{y}_1 + \epsilon \\ (1-t_2) & y \geq \widehat{y}_1 + \epsilon \end{cases} \tag{C.2}$$

D Proof: Lemmas

D.1 Lemma 1

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

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

The function (D.1) is continuously differentiable in the pre-tax income y. Differentiating by y, one gets:

$$\frac{\partial \Delta(d_k(y))}{\partial y} = d_k'(y)[u'(d_k(y)) - u'(d_k(y) - s^*)] < 0, \tag{D.2}$$

The Derivative (D.2) is strictly decreasing because: (i) $[u'(d_k(y)) - u'(d_k(y) - s^*)] < 0$, as $u(\cdot)$ is continuous, strictly increasing and strictly concave; (ii) $d_k'(y)$ is strictly increasing in y.

If $\Delta(d_0(\underline{y})) \leq 0$, then, because $\Delta(d_k(y))$ is continuous and strictly decreasing in y, $\Delta(d_k(y)) < 0$ for any $y \in (\underline{y}, \overline{y}]$. Thus, $\Delta(d_0(\underline{y})) = 0$, implying $\underline{y} = \widetilde{y}$. In this case, everyone at least weakly prefers education to work.

If $\Delta(d_0(\underline{y})) > 0$, then we can have either $\Delta(d_2(\overline{y})) \leq 0$ or $\Delta(d_2(\overline{y})) > 0$. If $\Delta(d_2(\overline{y})) \leq 0$, because $\Delta(d_k(y))$ is continuous and strictly decreasing in y, by the intermediate value theorem, $\exists! \, \widetilde{y} \in (\underline{y}, \overline{y}]$ such that $\Delta(d_k(\widetilde{y})) = 0$. It follows that if $y \leq \widetilde{y}$, then $V^w \geq V^e$; If $y > \widetilde{y}$, then $V^w < V^e$. If $\Delta(d_2(\overline{y})) > 0$ working is always the best option and there is no indifference threshold in $[\underline{y}, \overline{y}]$. Thus, if a threshold $\widetilde{y} \in [\underline{y}, \overline{y}]$ exists, it must be unique.

D.2 Lemma 2

Let us 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^*:

$$u(d_k(\widetilde{y})) - u(d_k(\widetilde{y}) - s^*) - \delta p(s^*)[\overline{w}(E) - \underline{w}] = 0 \tag{D.3}$$

In order to study how the variables α and $\underline{w}$ affect the threshold $\widetilde{y}$ we use the implicit function theorem. Let's define the derivative in (D.2) 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 $\underline{w}$, obtaining the results of Lemma 2:

$$\frac{\mathrm{d}\widetilde{y}}{\mathrm{d}\alpha} = \left[\frac{1}{D}\right] [T\delta p(s^*)\overline{w}'(E)] < 0, \tag{D.4}$$

$$\frac{\mathrm{d}\widetilde{y}}{\mathrm{d}\underline{w}} = \left[-\frac{\delta p(s^*)}{D}\right] > 0, \tag{D.5}$$

E Proof: Progressive taxation

We obtain (8) by applying the implicit function theorem to the indifferent individual. Consider the indifferent individual household such that $\Delta(d_1(\widetilde{y})) = V^w - V^e = 0$. To simplify the notation, we define the optimal subsidy simply as s^*:

$$u(d_k(\widetilde{y})) - u(d_k(\widetilde{y}) - s^*) - \delta p(s^*)[\overline{w}(E) - \underline{w}] = 0 \tag{E.1}$$

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

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

F Proof: Local progressivity

F.1 Increase in t_1

Consider the two measures for tax progressivity for a household i in the middle- and rich-income classes. They can be written as:

$$\pi_1(\mathbf{t}) = \frac{t_1 - T_1(y_i, \mathbf{t})/y_i}{1 - T_1(y_i, \mathbf{t})/y_i}, \quad \pi_2(\mathbf{t}) = \frac{t_2 - T_2(y_i, \mathbf{t})/y_i}{1 - T_2(y_i, \mathbf{t})/y_i} \tag{F.3}$$

whereby y_i is the income of household i. If i is in the middle class, then the derivative of the average tax rate, $T_1(y_i, \mathbf{t})/y_i$ with respect to t_1 is:

