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Tax Distortion, Countervailing Subsidies and Income Redistribution

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Tax Distortion, Countervailing Subsidies and Income Redistribution

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Abstract

A persistent controversy in the economics of higher education is the distributional consequences of tuition-fee subsidies. There are two points at issue. First, subsidies affect income distribution between *rich* and *poor* households, analyzed by cross-sectional studies. Second, there may also be long-run effects on income distribution, i.e., toward graduates who benefited from public higher education and away from non-graduates who contributed their taxes to finance these subsidies. This paper focuses on whether it is in the interest of the non-graduates to subsidize investments in higher education. We show that subsidies to higher education may be Pareto-superior, benefiting all agents rather than the minority of graduates alone. However, it is also likely that efficiency gains cannot be distributed among all agents if a large fraction of agents uses subsidies to reap windfall gains. Windfall gains occur because of the unavailability of agents' endowments and are identified as the main cause of unwanted distributional effects between graduates and non-graduates. Nevertheless, it would be possible to establish a voluntary graduate tax that works as a revelation mechanism and, consequently, breaks down the equity-efficiency trade-off.

Keywords: tax distortion, voluntary graduate tax, income redistribution

JEL Classification: H21, H22, I22

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1 Introduction

It has become part of the conventional wisdom in the economics of education that subsidies to higher education have a regressive distributional effect. Given that relatively more children from wealthier families enrol in higher education, many economists assume that these subsidies to higher education have an unwanted distributional impact. *The nurse is being taxed to support the higher education of the dentist's son*, as it is sometimes bluntly put.

The huge empirical literature on that issue, however, provides at most only scant evidence for this thesis. The debate started with the work of Pechman (1970), which contradicted the results provided by Hansen and Weisbrod (1969a). This disputation provoked a debate on the distributional effect that lasted nearly ten years, the "Hansen-Weisbrod-Pechman" debate (see Hansen and Weisbrod (1969a,b, 1971, 1978), Pechman (1970); Hartmann (1970); McGuire (1976); Conlisk (1977); Cohn et al. (1970)).

Although empirical evidence is at best inconclusive,¹ international research initiatives and textbooks often refer to the thesis of a regressive distributional impact, and many models take it for granted. Blaug (1982) was certainly right to ask in surprise "How is it possible that so many commentators keep repeating the Hansen-Weisbrod results as if they were gospel truths?"

It is interesting to note that almost all empirical studies are cross-sectional analyses. As such an analysis provides a snapshot of distributional impact at particular points in time, the studies can be criticized for ignoring the longitudinal dimension of the point at issue. This critique also applies to the distributional effect of higher-education subsidies (see, e.g., McGuire (1976); Bowman et al. (1986); Pechman (1972); Beckmann (2003)). In analyzing that effect, we have to distinguish between an analysis of children from various household types, and an analysis of educated and non-educated individuals throughout their lives. For the former, a cross-sectional examination is the only alternative; for the latter, the related literature uses a long-run analysis.²

The literature covering the long-run approach is inconclusive. For example, building on Grüske (1994), García-Peñalosa and Wälde (2000) argue that "[i]f the average tax payer has a lower lifetime income than the average university graduate [...], a subsidy to higher education financed from general taxation implies reverse lifetime redistribution, i.e. redistribution from the poor to the rich". Although the paper provides several very enlightening results, this approach can be critically assessed with respect to two aspects. First, it does not distinguish sufficiently between the change of distribution between *rich* and *poor*, and that between graduates and non-graduates throughout their lives. Second, Pareto-superior subsidies can also be identified as "regressive" using this approach,³

¹See Barbaro (2003) for a recent survey of the empirical literature

²See, e.g., (Atkinson and Stiglitz, 1985, p. 263) who argue that "[i]n empirical work, the unit of analysis is typically taken as the nuclear family or household, and the distribution based on all such units in existence at a particular date. On the other hand, the lifetime approach seems more relevant to *individuals*. A person may belong to several different families during his life, and it makes little sense to regard him as changing identity on leaving or entering a nuclear family".

³In a subsection, García-Peñalosa and Wälde (2000) also ask whether a particular individual is better or worse off if education is subsidized. They point out that it might be that all agents are better off after a subsidy has been introduced. Unfortunately, they do not compare the two approaches, nor do they demonstrate the circumstances under which this is possible. This is a gap that this present paper wishes to bridge.

as shown in Barbaro (2004) (for further discussions of this approach, see also Sturn and Wohlfahrt (1999, 2000)).

A second string is directly concerned with Pareto-superiority of subsidies to higher education. For example, Johnson (1984); Poutvaara and Kannianen (2000); Dur and Teulings (2003, 2004) and Bovenberg and Jacobs (2001) argue that, at least in closed economies, subsidies to higher education may be to the mutual advantage of both graduates and non-graduates. Johnson (1984) argues that unskilled individuals may also prefer a tax-financed subsidy to higher education, because they reap part of the gains due to complementarities between skilled and unskilled labor. The specification of the production process of the economy is that aggregate output is a linear-homogenous function of three types of labor (high-skilled, middle-skilled, and low-skilled labor). This specification implies that complementarities exist so that the low-skilled group may also benefit, although indirectly, from the subsidies. If this is the case, the higher-education subsidies are *equitable*, where Johnson defines *equity* as follows: "The distribution of the burden of educational costs may be said to be equitable if both groups want the same size at the prevailing level of s . If the size is also efficient, this value of s is positive so long as low-skilled labor is not very much more complementary with medium- than which high-skilled labor", where s denotes a certain fraction of the total social costs of the higher-education system.

This viewpoint is interesting because it highlights a simultaneous effect of efficiency-enhancing subsidies on both equity and efficiency. If human capital is seen as an *engine of economic growth*, or if subsidies to higher education raise the human-capital stock to an efficient level or compensate for existing inefficiencies, it seems possible that those who finance the subsidies through their taxes can demand compensation from those who benefit from the subsidies directly during their lifetime.⁴ If such compensation is possible, the goals of efficiency and equity can be in harmony, i.e. subsidies to higher education are Pareto-superior. Otherwise, there is a trade-off.

Poutvaara and Kannianen (2000) also deal with this argument. The main purpose of their paper is to study the possibility of a voluntary *social contract* benefiting all groups instead of a voting equilibrium where the minority (i.e. the high-skilled agents) are worse off. The distribution of the gains created by such a *social contract* depends on relative power, where the groups are engaged in Nash bargaining. However, free-rider behavior of the low-skilled agents in an open economy may undermine such a contract. Their willingness to commit to an educational subsidy vanishes as they anticipate the inflow of educated agents from abroad when the domestic rate of return on education exceeds that abroad.

Similar to Johnson (1984), Dur and Teulings (2003, 2004) develop a framework with skilled and unskilled workers as production inputs. The literature on the ability bias in the return to education indicates that education and innate ability are complementary (see, e.g., Angrist and Krueger (1991)). They emphasize that subsidies to all levels of education particularly favor those workers of high ability. Then, if such complementarities apply, optimism on the distributional effect may be discounted. Bovenberg and Jacobs (2001) regard distribution and subsidies to education as Siamese twins.

⁴The basic intuition for that has been put forth very clearly by (Baran and Sweezy, 1966, p. 150): "If what government takes would otherwise not have been produced at all, it cannot be said to have been squeezed out of anybody. Government spending and taxing, which used to be primarily a mechanism for transferring income, have become, in large measure, a mechanism for creating income."

