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Fiscal Federalism

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ABSTRACT: We study voting over higher education finance in an economy with risk averse households who are heterogeneous in income. We compare four different systems and analyse voters' choices among them: a traditional subsidy scheme, a pure loan scheme, income contingent loans and graduate taxes. Using numerical simulations, we find that majorities for income contingent loans or graduate taxes become more likely as the income distribution gets more equal. We also perform sensitivity analyses with respect to risk aversion and the elasticity of substitution between high skilled and low skilled workers.

JEL Codes: H52, H42, D72

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1 Introduction

In this paper, we study household preferences over different systems of higher education finance. Traditionally, most western democracies have subsidised higher education costs, with the subsidies financed by general tax revenue. But this 'traditional tax-subsidy scheme' (TS for short) has been criticised on several grounds. First, since subsidies are financed by general taxes, but children from rich families are more likely to go to college, this financing scheme may lead to 'reverse' redistribution from poor to rich.[1] Second, even with subsidies, private education choices may not be efficient. For instance, poor but able students might not be capable of affording higher education if the subsidy is too low.[2] García-Peñalosa and Wälde (2000) show that, with risk neutral students and credit constraints, it is impossible to attain efficiency and equity at the same time with the TS system.

Recently, therefore, several countries have reformed higher education finance or are considering to do so. While some countries are moving towards greater reliance on user fees, proposals are usually coupled with some loan scheme. Among these schemes are what are called 'pure loan schemes' (PL), where the government makes loans available to students who are credit constrained. These loans then have to be paid back at (or below) market rates. While this system relieves credit constraints, it has the disadvantage that it does not provide insurance against the risk of failure. A typical number is that 25% of college students do not complete graduation. Hence, studying is an uncertain gamble, and individuals who wish to go to college will demand insurance against the risk of failure. If such insurance is not available in private markets, there is a role for insurance provided through the financing system.

Systems that do provide this type of insurance are income contingent loans (IC) or graduate taxes (GT).[3] Under IC, students receive loans which have to be repaid only after

[1] See Johnson (2006) for one recent reference.

[2] Fernandez and Rogerson (1995) argue that rich households may keep subsidies low in order to prevent the poor from obtaining education and at the same time extract resources from the poor through general income taxation.

[3] Chapman (2006) uses the terminology ICL with risk sharing for what we call IC system, and ICL with risk pooling for what we term GT. In his definition, under graduate taxes, there is no connection between total taxes and the costs of education. We follow the definition by García-Peñalosa and Wälde (2000) here.

graduation, with repayment schedules typically depending on income. Loans to unsuccessful students are covered by general tax revenue. Under the GT system, again only successful graduates repay their loans, but defunct loans are now financed only by the graduates. Different forms of IC systems have been introduced in Sweden, Australia, New Zealand and the UK (see Chapman, 2006, for an overview). Many other countries are now discussing such schemes. Chapman (2006) cites the regressivity of traditional subsidy financing as one of the reasons that led to the adoption of income contingent loans in Australia, New Zealand and the UK.

We study voting on the financing schemes just described: TS, PL, IC and GT. We assume risk averse households who differ by income. Individuals in their first period may study or work as low skilled workers. In the second period, successful graduates work as high skilled, whereas unsuccessful students work as low skilled workers. Households are risk averse and wages are endogenous. Within each system, taxes and subsidies are determined by majority voting. We first analyse each system separately and then study household preferences over the systems. We simulate the model numerically and study how changing parameters changes the support for the different systems. We find that majorities for GT or IC over TS become larger when risk aversion rises, the elasticity of substitution rises (although this effect may be non-monotonic) or when the income distribution becomes either less skewed, or median and average income both fall for given skewness. There are also a number of other interesting findings. For instance, we find that poor households tend to prefer traditional subsidy financing to graduate taxes or income contingent loans, which runs against the logic of the regressivity of the traditional subsidy system. The reason lies in the fact that this system leads to high unskilled wages (see below).