$$\frac{\partial\left[T_1(y_i, \mathbf{t})/y_i\right]}{\partial t_1} = \begin{cases} 1 - \frac{\widehat{y}_0}{y_i} - \frac{\tau_1(y_i)}{y_i} & \text{if } y \in (\widehat{y}_0, \widehat{y}_0 + \epsilon) \\ 1 - \frac{\widehat{y}_0}{y_i} - \frac{\tau_1(\widehat{y}_0+\epsilon)}{y_i} & \text{if } y \in [\widehat{y}_0 + \epsilon, \widehat{y}_1] \end{cases} \tag{F.4}$$

which is always strictly positive by property T4 of the tax function (5). Moreover, since (F.4) is bounded from above at 1, the following inequality must hold:

$$\frac{\partial\left[T_1(y_i, \mathbf{t})/y_i\right]}{\partial t_1} < 1 \tag{F.5}$$

If i is in the rich income class, then the derivative of the average tax rate, $T_2(y_i, \mathbf{t})/y_i$ with respect to t_1 is:

$$\frac{\partial\left[T_2(y_i, \mathbf{t})/y_i\right]}{\partial t_1} = \begin{cases} \frac{\widehat{y}_1 - \widehat{y}_0 + \tau_2(y_i) - \tau_1(\widehat{y}_0+\epsilon)}{y_i} & \text{if } y \in (\widehat{y}_1, \widehat{y}_1 + \epsilon) \\ \frac{\widehat{y}_1 - \widehat{y}_0 + \tau_2(\widehat{y}_0+\epsilon) - \tau_1(\widehat{y}_0+\epsilon)}{y_i} & \text{if } y \in [\widehat{y}_1 + \epsilon, \infty) \end{cases} \tag{F.6}$$

which is always strictly positive by property T4 of the tax function (5).

Applying the quotient rule to calculate the derivative of the progressivity measure (F.3) with respect to t_1 if i is in the middle class, we get:

$$\begin{aligned} \frac{\partial \pi_1(\mathbf{t})}{\partial t_1} &= \frac{1}{\left(1 - T_1(y_i, \mathbf{t})/y_i\right)^2}\left[1 - \frac{T_1(y_i, \mathbf{t})}{y_i} - \frac{\partial\left[T_1(y_i, \mathbf{t})/y_i\right]}{\partial t_1}(1 - t_1)\right] \\ &= \frac{1}{\left(1 - T_1(y_i, \mathbf{t})/y_i\right)^2}\left[1 - \frac{\partial\left[T_1(y_i, \mathbf{t})/y_i\right]}{\partial t_1}\right] > 0, \end{aligned} \tag{F.7}$$

whereby (F.7) holds because of condition (F.5) and because:

$$\frac{T_1(y_i, \mathbf{t})}{y_i} = \frac{\partial\left[T_1(y_i, \mathbf{t})/y_i\right]}{\partial t_1} t_1$$

Applying the quotient rule to calculate the derivative of the progressivity measure (F.3) with respect to t_1 for i if they are in the highest income class, we get:

$$\frac{\partial\pi_2(\mathbf{t})}{\partial t_1} = \frac{1}{(1-T_2(y_i,\mathbf{t})/y_i)^2}\left[\frac{\partial[T_2(y_i,\mathbf{t})/y_i]}{\partial t_1}\left(\frac{T_2(y_i,\mathbf{t})}{y_i}-1\right)+\frac{\partial[T_2(y_i,\mathbf{t})/y_i]}{\partial t_1}\left(t_2-\frac{T_2(y_i,\mathbf{t})}{y_i}\right)\right]$$

$$= -\frac{\partial\left[T_2(y_i,\mathbf{t})/y_i\right]}{\partial t_1}\left[\frac{1-t_2}{(1-T_2(y_i,\mathbf{t})/y_i)^2}\right] < 0 \tag{F.8}$$