In summary, the main argument of this literature is that the distributional effects are not necessarily inequitable (in the sense that they do not leave non-graduates worse off) because the agents can negotiate about the value-added. This argument, however, assumes that public higher education can be regarded as a means to enhance efficiency. We will, therefore, not confine ourselves to the distributional impact but also consider some aspects of efficiency.

In this paper, we emphasize the role of windfall gains that occur from subsidizing higher education. It is shown that the existence of windfall gains is likely to prevent subsidies from being Pareto-superior although they remain efficiency enhancing. Non-graduates may be left worse off although aggregate net lifetime earnings—the sum of the net lifetime earnings of those who can and those who cannot attend higher education—are maximized when higher-education investments are subsidized up to an efficient level. This argument (i.e., that an equity-efficiency trade-off can occur due to windfall gains created by efficiency-enhancing subsidies) has been neglected in the literature so far.

The reason why windfall gains occur if subsidies to higher education are organized as unconditional grants is the lack of information about agents' ability. Nevertheless, it can be shown that a voluntary graduate tax (a similar proposal has been put forth recently by Poutvaara (2004)) can be regarded as a revelation mechanism so that alternative funding schemes are likely to break down the equity-efficiency trade-off. We show that such a voluntary graduate tax is a better means of achieving both efficiency and equity goals.

The necessary condition for Pareto-superior subsidies is the enhancement of efficiency. There would be no potential Pareto improvement by establishing public education in a first-best situation, according to the First Fundamental Theorem of Welfare Economics. As there are no market imperfections, the *laissez-faire* outcome is Pareto optimal.

Advocates of public activities in the sector of education have, in particular, referred to externalities, credit constraints, and distributional aspects. The discussion about externalities gained more importance in the 1980s and 1990s, particularly due to Haveman and Wolfe (1984) and to new developments in growth theory, after earlier attempts at explanation using neoclassical marginal productivity theory had been dismissed (cf. (Blaug, 1970, pp. 112ff)). However, the empirical evidence for positive externalities is scant at best (see Acemoglu and Angrist (1999); Bils and Klenow (2000); Krueger and Lindahl (2000) for recent contributions).

The importance of credit constraints is, in principle, indisputable. Capital-market imperfections, so the argument goes, may hinder poor agents financing the costs of obtaining higher education (see Saint-Paul and Verdier (1993); Perotti (1993); Benabou (2000, 2002)). However, there is little empirical evidence (see, e.g., Carneiro and Heckman (2002); Cameron and Heckman (2001); Keane and Wolpin (2001)). Friedman (1962) and others (see Epple and Romano (1998) for an overview) have persuasively argued that vouchers or student loans, for example, are a better means to compensate for unwanted effects that result from credit constraints. However, even if all classical arguments in favor of public subsidization cannot be dismissed as a whole, most economists argue that these arguments cannot justify the wide prevalence of education subsidies in many countries, in particular in Europe.

While earlier discussions were centered around the expenditure side of the budget, recent⁵

⁵Previous examinations of the effect of taxation on human-capital accumulation are, e.g., Heckman (1976), and Eaton and Rosen (1980). In both works, labor-income taxation was found to have a neutral effect, but

contributions focus more on revenue. The impact of taxes on human-capital accumulation has become the central element in the recent literature. Trostel (1993, 1996) has shown that taxation has a negative impact on human capital investments and that education subsidies should primarily be seen and justified as a compensation for this tax distortion. In making this argument, Trostel uses an econometric model with a proportional tax rate, and it is assumed that the direct costs of obtaining higher education are not tax-deductible.

Dupor et al. (1998) analyzed the distorting impact of progressive taxation based on US tax law in 1970. The findings show that progressivity led to an approximately 5-percent decline in human-capital investment in 1970. Based on data from 1990, the impact differs considerably depending on the choice of schooling, and lies between close to zero and -22% . Sturn and Wohlfahrt (2000) refer to the *foregone smoothing benefit*. Due to tax progression combined with the annual tax assessment, graduates pay more taxes than non-graduates with the same net lifetime earnings because graduates accumulate their income in a shorter period of time. In summary, recent contributions focus more on the inefficiencies created by taxation than on the externalities created by human-capital investment. In these papers and in previous examinations (Heckman (1976); Eaton and Rosen (1980)), investment in education is a continuous decision, i.e., homogenous agents optimize the time devoted to education. In practice, however, we observe that the investment decision in favor of higher education is made by some agents whereas others avoid higher education. In this paper, we show that equity effects of education subsidies differ remarkably if the educational-investment decision is discrete. The reason is that here the tax distortion affects only a fraction of the population instead of the whole, as in the aforementioned studies.

This paper is organized as follows: we present the model in which our analysis takes place in subsection 2. Sections 3 and 4 deal with the efficiency and equity effects of unconditional grants to higher education. By doing so, we emphasize the role of tax distortions and windfall gains. In section 5, we discuss the concepts of a voluntary graduate tax and of student loans with income-related repayments. In subsection 5.1 we present and propose the concept of a voluntary graduate tax. It is shown that this funding scheme is a better means to achieve both equity and efficiency. Section 6 then concludes.

2 The model

To make our point, we use an amended version of the model presented by Creedy and François (1990). Their model consists of a population of agents who differ with respect to their innate endowment. It is a two-period model. In the first period, all agents face the decision of whether to enrol in a degree or not. In the second period, all agents work, either as graduates or as non-graduates. The government is assumed to raise taxes. The entire public revenue is spent financing subsidies to higher education, and for a publicly provided good. The graduation rate depends on the tax rate, the rate of subsidization, and on an externality created by those who attend higher education.

Our framework differs from the model of Creedy and François (1990) in two particulars. First, we neglect the existence of externalities. A justification for fiscal activities is given by a distortion

in both papers only the opportunity costs of obtaining higher education are considered.

created by income taxation according to the recent literature cited in the introduction. Second, in our model a tax is levied on agents' incomes, thereby assuming a constant tax rate to be exogenously given. The resulting revenue is spent on redistribution and subsidization purposes. Each agent receives an identical lump-sum transfer, denoted by \aleph , whose amount depends on the tax base, the tax rate, and the amount devoted to financing higher-education subsidies. At this point, a trade-off becomes evident. The more that is spent to support higher education through an unconditional grant, the lower the proportion of all revenue devoted to the redistribution policy. On the other hand, the tax base might be positively affected by subsidization so that two effects work in an opposite direction. If no subsidization takes place, however, the entire revenue is distributed uniformly among all individuals.

In contrast to the lump-sum transfer, the effect of income taxation is twofold. It allows the described redistribution policy, but it distorts the choice between education and work in the first period. This distortion calls for efficiency-enhancing subsidies. The efficiency gains created by a (partial) subsidization are potentially Pareto-superior.

Assume that a population is heterogeneous with respect to innate endowment, y_i , with $0 < y_i \leq \hat{y}$. Population size is normalized to unity. As in Creedy and François (1990), we consider that the cohort lives in two periods. In the first period, each agent can choose between higher education and work. In the second period, the entire population works. An individual's gross income is determined by its individual innate endowment and its return to higher education (if obtained). The distribution of the initial endowments is represented by the density function, $f(y)$, and its corresponding distribution function, $F(y)$. A constant and exogenously given tax rate, t , with $0 < t < 1$, is levied on all income.