F.2 Increase in t_2

The derivative of $\partial\pi_1(\mathbf{t})$ by t_2 is straightforward, as households in the middle class do not pay t_2:

$$\frac{\partial\pi_1(\mathbf{t})}{\partial t_2} = 0 \tag{F.9}$$

Applying the quotient rule to calculate the derivative of the progressivity measure $\pi_2(\mathbf{t})$ with respect to t_2 for an agent i in the rich income class, we get:

$$\frac{\partial\pi_2(\mathbf{t})}{\partial t_2} = \frac{1}{(1-T_2(y_i,\mathbf{t})/y_i)^2}\left[\left(1-\frac{\partial[T_2(y_i,\mathbf{t})/y_i]}{\partial t_2}\right)\left(1-\frac{T_2(y_i,\mathbf{t})}{y_i}\right)+\frac{\partial[T_2(y_i,\mathbf{t})/y_i]}{\partial t_2}\left(t_2-\frac{T_2(y_i,\mathbf{t})}{y_i}\right)\right]$$

$$= \frac{1}{(1-T_2(y_i,\mathbf{t})/y_i)^2}\underbrace{\left[1-\frac{T_2(y_i,\mathbf{t})}{y_i}-\frac{\partial\left[T_2(y_i,\mathbf{t})/y_i\right]}{\partial t_2}(1-t_2)\right]}_{\Theta} > 0, \tag{F.10}$$

which can be proven to be positive. To do so, we explore the terms in the square brackets in (F.10) next.

$$\frac{T_2(y_i,\mathbf{t})}{y_i} = \begin{cases} \frac{t_1(\widehat{y}_1-\widehat{y}_0)}{y_i}+t_2(1-\frac{\widehat{y}_1}{y_i})+\frac{\tau_1(\widehat{y}_0+\epsilon)(t_0-t_1)}{y_i}+\frac{\tau_2(y_i)(t_1-t_2)}{y_i} & \text{if } y_i\in(\widehat{y}_1,\widehat{y}_1+\epsilon) \\ \frac{t_1(\widehat{y}_1-\widehat{y}_0)}{y_i}+t_2(1-\frac{\widehat{y}_1}{y_i})+\frac{\tau_1(\widehat{y}_0+\epsilon)(t_0-t_1)}{y_i}+\frac{\tau_2(\widehat{y}_1+\epsilon)(t_1-t_2)}{y_i} & \text{if } y_i\in[\widehat{y}_1+\epsilon,\infty) \end{cases} \tag{F.11}$$

$$\frac{\partial \left[T_2(y_i, \mathbf{t})/y_i\right]}{\partial t_2}(1-t_2) = \begin{cases} \left(1 - \frac{\widehat{y}_1}{y_1} - \frac{\tau_2(y_i)}{y_i}\right)(1-t_2) & \text{if } y \in (\widehat{y}_1, \widehat{y}_1 + \epsilon) \\ \left(1 - \frac{\widehat{y}_1}{y_1} - \frac{\tau_2(\widehat{y}_0+\epsilon)}{y_i}\right)(1-t_2) & \text{if } y \in [\widehat{y}_1 + \epsilon, \infty) \end{cases} \tag{F.12}$$

Let us consider the terms in parenthesis, defined as Θ, in (F.10). Then, remembering that $t_0 < t_1$, if $y_i \in (\widehat{y}_1, \widehat{y}_1 + \epsilon)$:

$$\begin{aligned}
[\Theta] = 1 &- \frac{t_1\left(\widehat{y}_1 - \widehat{y}_0\right)}{y_i} - t_2\left(1 - \frac{\widehat{y}_1}{y_i}\right) - \frac{\tau_1(\widehat{y}_0+\epsilon)(t_0-t_1)}{y_i} - \frac{\tau_2(y_i)(t_1-t_2)}{y_i} \\
&- \left(1 - \frac{\widehat{y}_1}{y_1} - \frac{\tau_2(y_i)}{y_i}\right) + t_2\left(1 - \frac{\widehat{y}_1}{y_i}\right) - \frac{\tau_2(y_i)t_2}{y_i}, \\
= &- \frac{t_1\left(\widehat{y}_1 - \widehat{y}_0\right)}{y_i} - \frac{\tau_1(\widehat{y}_0+\epsilon)(t_0-t_1)}{y_i} - \frac{\tau_2(y_i)t_1}{y_i} + \frac{\widehat{y}_1}{y_1} + \frac{\tau_2(y_i)}{y_i}, \\
= &\frac{\widehat{y}_0 t_1}{y_i} - \frac{\tau_1(\widehat{y}_0+\epsilon)(t_0-t_1)}{y_i} + \frac{\widehat{y}_1}{y_1}(1-t_1) + \frac{\tau_2(y_i)(1-t_1)}{y_i} > 0
\end{aligned} \tag{F.13}$$

Remembering that $t_0 < t_1$, if $y \in [\widehat{y}_1 + \epsilon, \infty)$, then $[\Theta]$ becomes:

$$\begin{aligned}
[\Theta] = 1 &- \frac{t_1\left(\widehat{y}_1 - \widehat{y}_0\right)}{y_i} - t_2\left(1 - \frac{\widehat{y}_1}{y_i}\right) - \frac{\tau_1(\widehat{y}_0+\epsilon)(t_0-t_1)}{y_i} - \frac{\tau_2(\widehat{y}_0+\epsilon)(t_1-t_2)}{y_i} \\
&- \left(1 - \frac{\widehat{y}_1}{y_1} - \frac{\tau_2(\widehat{y}_0+\epsilon)}{y_i}\right) + t_2\left(1 - \frac{\widehat{y}_1}{y_i}\right) - \frac{\tau_2(\widehat{y}_0+\epsilon)t_2}{y_i}, \\
= &- \frac{t_1\left(\widehat{y}_1 - \widehat{y}_0\right)}{y_i} - \frac{\tau_1(\widehat{y}_0+\epsilon)(t_0-t_1)}{y_i} - \frac{\tau_2(\widehat{y}_0+\epsilon)t_1}{y_i} + \frac{\widehat{y}_1}{y_1} + \frac{\tau_2(\widehat{y}_0+\epsilon)}{y_i}, \\
= &\frac{\widehat{y}_0 t_1}{y_i} - \frac{\tau_1(\widehat{y}_0+\epsilon)(t_0-t_1)}{y_i} + \frac{\widehat{y}_1}{y_1}(1-t_1) + \frac{\tau_2(\widehat{y}_0+\epsilon)(1-t_1)}{y_i} > 0
\end{aligned} \tag{F.14}$$

Thus, because (F.14) and (F.13) are always positive, it must be true that derivative (F.10) is positive.

G Data

We draw on several data sources for our stylized facts: (i) household-level microdata from the (2022)Luxembourg Income Study (LIS) (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 calculations from OECD (2022c) to identify local tax progressivities at different points along the income distribution and households above the zero-tax threshold $\widehat{y}_0$, (iii) country-level data on higher education enrollment from World Bank (2022), higher educational spending from Eurostat (2022b), and various macroeconomic variables from World Bank (2022), (OECD, 2022a), and (Eurostat, 2022a).

G.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.[35] 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 and their partner, if any; thus, parental income is the sum of the income of the head of the household 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 head of the household's or their partner's income is missing, rather than imposing a lower total parental income. Student-workers are also excluded from the sample as they might reduce or do not ask for financial help to their parents.

[35]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.

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 higher education and advanced non-higher (generally, post-secondary) education, this inclusion is nevertheless necessary as the data specify neither the current type of education nor the type of upper-secondary school that has been completed.[36] The household income is also adjusted by using the 2017 USD PPPs deflators as provided by the Luxembourg Income Study.

G.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.

G.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 higher education, the unemployment rate, the

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

inflation rate, gross national income per capita, the percentage of people living in urban area, and the gross graduation rate from first degree programs (at ISCED 6 and 7) from World Bank (2022). We rely on Eurostat for data on higher education expenditures as a percentage of GDP (Eurostat, 2022b) and the employment rate of individuals with upper secondary and post-secondary (non-higher) education (Eurostat, 2022a). We also include countries' long-term interest rate from OECD (2022a) and general government spending from OECD (2022b).

To be able to hold the overall level of redistribution built into the tax and welfare system constant, we estimate the Reynolds-Smolensky index 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 – although we lose a few observations due to data availability.[37]

H Empirical evidence

H.1 Higher education enrollment and income tax progressivity

The stylized facts present the relationship between the enrollment rate in higher education and tax progressivity. We regress the gross enrollment rate in higher 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

[37]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 higher education expenditure in Eurostat (2022b).