An individual chooses higher education if his or her net lifetime earnings with a university degree would exceed the lifetime earnings if he or she did not invest in higher education. The degree causes direct (and non tax-deductible) costs, c , for each individual, where a proportion ρ with $0 \leq \rho \leq 1$ is borne by the taxpayers. The government knows only the distribution of the innate abilities, but cannot observe the endowment of each agent. Accordingly, the government can not establish individual-specific subsidies.

It is important to note that the costs of higher education, c , are not tax-deductible. The total costs, therefore, consist of the direct costs, such as teaching aids and tuition fees, and earnings foregone. *Basic* incomes equal the innate endowment, y_i . Students have the opportunity to work even in the first period and, thus, earn the portion h of the income earned without higher education. Therefore, the total cost of obtaining higher education amounts to

$$(1 - h)y_i(1 - t) + c(1 - \rho). \tag{1}$$

Individuals who have completed a degree in the first period will raise their income in the second period because of the rate of return to education. To simplify matters, it is assumed that the individual rate of return to education, s_i , is proportional to the individual endowment:

$$s_i \equiv u \cdot y_i. \tag{2}$$

As noted above, in the first period each individual faces the decision of whether to enrol in a degree or, alternatively, to start working without a university degree. The share of those choosing higher education depends on the exogenously given distribution of y .

The present values of the net lifetime income of educated agents, V^E , and of non-educated ones, V^N , are given by

$$V_i^E = (1-t)h y_i - c(1-\rho) + \frac{(1-t)y_i(1+u y_i)}{1+r} + \aleph \quad (3)$$

and by

$$V_i^N = (1-t)y_i + \frac{(1-t)y_i}{1+r} + \aleph. \quad (4)$$

It is straightforward to find an ability level corresponding to that of an agent who is indifferent to investing in his or her higher education by setting (3) = (4). The agent's endowment is denoted by \tilde{y} and is henceforth referred to as the *educational-choice margin (ECM)*. It is

$$\tilde{y}^{[p]} \equiv \psi + \sqrt{\psi^2 + \omega \cdot \frac{(1-\rho)}{(1-t)}} \quad (5)$$

where $\psi \equiv \frac{(1-h)(1+r)}{2u}$ and $\omega \equiv \frac{c}{u}(1+r)$.⁶ We assume that agents behave atomistically, neglecting the impact of their investment on aggregate income and total tax revenue.

As can be seen, the lump-sum transfer has no impact on the educational-choice margin. This is because the lump-sum transfer is granted to both types of agents uniformly and, therefore, does not distort the choice of educational investment.

For the ongoing discussion, it is useful to define a benchmark equilibrium. For this, we take the non-interventionist, redistribution-free equilibrium, where the government does not implement any income policy, so that the educational-choice margin is fully determined by market forces. This benchmark case is determined by $\rho = t = 0$. The educational-choice margin is then given by

$$\tilde{y}^{[bm]} = \psi + \sqrt{\psi^2 + \omega}. \quad (6)$$

The second case considers a distortionary taxation ($0 < t < 1$) and investments in higher education are not subsidized ($\rho = 0$). As noted above, we assume that the direct cost of obtaining higher education is not effectively tax-deductible. This assumption, which holds for a wide range of countries (see Trostel (1993)), is the driving force in Trostel (1993, 1996). In those papers, Trostel argues that a subsidy to higher education may be regarded as a means to compensate for the distorting nature of taxation. The educational-choice margin in this case is given by

$$\tilde{y}_0^{[p]} = \psi + \sqrt{\psi^2 + \frac{\omega}{(1-t)}}. \quad (7)$$

As can be seen, the higher t the higher the educational-choice margin and, consequently, the lower the graduation rate. On the other hand, the educational-choice margin is lowered if part of the

⁶As $V^{[E]}$ slopes quadratically, there is a second solution. It is given by $\psi - \sqrt{\psi^2 + \omega \cdot \frac{(1-\rho)}{(1-t)}}$. As ω, ρ , and t are all nonnegative, and $0 \leq \rho \leq 1$, $0 \leq t < 1$, this second solution is negative because the square root exceeds ψ . Hence, (5) is unique in the relevant range.

cost of obtaining higher education is borne by the state. This can be seen by comparing (5) and (7).

In the case of taxation without subsidization, three groups have to be considered. The first group consists of those agents with an innate endowment below $\tilde{y}^{[bm]}$. They would not invest in higher education in the benchmark case and would be even less likely to if a distorting tax system were introduced. The proportion of these agents is henceforth denoted by $n_1 \equiv F(\tilde{y}^{[p]})$. The second group consists of those agents who would invest in their higher education in the benchmark case, but are deterred from doing so because of the establishment of a distorting income tax. A subsidy is then required to give them an incentive to correct their investment decision. If agents invest in their higher education because of a government compensation for existing distortions, then we call this decision *extrinsic*. We denote the fraction of agents investing in higher education extrinsically by $n_2 \equiv F(\tilde{y}_0^{[p]}) - n_1$. For the third group of agents, it is worthwhile investing in higher education although this investment is discouraged by income taxation. Their investment is said to be motivated *intrinsically*. The fraction of agents investing intrinsically is denoted by $n_3 \equiv 1 - n_1 - n_2$. \bar{y}_j with $j = \{1, 2, 3\}$ denoting the mean endowment of agents in group j , and $V(y_j)$ the variance of their innate endowments.

In the next section, we will analyze the combined effect of taxation and subsidization of human-capital formation. By doing so, we derive the condition for efficiency-enhancing subsidies given the existence of the distorting nature of taxation.

3 Subsidization and efficiency

Starting from the benchmark case ($\rho = t = 0$), there would be no potential for Pareto improvement through the establishment of public education, according to the First Fundamental Theorem of Welfare Economics. As there are no tax distortions or other market failures, the outcome is Pareto optimal. Subsidization financed by a non-distorting tax⁷ would always lead to a redistribution.

The more reasonable case, however, is that where a distorting income tax is imposed. Hence, starting from $\tilde{y}_0^{[p]}$, we are interested in the effect of various ρ -values on the educational-choice margin. In particular, we wish to infer the optimal rate of subsidization if $\tilde{y}_0^{[p]}$ equals the educational-choice margin in the benchmark case, $\tilde{y}^{[bm]}$. The subsidy to higher education is said to be efficient (Pareto optimal) if it leads to increased aggregate income.

Proposition 1 *Under proportional taxation, fiscal activity, which consists of the combination of revenue and spending policy, is optimal if the rate of subsidization equals the tax rate. If the rate of subsidization exceeds the tax rate, the educational-choice margin falls and p rises. In the opposite case, p falls if $\frac{\rho}{t} < 1$.*

Proof. If $\frac{\rho}{t} = 1$, it follows that the term $\frac{(1-\rho)}{(1-t)} = 1$ and, hence, $\tilde{y}^{[p]} = \psi + \sqrt{\psi^2 + \omega} = \tilde{y}^{[bm]}$. ■

⁷Optimal-tax theory states that the optimal tax is a lump-sum tax (see, e.g., (Eaton and Rosen, 1980, p. 706)). We can prove that a lump-sum tax, denoted by τ , does not influence the educational-choice margin: The present value of a graduate's lifetime income is given by $hy_i - c + \frac{y_i(1+s_i)}{1+r} - \tau$ and that of a non-graduate by $y_i \left(1 + \frac{1}{1+r}\right) - \tau$. By equating both, the resulting educational-choice margin is independent of τ .

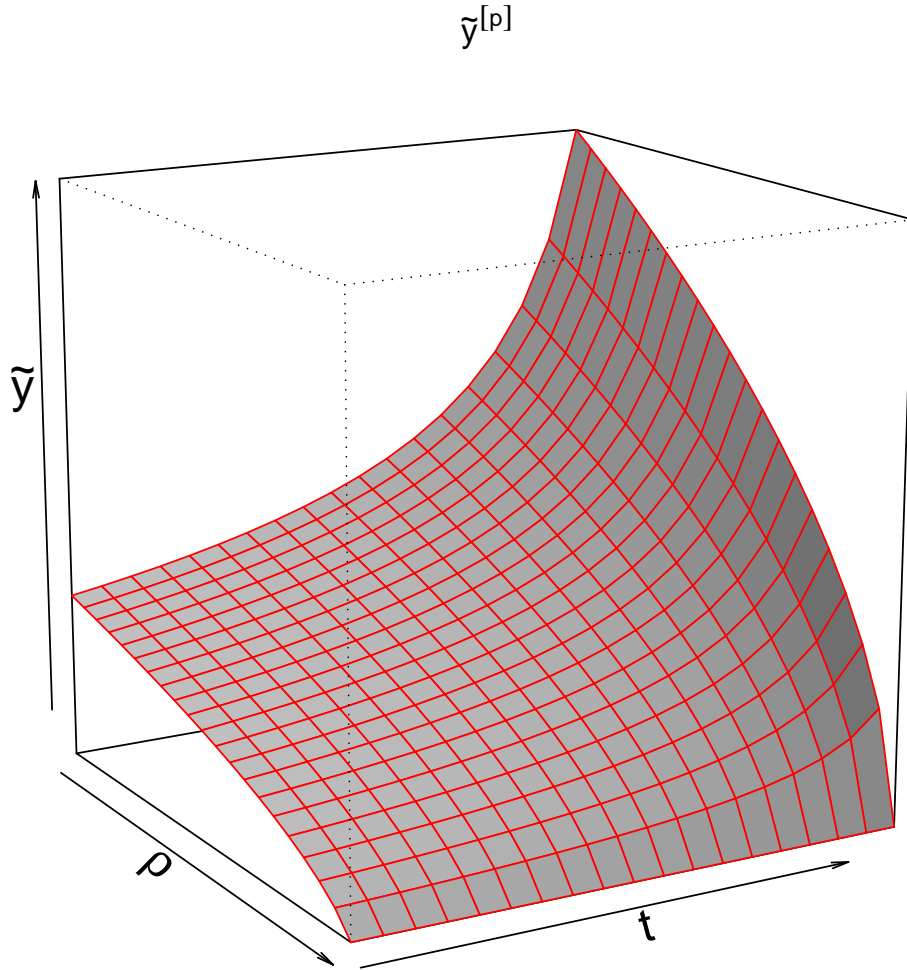


Figure 1: $\tilde{y}^{[p]}$ for various ρ - and t -values

Figure 1 shows the *ECMs* that result from various ρ - and t -values. As can be seen along the ρ -axis, the higher the rate of subsidization, the lower the educational-choice margin. The opposite holds for the tax rate, except for one special case. This special case arises if the costs of obtaining higher education are totally borne by the government.

Proposition 2 *If the direct costs of obtaining higher education are completely borne by the state ($\rho = 1$), t has no effect on p .*

Proof. If $\rho = 1$, it follows that $\tilde{y}^{[p]} = 2\psi = \frac{(1-h)(1+r)}{u}$ and, thus, is independent of t . ■

The intuition is as follows: The only distortion under this simple case of a proportional tax system arises from the non-deductibility of the direct cost of obtaining higher education. However, if the direct costs of higher education are completely borne by the state, the distortionary effect

of non-deductibility does not play any role, because in that case the agents would have nothing to deduct.

Optimality implies that aggregate net lifetime earnings—the sum of the net lifetime earnings of those who do and those who do not invest in higher education—are maximized when subsidization completely countervails the tax distortion. As we do not consider any disincentives from taxation on the labor market (i.e., substitution effects on leisure) in our framework, aggregate net lifetime income equals aggregate gross income minus the aggregate costs of obtaining higher education. We denote aggregate income by W , so that

$$\begin{aligned}
 W = & \left(1 + \frac{1}{1+r}\right) \int_0^{\tilde{y}} y dF(y) + \frac{1}{1+r} \int_{\tilde{y}}^{\hat{y}} y dF(y) \\
 & + \frac{u}{1+r} \int_{\tilde{y}}^{\hat{y}} y^2 dF(y) + h \int_{\tilde{y}}^{\hat{y}} y dF(y) - c(1 - F(\tilde{y})).
 \end{aligned} \tag{8}$$

Here, for simplicity reasons, we denote $\tilde{y}^{[p]}$ by \tilde{y} . Differentiating W with respect to the rate of subsidization yields

$$\tilde{y}(\rho) \cdot \tilde{y}'(\rho) f(\tilde{y}) \left[1 - u\tilde{y} \frac{1}{1+r} - h\right] + c f(\tilde{y}) \cdot \tilde{y}'(\rho) = 0. \tag{9}$$

As a first order condition we derive $\rho = t$ (see Appendix B).

The fact that a rate of subsidization up to t raises aggregate income implies that subsidies may be Pareto-superior. It is potentially feasible to distribute the efficiency gains so that all agents, including the non-graduates, are better off, although non-graduates have not benefited directly from subsidization. As noted in the introduction, Johnson (1984), e.g., argues that non-graduates' incomes may be increased in such a manner. In the next section, therefore, we will go into in more detail about the equity effects of subsidies to higher education. We will show that there is a counterforce that limits the distributive virtues of subsidies to education.

4 Subsidization and equity: Are subsidies Pareto-superior?

A funding scheme is said to be equitable if all groups increase their net lifetime income due to subsidization. Otherwise, non-graduates are worse off and a redistribution from non-graduates to graduates has occurred. In the latter case, we can ascertain an equity-efficiency trade-off. Note also that subsidies may be efficient if they are not equitable (i.e., lowering the net lifetime income of the non-graduates). If such subsidies raise net lifetime income of all agents, then equity-efficiency harmony exists. In this case, subsidization is said to be Pareto-superior.

Equity, therefore, requires raising the income of each of the three groups.⁸ To verify whether

⁸Here we follow (Sinn, 1995, p 497), who clearly distinguished between *equity* and *equitable*. As he said, "equity is an aspect of efficiency".

subsidies achieve this, we treat each group in succession for the case $\rho = t$.⁹ By doing so, we distinguish three kinds of income: gross income, net income (gross income minus taxes), and disposable income, i.e., net income plus the lump-sum transfer minus the cost of obtaining higher education (if obtained). The most important of these is disposable income. As we set the tax rate exogenously and constant, a rising gross income implies a rising net income and vice versa.

- Group 1. The gross income of group-1 agents (non-graduates) remains untouched as does their net income. The only effect they experience is a change in \aleph . As total revenue is spent on redistribution and subsidization, the introduction of a subsidy leads to a twofold effect on \aleph . In the first period, a direct and an indirect effect are at work. The direct effect on \aleph derives from the obvious fact that a proportion of the entire revenue is now spent for subsidization rather than for the lump-sum transfer alone. The indirect effect derives from the fact that group-2 agents earn less in the first period than otherwise (opportunity costs of obtaining higher education) and therefore pay less in taxes.