(OECD, 2022c). We estimate the following regression:

$$\text{Gross enrollment}_{c,t} = \beta_0 + \beta_1 \pi_{100\%APW,c,t-1} + \gamma' X_{c,t-1} + \theta_c + \theta_t + \epsilon_{c,t}, \tag{H.15}$$

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. We use lagged explanatory variables to account for a delayed reaction in the enrollment rate. In this way, we also try to mitigate the possibility of reverse causality.

Table 3: Regression: Gross enrollment in higher 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**
	(1.402)	(1.301)	(1.137)	(1.315)	(1.430)	(1.144)
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: Columns (1)-(6) report the gross enrollment in higher education regressed on the lagged income tax progressivity computed at the average production worker's wage (1), and lagged control variables such as higher education expenditures as a percentage of GDP (2), natural log of gross national income per capita, general government expenditure, Reynolds-Smolensky index, the average annual unemployment rate, the annual inflation rate, the long-term interest rate (3), the percentage of people living in urban area (4), the gross graduation rate from first degree programs (at ISCED 6 and 7) (5) and the employment rate of individuals with upper secondary and post-secondary (non-higher) education (6). Country-level clustered bootstrap standard errors (1000 replications) 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. Full results are reported in the Online Appendix.

Table 3 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 higher education spending, which has no significant relationship on 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.

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 higher education and the additional cost that is required to attend.Column (5) includes the lagged gross graduation rate . Column (6) includes the lagged employment rate of individuals with upper secondary and post-secondary (non-tertiary) education.

H.2 Parental income gradient, local progressivity, and perverse redistribution

In Table 1, we use microdata and we regress the binary choice to attend higher education on parental incomes quintile dummy variables to capture the negative gradient and interact these quintile dummies with the local progressivity measures. Pooling all available LIS microdata samples and adjusting the sampling weights, we estimate the following linear probability model:

$$\begin{aligned} HEd_{i,c,t} &= a_0 + \alpha' \text{Parental Income Quintile}_{i,c,t} + \beta' \pi_{\%APW,c,t-1} \\ &+ \gamma' \text{Parental Income Quintile}_{i,c,t} \times \pi_{\%APW,c,t-1} + \eta' X_{c,t-1} + \zeta' Z_{i,c,t} \\ &+ \theta_c + \theta_t + \theta_{cohort} + \theta_c * cohort_{i,c,t} + \epsilon_{i,c,t}, \end{aligned} \tag{H.16}$$

where $HEd_{i,c,t}$ is a binary indicator variable equal to one if a child in household i in country c in year t attends higher education, Parental Income Quintile$_{i,c,t}$ is a set of dummy variables representing household i's income quintile, excluding the highest quintile, $\pi_{\%APW,c,t-1}$ 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 higher 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.[38]

Table 4 presents the results of (H.16) using measures of local tax progressivity at different multiples of the average productive wage. The correlation between the probability of a household's child attending higher education and the income quintiles, with respect to the richest quintile Parental Income Quintile$_5$, 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 into higher education compared to the highest quintile decreases.

These results are robust to adding aggregate and individual controls, even if the sample size reduces due to data availability. Table 4 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 (H.16), we calculate the marginal effect of the interactions between tax progressivity and income quintiles on the probability of going into higher education by income quintiles. We present these marginal effects in Table 5. Recall that the reference category is the highest income quintile, Parental Income Quintile$_5$.

[38] 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. In the Online Appendix B, we run the same regression without Austria, Germany and Switzerland as those countries have high school tracks that can allow directly go into tertiary education (but only into advanced non-tertiary education) after the high school graduation.