Formally, total costs per capita of the subsidies are given by

$$C(\rho, \tilde{y}(\rho)) \equiv p \cdot \rho c + t \cdot (1 - h) \int y dF(y) \quad (10)$$

where the limits of integration are given by $\tilde{y}^{[bm]}$ and $\tilde{y}_0^{[p]}$.

The first term of the right-hand side of equation (10) features the change in the expenditure side of the budget. A part of the total revenue is now spent for subsidization rather than for redistribution alone. The decline in tax revenues in the first period, caused by the indirect costs of obtaining higher education, is represented by the second term.

While the non-graduates face costs in the first period, they benefit from subsidization in the second period. The intuition is that they will also participate in the private rentability of human-capital investments through taxation and the use of the additional tax revenues for a higher lump-sum transfer. On the other hand, only a small portion of the taxed benefits from the private rentability of the investment could be assigned as benefits from the non-graduates' point of view. The private rentability of those who invest intrinsically would otherwise (i.e. without subsidization) also be taxed, so that only the tax revenue from the additional income of *group-2 agents* could be assigned as a benefit from subsidization. Formally, the benefit function (per capita) is $B(\tilde{y}(\rho))$ where

$$B(\tilde{y}(\rho)) \equiv t \cdot \frac{u}{n(1+r)} \int y^2 dF(y), \quad (11)$$

and the same limits of integral as in (10) apply. Note that the effect on \aleph is the same for all agents, as the lump-sum transfer is earmarked to be shared uniformly among all agents.

Again, it is crucial to note that group-1 agents are better off only if \aleph rises due to subsidization, because the second source of their disposable income, net income, remains unchanged in both cases, with and without subsidization.

⁹Note that here $n_1 = 1 - F(\tilde{y}^{[bm]})$.

- Group 2. In contrast to group-1 agents, subsidization affects both income sources of group-2 agents, net income as well as \aleph . Nevertheless, we can easily show that group-2 agents are net gainers from the subsidy. These agents consist of those who change their investment decision after a subsidy has been established. Their reason is that they find it worthwhile investing in their education, because of the subsidy. This means that the present value of their lifetime income is higher as a graduate than as a non-graduate.
- Group 3. As noted above, group-3 agents' investment in education is motivated intrinsically. They would invest in education even if the government did not counteract tax distortions. As a consequence, group-3 agents receive the same gross income (and the same net income) as without subsidization. Hence, they reap the subsidies as a pure windfall gain. They are therefore net gainers as long as $\rho c + \Delta\aleph > 0$ applies.

In summary, a subsidy to higher education affects the educational behavior of group-2 agents. Group-3 agents, on the other hand, reap pure windfall gains. Such windfall gains may have a lowering effect on \aleph because they lower the fraction of total revenue that is devoted to financing the lump-sum transfer. We obtain, therefore, the following Proposition:

Proposition 3 *A subsidy that is granted to each agent who invests in higher education intrinsically reduces the lump-sum transfer by ρc .*

In contrast to the effect of subsidizing group-3 agents, the subsidies to group-2 agents have a positive effect on \aleph . Formally, we obtain the following Proposition:

Proposition 4 *If all agents with an endowment below $\tilde{y}_0^{[p]}$ and above the efficient level $\tilde{y}^{[bm]}$ are subsidized by $\rho \cdot c$, then \aleph rises.*

We can prove Proposition 4 as follows:

Proof. For an individual whose endowment y_i is equal to $\tilde{y}^{[bm]}$, as a consequence of Proposition 1, the following equality applies:

$$u y_i^2 \frac{1-t}{1+r} = (1-h)y_i(1-t) + (1-\rho)c, \quad \text{with } \rho = t. \quad (12)$$

The left-hand side of equation (12) measures the additional net lifetime income (in present value terms) due to the investment in higher education, and the right-hand side the total costs of obtaining higher education, consisting of the direct and indirect costs of obtaining higher education. We can now multiply both sides by $\frac{t}{(1-t)}$ to obtain an equation whose left-hand side yields the additional tax revenues and consequently raising \aleph , and whose right-hand side indicates foregone tax revenues in the first period plus the expenditures for subsidizing this individual:

$$t \cdot \frac{u y_i^2}{(1+r)} = t [(1-h)y_i + c]. \quad (13)$$

Equation (13) states that it has no effect on \aleph if an individual with an endowment equal to $\tilde{y}^{[bm]}$ is subsidized by $\rho \cdot c$. All individuals with an higher endowment, however, will find it worthwhile

to invest in higher education so that (12) becomes an inequality with its left-hand side exceeding its right-hand. The opposite case holds for all individuals with an endowment below $\tilde{y}^{[bm]}$.

It is now simple to consider all individuals with an endowment below $\tilde{y}_0^{[p]}$ by generalizing equations (12) and (13) to

$$u y_i^2 \frac{1-t}{1+r} \leq (1-h)y_i(1-t) + (1-\rho)c, \quad \forall y_i \leq \tilde{y}^{[bm]} \quad (14)$$

and

$$t \cdot \frac{u y_i^2}{(1+r)} \leq t[(1-h)y_i + c], \quad \forall y_i \leq \tilde{y}^{[bm]}. \quad (15)$$

Only the case in the bottom line of equation (15) is concerned with an increasing \aleph . ■

To sum up, we have seen that each subsidized group-2 agent contributes to an increasing lump-sum transfer and affects the disposable income of each group-1 agent positively. The opposite applies to each subsidized group-3 agent. It is therefore interesting to derive a critical value, denoted by \tilde{n}_3 , which states that if n_3 exceeds \tilde{n}_3 , then subsidization is inequitable in the sense that it lowers the lump-sum transfer compared to a situation without subsidization. This critical value is given by

$$n_3 \leq \frac{V(y_2) + \bar{y}_2^2}{\omega} - n_2 \left(\frac{(1-h)}{c} \bar{y}_2 + 1 \right) \equiv \tilde{n}_3. \quad (16)$$

5 Alternative funding options

Over recent decades, the pros and cons of various kinds of higher-education funding have been discussed. In this section, we will discuss some of the proposals for a funding reform in the light of our framework and the main results we have obtained so far.

In the preceding sections we emphasized the role of tax distortions. We ignored the role of externalities and we made no attempt to address the role of capital-market imperfections or unequal opportunity to access higher education. The persistent debate on alternative funding options, however, often tries to consider most of these problems and to look for alternative funding schemes that alleviate or solve all or most of these problems.

Among others, the most popular ideas for a funding reform are: a graduate tax, vouchers, differential fees, and loans (see, e.g., Greenaway and Haynes (2003)). Most of these are mutually compatible in the sense that they work in a similar manner. Both vouchers and loans aim to correct market failures such as credit constraints. However, both schemes intend that graduates repay support received during their lifetime. A graduate tax is a mechanism to differentiate with respect to a concept, often weakly defined, of *ability to pay*; differential fees have a similar aim. However, only a small minority of economists claim that grants should be wholly state financed. The opposite attitude, however, seems to interest more economists but two main drawbacks are also widely accepted. The first is concerned with equity considerations: tuition fees have become a target of much social hostility, not least because they have to be paid at a time when young people have the least money. The second disadvantage is concerned with efficiency: considering the first

drawback, parental contributions become more and more important and, despite the suggestion that this might also be socially undesirable, it separates payers (parents) and users (students). Consequently, so the argument goes, higher education is not an efficient decision because of a principal-agent problem. Furthermore, this divergence of payers and users may be the source of what John Stuart Mill labeled *fiscal illusion*.¹⁰

Therefore, the debate within the economics of education is centered on a scheme somewhere between fully subsidized costs of obtaining higher education and tuition fees in its rough form. The main question in this field seems to be the relationship between the benefit granted during the investment period and the amount of *repayment* over the subsequent lifetime. The options here can be summarized by

- a pure (mortgage-type) loan scheme,
- a loan with income-related repayment (up to the borrowed amount), and
- a graduate tax

Under a loan scheme, a graduate repays what he or she has borrowed until the loan (plus interest) has been paid off, at which point repayments cease. With an income-related repayment, the borrowed amount can be regarded as a maximum value of repayment. Agents who are not very successful in the labor market repay less than received. Interestingly, most education economists seem to favor an income-related repayment. (Blaug, 1980, p. 45) has pointed out that "virtually every advocate of student loans in Britain [...] favors an income-related loans scheme [...] and not a personal loan repayable in a fixed number of years after taking up employment."

A graduate tax, however, is a tax supplement that applies only to graduates. If the graduate tax is regarded as a *repayment* for benefits received during the education period, the repayable amount may have the opposite effect to an income-related repayment of a loan. High-income graduates are pushed to *repay* more than they received. Graduates, in this case, are taxed twice. Glennerster (2003), and Glennerster et al. (2003) refer to two equity grounds that both date back to Adam Smith: capacity to pay and disproportionate benefit.

As we argued [...] graduates disproportionately benefit from higher education in ways no other group does from investment made in them by their fellows. State funded lifetime expenditure on the higher education of the richest fifth is worth five times as much as that on the lowest fifth. A graduate tax combines the principles of ability to pay, disproportionate benefit and efficient collection. Adam Smith's perfect tax! (Glennerster, 2003, p. 26)

However, the concept of a graduate tax has been supported by several economists. Arrow (1993); Lincoln and Walker (1993) regard a graduate tax as a means to achieve a just contribution by students for the subsidies they received. Pennings (2000) pointed out that a graduate tax is an example for a *zero expected cost* investment stimulus. García-Peñalosa and Wälde (2000) propose a lump-sum graduate tax in a model with capital-market imperfections and an uncertain outcome

¹⁰"Perhaps [...] the money which [the taxpayer] is required to pay directly out of his pocket is the only taxation which he is quite sure that he pays at all". (Mill, 1848[1994], p. 237).

from the educational investment. The lump-sum graduate tax is higher than the received subsidy in order to finance the subsidies for those who also invest in higher education but do not pass a final exam. Finally, Poutvaara (2004) propose a voluntary graduate tax and emphasize that it can be seen as a triple dividend in new EU member states, "benefiting the emigrants, those left behind in the new member states and the old member states alike" (Poutvaara, 2004, p. 25).

One of the most popular advocates for an income-related loan is Nicholas Barr. He argued that the main advantage of an income-related loan with regard to *equity* is that "no-one repays more than he/she has borrowed" (Barr, 1989, p. 64). By arguing in this way, Barr unveils exactly the opposite view on equity compared to the view of Glennerster, referred to above.

The most obvious advantage of a graduate tax is that it would be relatively straightforward to introduce.¹¹ A graduate tax that is organized as a higher tax bracket in the income tax schedule can be raised without significant administrative costs. In particular, if the loan varies between agents (e.g., with respect to faculty, university, gender, and so on), it would be too complicated to recover the precise amount from each former student. The basic presumption is that administrative costs are minimized when a small scheme is *piggy-backed* onto a larger one like the income tax.

The differences between the two concepts discussed here, however, are not as great as they may appear initially.¹² If a graduate tax is optional and the investment outcome is certain, the differences from a loan with income-related repayment vanish. Furthermore, this scheme is much more likely to achieve both goals, equity and efficiency, than the current practice in many European countries, as will be shown in the next subsection.

5.1 A voluntary graduate tax

In the preceding section it was emphasized that unwanted distributional consequences of public subsidization result primarily from the impracticability of discriminating between the subsidies granted to different students. The reason, as mentioned above, is the lack of information on individuals' endowments. This missing information is the main source of problematic equity effects.

¹¹In this framework, we consider only a proportional tax system. Under this simple tax regime, the graduate tax is also simple to levy. However, under more complicated tax structures, in particular if taxation is progressive and, e.g., married couples can be taxed jointly, a graduate tax may create further problems. Consider, for example, if only one partner has invested in higher education. What should then be regarded as the tax base for the graduate tax? The author is indebted to Barbara Wolfe for highlighting this point.

¹²The main differences between a voluntary graduate tax and a loan scheme with income-related repayment can be seen when we consider that the outcome of education is uncertain. Assume, for example, that agents do not know exactly their innate endowment, although they are able to form an unbiased estimate of it. As in Levhari and Weiss (1974); Eaton and Rosen (1980), we assume that endowment is given by $x y_i$, where x is a random variable with a mean of unity and with support $[a_1 \geq 0, a_2]$. Note that agents are still risk-neutral. An agent with an expected endowment slightly above $\tilde{y}_0^{[p]}$ will also use the loan if its repayment is income-contingent. The repayment equals the loan if x , unveiled in the second period, is unity, while the agent will repay less than received if $x < 1$ but will not repay more otherwise. Agents with an endowment equal to $\tilde{y}_0^{[p]} + \varsigma$, where $\varsigma < a_1$, would also find it worthwhile to use the loan scheme as they have nothing to lose. The scheme, then, is a means not only to offset tax distortions, but also to assure against uncertainty, which is not justified on efficiency grounds as agents are not risk-averse. Under a voluntary graduate tax, the agent with an endowment equal to $\tilde{y}_0^{[p]} + \varsigma$ would not demand the subsidy.

In this subsection, we will demonstrate that a voluntary graduate tax could be used as a revelation mechanism. This funding scheme allows us both to support higher education up to an efficient level and to avoid the problematic distributional consequences better than unconditional grants, although it might be that both goals can only be approximately achieved simultaneously.

The model works as follows. Each agent is eligible for a subsidy to cover (partly) the direct costs of obtaining higher education, denoted by γ with $0 < \gamma \leq 1$. Those who use the subsidy are liable to a graduate tax on their income in the second period, denoted by β with $0 < \beta < (1 - t)$. Each agent can choose whether to obtain a subsidy in the first period and consequently to accept the graduate tax on his or her income as a graduate, or to opt out. In the latter case, second-period income is taxed by the constant tax rate t with $0 < t < 1$.

As in the previous analysis, there are three groups. For the first group (group 1) it is still not worthwhile to invest in higher education. Group-2 agents will take out a subsidy and therefore take up a degree, while group-3 agents will invest in higher education without drawing on the funding system. The reason for the last group's decision is that the burden from the graduate tax exceeds the benefit from the loan. There exist, as a consequence, two educational-choice margins, an upper one and a lower one. The upper one denotes that agent who is indifferent about the alternatives, i.e., to draw on the funding scheme or not. However, for this agent it is worthwhile to invest in higher education in any case. Those agents with endowments below the lower educational-choice margin will, nevertheless, abstain from investing in higher education.