Table 4: Regression: Parental income gradient and tax progressivity

Variables	Probability of university attendance (1)	(2)	(3)
Parental Income Quintile$_1$	-0.191***	-0.191***	-0.103***
	(0.009)	(0.009)	(0.015)
Parental Income Quintile$_2$	-0.154***	-0.151***	-0.093***
	(0.008)	(0.008)	(0.012)
Parental Income Quintile$_3$	-0.131***	-0.130***	-0.075***
	(0.008)	(0.008)	(0.011)
Parental Income Quintile$_4$	-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)
Parental Income Quintile$\times\pi_{\%APW,t-1}$	✓	✓	✓
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

Notes: The table shows the parental income gradient in higher education interacted with three measures of progressivity (67%, 100% and 167% of the APW): without controls (1), with aggregate controls (2) and with aggregate and individuals controls (3). Household-level clustered standard errors in parentheses. ***, **, and * indicate levels of statistical significance at 1, 5, and 10 percent, respectively.

Table 5: 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*		
Parental Income Quintile_1	−0.028**	−0.015	0.029*
	(0.013)	(0.016)	(0.015)
Parental Income Quintile_2	−0.025**	0.009	−0.004
	(0.012)	(0.015)	(0.014)
Parental Income Quintile_3	−0.008	0.013	−0.024*
	(0.012)	(0.014)	(0.013)
Parental Income Quintile_4	−0.014	−0.004	−0.009
	(0.012)	(0.015)	(0.014)
B	*Aggregate Controls*		
Parental Income Quintile_1	−0.029**	−0.028*	0.028*
	(0.013)	(0.016)	(0.015)
Parental Income Quintile_2	−0.026**	−0.003	−0.007
	(0.013)	(0.015)	(0.015)
Parental Income Quintile_3	−0.010	0.001	−0.026*
	(0.013)	(0.014)	(0.014)
Parental Income Quintile_4	−0.016	−0.017	−0.011
	(0.013)	(0.015)	(0.014)
C	*Aggregate + Individual Controls*		
Parental Income Quintile_1	−0.044**	−0.007	0.088***
	(0.017)	(0.021)	(0.026)
Parental Income Quintile_2	−0.034**	0.002	0.044*
	(0.015)	(0.017)	(0.023)
Parental Income Quintile_3	−0.010	−0.003	0.013
	(0.015)	(0.017)	(0.023)
Parental Income Quintile_4	−0.021	−0.010	0.014
	(0.014)	(0.015)	(0.023)

Notes: The table shows the marginal effect of the interaction between parental income quintiles and three measures of progressivity (Columns (1)-(3) are 67%, 100% and 167% of the APW, respectively). Panel A represents the marginal effects of the regression without controls, Panel B with aggregate controls, and Panel C with aggregate and individuals controls. Household-level clustered standard errors in parentheses. ***, **, and * indicate levels of statistical significance at 1, 5, and 10 percent, respectively.

Exploring the estimates of the local tax progressivity and the parental income quintiles, in Panel A (based on Table 4, 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, Parental Income Quintile_1 and Parental Income Quintile_2. We argue that this result occurs because 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 higher education higher than the marginal fiscal cost, they will be less likely to send their children into 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. Column (3) shows that an increase in local progressivity at 167% of APW increases the first household quintile's propensity to send their children to university, but the effect is dampened significantly in the third quintile, Parental Income Quintile_3.

Panel B presents the marginal effects when we include aggregate controls in (H.16) (based on Table 4, second column). The aggregate controls include lagged general governmental spending and lagged government spending in higher 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. Panel B presents similar results to Panel A, in terms of sign, statistical significance, and size of the effect. The only difference is that the probability of sending children into 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 is not robust to the inclusion of additional controls.

In Panel C (based on Table 4, third column), we observe the marginal effects when we include both aggregate and individual controls in (H.16). 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 Panel C are similar to the results in Panel 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, Parental Income Quintile_1 and Parental Income Quintile_2. Similar to Panel 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 Panel C shows that the progressivity at 167% of APW is positively and significantly (at the 1% level) correlated with the probability of a household in the first quintile, Parental Income Quintile_1, and in the second quintile, Parental Income Quintile_2 (at the 10% level), sending their children into higher education. Column (3) confirms that the probability of the poorest households sending their children into higher education increases when the local progressivity of richer households is increased.

The marginal effects reported in Table 5 highlight 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 into higher education, even if they are paying income taxes, decreases. This represents a reduction in the perverse redistribution in higher 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 enrollment of individuals from poorer households, if the increase in progressivity occurs in the poorest income classes.