5.1.1 Optimal policy

If we assume the government's goal is efficiency, the government will set the rate of subsidization so that the lower educational-choice margin coincides with $\tilde{y}^{[bm]}$. For that, we need to consider a graduate's present value of net lifetime income after having drawn upon the scheme. It is given by

$$V_i^{E[1]} \equiv h y_i (1 - t) - c(1 - \gamma) + (1 - t - \beta) y_i \cdot \frac{(1 + u y_i)}{(1 + r)} + \aleph. \quad (17)$$

The lower bound is then obtained by equating (17) and (4).¹³ It is given by

$$\begin{aligned} \tilde{y}^{[1]} \equiv & \frac{\psi(1-t)}{1-t-\beta} + \frac{\beta}{2u(1-t-\beta)} \\ & + \sqrt{\left[\frac{\psi(1-t)}{1-t-\beta} + \frac{\beta}{2u(1-t-\beta)} \right]^2 + \frac{\omega(1-\gamma)}{(1-t-\beta)}}. \end{aligned} \quad (18)$$

The efficient educational-choice margin and $\tilde{y}^{[1]}$ coincide if the subsidy is set to

$$\gamma_1 \equiv t + \beta \left[1 + \tilde{y}^{[bm]} \theta \right] \quad (19)$$

where $\theta = \frac{1}{c(1+r)} + \frac{(1-h)}{c}$. It is obvious that the square root in (18) cannot become negative¹⁴ for

¹³It was: $V_i^{N[dp]} = y_i(1-t) + \frac{y_i(1-t)}{1+r} + \aleph$.

¹⁴If the square root becomes negative, the economic intuition is the following: the higher γ the greater the size of agents with the lowest ability who invest in higher education. In this case (that we have ruled out), a fourth group of agents accrues starting from the left-hand side of the density function of y . If γ is so huge that the square root becomes negative, then no agent will reject an educational investment.

any value of γ less or equal to 1. Therefore, for every $0 \leq \gamma_1 \leq 1$ a solution that ensures efficiency exists. Furthermore, from the condition that $\gamma_1 \leq 1$ follows that the graduate tax cannot exceed $\hat{\beta}_1$, where

$$\hat{\beta}_1 \equiv \frac{1-t}{1+\theta \cdot \tilde{y}^{[bm]}}. \quad (20)$$

If γ is set equal to γ_1 to ensure efficiency, it is interesting to analyze the extent to which group-3 agents draw on the funding scheme. No one will do so if it is not advantageous for the least talented agent in group 2 to draw on the subsidy in the first period. It is quite simple to derive a combination of γ and β , which ensures this goal: we equate a graduate's present value of lifetime income after having used the funding scheme, and the present value of those graduates who renounced the scheme. Thus, we equate $V_i^{E[1]}$ which has already been derived in equation (4) and

$$V_i^{E[2]} \equiv hy_i(1-t) - c + (1-t)y_i \cdot \frac{(1+uy_i)}{(1+r)} + \aleph. \quad (21)$$

As the educational-choice margin we obtain¹⁵

$$\tilde{y}^{[2]} \equiv -\frac{1}{2u} + \sqrt{\frac{1}{4u^2} + \omega \cdot \frac{\gamma}{\beta}}. \quad (22)$$

Windfall gains are completely avoided if $\tilde{y}^{[2]} = \tilde{y}_0^{[p]}$. A subsidy that satisfies this condition is given by

$$\gamma_2 = \beta \left[\frac{1}{1-t} + \tilde{y}_0^{[p]} \cdot \theta \right]. \quad (23)$$

This upper bound divides those who invest in higher education into groups with and without use of the subsidy. For all $y_i > \tilde{y}^{[2]}$, it is worthwhile to opt out. Similarly, the condition $0 \leq \gamma_2 \leq 1$ requires that the graduate-tax rate reaches its maximum value at

$$\hat{\beta}_2 \equiv \frac{1}{\frac{1}{(1-t)} + \theta \cdot \tilde{y}_0^{[p]}}. \quad (24)$$

5.1.2 Can both goals be achieved?

In the preceding sections we derived two values for γ , one that ensures efficiency and another that avoids windfall gains. The government has to choose one of the two values, so it is not clear whether both goals can be achieved simultaneously. As both γ_1 and γ_2 depend on β , we can check for the possibility that a value of β exists that leads to $\gamma_1 = \gamma_2$. It is obvious that such a β -value exists, because γ_2 increases more strongly in β than γ_1 ,¹⁶ but γ_1 intercepts the β -axis at t whereas γ_2 starts at the origin. On the other hand, to avoid windfall gains from the higher-education investment of agents with the lowest ability, we do not allow any γ to become greater than 1. As a consequence, it might be that a graduate tax that ensures coinciding values of γ lies below $\hat{\beta}_1$ and $\hat{\beta}_2$.

¹⁵The same result can be obtained by equating γc and $\frac{\beta}{(1+r)} y_0^{[p]} (1 + u y_0^{[p]})$.

¹⁶This can be proved very easily: $\tilde{y}_0^{[p]} > \tilde{y}^{[bm]}$ and $\frac{1}{1-t} > t$.

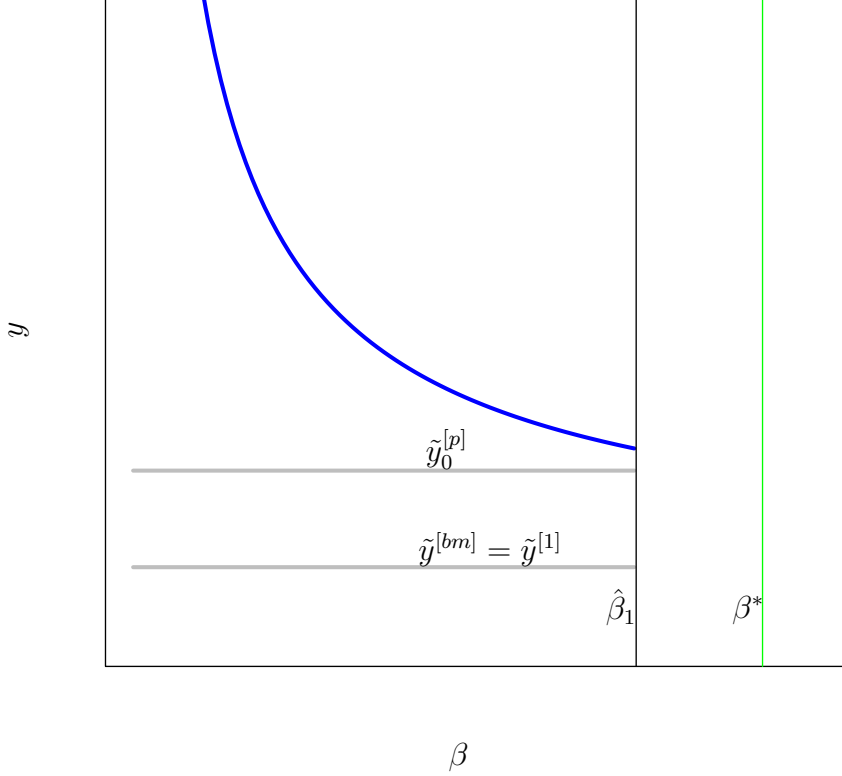


Figure 2: Equity effects of an efficiency-orientated policy

The condition for a simultaneous achievement of both goals is that $\tilde{y}^{[bm]}$ pays a graduate tax that amounts to $(1-t)c$ if $\gamma = 1$ and also $\tilde{y}_0^{[p]}$ in that case would pay c . This means that a certain relationship between $\tilde{y}_0^{[p]}$ and $\tilde{y}^{[bm]}$ has to exist to achieve both goals simultaneously. This relationship, however, is determined as the difference between the two educational-choice margins, which is given by $\sqrt{\psi^2 + \frac{\omega}{(1-t)}} - \sqrt{\psi^2 + \omega}$. This is the intuition for the following proposition:

Proposition 5 *It is not possible to achieve both goals simultaneously.*

Proof. See Appendix A ■

Given Proposition 5, the question that arises is: which combination of γ and β minimizes the windfall gains? To answer this question we analyze the slope of $\tilde{y}^{[2]}(\gamma_1)$. It can be derived as follows: we insert γ_1 into $\tilde{y}^{[2]}$ and generate the first derivation with respect to β . By doing so we

obtain

$$\frac{\partial \tilde{y}^{[2]}}{\partial \beta} = -\frac{t\omega}{2\beta^2 \cdot \sqrt{\left(-\frac{1}{2u}\right)^2 + \omega \frac{\gamma_1}{\beta}}}. \quad (25)$$

As ω , t , and β are positive, the slope is negative. The consequence of these properties is that the closer the graduate tax is to β^* , the smaller the number of agents who reap windfall gains. Thus, the higher γ_1 , the closer $\tilde{y}^{[2]}$ is to $\tilde{y}_0^{[p]}$. The resulting curve is illustrated in Figure 2. The higher β , the closer this curve is to $\tilde{y}_0^{[p]}$. The gray horizontal lines represent the two educational-choice margins under consideration. The vertical line close to the right, marked with β^* , indicates that value of β where the $\tilde{y}^{[2]}$ -line would coincide with the $\tilde{y}^{[p]}$ -line.

By considering the slope of $\tilde{y}^{[2]}(\gamma_1)$ and Proposition 5, we can derive the following Proposition:

Proposition 6 *If $\hat{\beta}_2 < \beta^*$, then the best policy is for the subsidy to cover the entire cost of obtaining higher education.*

6 Conclusion

The debate on higher education reform is widespread. Advocates of reform often refer to the argument that subsidies to higher education are regressive in their distributional consequences, and these advocates often ignore efficiency arguments. Their opponents, however, often seem to ignore efficiency losses to which huge subsidies may lead and that these efficiency losses are concerned with negative distributional effects.

Our analysis suggests that the question of distributional consequences is much more variegated than a glance at many textbooks and models would suggest. It is beyond controversy that a cross-sectional analysis is the most appropriate universe to deal with the impact on *rich* and *poor* households. Such studies have been carried out for many countries and the results indicate that the *Friedman-thesis* should be handled with some care. In the long run, however, the question remains whether students reap subsidies at the expense of non-graduates.

However, distributional considerations are only part of the discussion. Most attention should be given to efficiency arguments. With regard to the normative justification for educational subsidization, this paper has emphasized an efficiency justification for subsidies to higher education besides the classical arguments. We have shown that subsidizing education is optimal in a second-best sense, because it offsets the distortionary effects of taxation on human-capital accumulation.

Some authors argue that if an inefficiency can be countervailed by subsidies, the distributional effects on graduates and non-graduates may not be regressive because these groups can negotiate on the value-added. We have called this viewpoint into question by emphasizing the role of windfall gains, which are likely to vitiate this optimistic view. Although this argument is not very difficult, it has so far been neglected in the related literature.

However, the paper also shows that windfall gains are avoidable to a large extent. A voluntary graduate tax is shown as a means of achieving this, and furthermore, as a revelation mechanism. At least in our framework, a voluntary graduate tax offsets the distortionary role of taxation and is likely to be a means to establish a Pareto-superior policy to the mutual advantage of both graduates and non-graduates.

Appendix

A Proof of Proposition 5

It will be shown that β^* leads to $\gamma_1 = \gamma_2 > 1$. To do so, we analyze the case where costs are fully covered by the state ($\gamma = 1$). In this case, efficiency is achieved if that agent with an endowment $y_i = \tilde{y}^{[bm]}$ pays a graduate tax equal to $(1-t)c$. The condition for equity is that $\tilde{y}_0^{[p]}$ pays a graduate tax c (see the footnote on page 17). Consequently, both aims are achieved if, and only if, the graduate tax of that agent with an endowment $\tilde{y}_0^{[p]}$ is $\frac{1}{1-t}$ as high as the graduate tax of the $\tilde{y}^{[bm]}$ -agent. We hence obtain as conditions for efficiency and equity, respectively

$$\beta \tilde{y}^{[bm]} \frac{(1+u\tilde{y}^{[bm]})}{(1+r)} \stackrel{!}{=} (1-t)c \quad (26)$$

$$\beta \tilde{y}_0^{[p]} \frac{(1+u\tilde{y}_0^{[p]})}{(1+r)} \stackrel{!}{=} c. \quad (27)$$

We multiply (27) by $(1-t)$ to equate both conditions. It yields

$$\tilde{y}_0^{[p]}(1-t) - \tilde{y}^{[bm]} = -u \left[\left(\tilde{y}_0^{[p]} \right)^2 (1-t) - \left(\tilde{y}^{[bm]} \right)^2 \right]$$

\Leftrightarrow

$$\frac{\tilde{y}_0^{[p]}(1-t) - \tilde{y}^{[bm]}}{\left(\tilde{y}_0^{[p]} \right)^2 (1-t) - \left(\tilde{y}^{[bm]} \right)^2} = -\frac{u}{(1+r)}. \quad (28)$$

A solution exists only if either the numerator or the denominator in the left-hand side of (28) is negative.

Lemma 1 $\tilde{y}_0^{[p]}(1-t) - \tilde{y}^{[bm]} < 0$

Proof. $\tilde{y}_0^{[p]}(1-t) = \psi(1-t) + \sqrt{(1-t)^2\psi + (1-t)\omega}$ is less than $\tilde{y}^{[bm]} = \psi + \sqrt{\psi^2 + \omega}$, because $(1-t) < 1$ and also $(1-t)^2 < 1$ for all $0 < t < 1$. ■

Lemma 2 $\left(\tilde{y}_0^{[p]} \right)^2 (1-t) - \left(\tilde{y}^{[bm]} \right)^2 < 0$

Proof. $\left(\tilde{y}_0^{[p]} \right)^2 = \psi^2 + 2\psi\sqrt{\psi^2 + \frac{\omega}{(1-t)}} + \psi^2 + \frac{\omega}{(1-t)}$. This equation multiplied by $(1-t)$ yields

$$2\psi^2(1-t) + 2\psi\sqrt{(1-t)^2\psi^2 + (1-t)\omega} + \omega. \quad (29)$$

On the other hand, $\left(\tilde{y}^{[bm]} \right)^2 = 2\psi^2 + 2\psi\sqrt{\psi^2 + \omega} + \omega$. The square root and the first term are greater than those in (29). ■

B Solving equation (9)

Differentiating W yields

$$\tilde{y}(\rho) \cdot \tilde{y}'(\rho) f(\tilde{y}) \left[1 - u\tilde{y} \frac{1}{1+r} - h \right] + c f(\tilde{y}) \cdot \tilde{y}'(\rho) = 0.$$

$$\Leftrightarrow \tilde{y}' f(\tilde{y}) \left[\tilde{y}(1-h) - \tilde{y}^2 \frac{u}{(1+r)+c} \right] = 0 \quad \Leftrightarrow \quad \tilde{y}(1-h) - \tilde{y}^2 \frac{u}{(1+r)+c} = 0$$

$$\mathbb{L} = \{ \psi + \sqrt{\psi^2 + \omega} \}$$

If and only if $t = \rho$, then $\tilde{y}^{[p]} = \mathbb{L}$

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