The paper is related to two strands of literature. One part of the literature studies equity and efficiency of different higher education systems.[4] García-Peñalosa and Wälde (2000), for instance, argue that the TS system cannot achieve efficiency and equity at the same time. Del Rey and Racionero (2006) advocate an IC system which covers tuition and living costs to achieve efficiency. We use the same type of model as García-Peñalosa and Wälde (2000) and Del Rey and Racionero (2006), but, whereas both assume risk aversion and exogenous wages, we allow wages to be endogenously determined. This has some important effects, as already argued by Johnson (1984): for instance, the poor may

[4]See, e.g., Barr (2004), Greenaway and Haynes (2003), Chapman (2006), García-Peñalosa and Wälde (2000) and Del Rey and Racionero (2006).

benefit from the TS system, because increasing the number of students increases low skilled wages. The same effect will also be important in analysing the choice among systems. Also, Del Rey and Racionero (2006) focus exclusively on efficiency whereas García-Peñalosa and Wälde (2000) look at efficiency and equity. We also analyse redistributional effects, but we go beyond the analysis of García-Peñalosa and Wälde (2000) in that we compare the systems with endogenously determined equilibrium subsidies and taxes and explicitly analyse household preferences over these systems.

There is also a relatively large literature on the political economy of education, much of which focuses on primary and secondary education, however. For example, Epple and Romano (1996) and Stiglitz (1974) study the provision of public education with private alternatives. Epple and Romano (1996) argue that rich and poor voters may prefer low public education provision while middle class voters want high provision. Fernandez and Rogerson (1995) study subsidies for education and show how the rich and middle class may vote for relatively low subsidies to keep the poor from studying. This results in reverse redistribution. A similar finding is obtained by Anderberg and Balestrino (2008), who apply the Epple-Romano logic to subsidies to higher education with credit constraints.[5] De Fraja (2001) studies voting on higher education subsidies and finds that it may result in a (partial) ends-against-the-middle equilibrium as in Epple and Romano (1996): some low ability-low income households vote with the rich for low subsidies. None of these papers, however, explicitly determines households' preferences over different financing schemes.

Our paper proceeds as follows. The next section presents the model, and Section 3 describes the equilibrium. Section 4 presents results from a numerical simulation, with varying parameters. The last section concludes.

2 The Model

2.1 The economy

Our model economy contains an infinite number of heterogeneous households containing one parent and one child, and we assume that all decisions are taken by the parent. Households differ in their financial wealth ω_i, which is distributed with cumulative distribution

[5] Creedy and Francois (1990) also study voting on higher education expenditures. They assume that subsidising higher education benefits non-students through an aggregate externality.

function $G(\omega_i)$ and density $g(\omega_i)$. We assume that higher education costs are a fixed amount $e > 0$ for all households. Because of imperfect credit markets households cannot borrow against future income. Therefore, without financial aid households who are credit constrained will be excluded from obtaining higher education.

Individuals live for two periods. Parents are assumed to be altruistic towards their children and maximise a well-behaved utility function

$$U_i = u(c_i^J + \delta c_i^O), \tag{1}$$

with $u' > 0 > u''$, where c_i^J is consumption of household i when the child is young and c_i^O consumption when the child is old (and parents have died), and δ is the discount factor. Note that, for simplicity, we assume that the intertemporal elasticity of substitution is infinite (see also García-Peñalosa and Wälde, 2000).[6]

When their children are young, parents choose whether to let them study or work. Young workers work in a low-skilled job and earn a wage w_L. When old, the unskilled again work for wage w_L. The 'young' period consists of that period during which students obtain their education (say, 16 to 25 years), which is shorter than the working life period (say, 25 to 65). Therefore, we will assume that the young who work earn wages for a fraction $\gamma < 1$ of an entire period.

Individuals who study do not work during the first period. Successful students earn a high skilled wage w_H in the second period, and we assume that every student is successful with probability p. With probability $(1-p)$ a student fails and works in a low skilled job, earning a wage w_L. The success probability should be interpreted as the probability of obtaining a high skilled job, conditional on having successfully completed a degree. However, in practice unemployment or low-skilled employment of college graduates is usually low, so one may think of p as the probability of obtaining a degree conditional on studying.

Since utility is concave in consumption, households are strictly risk averse. This implies that financing higher education has two functions: a redistributive function and an insurance function against the risk of failure. Throughout the analysis, we assume decreasing absolute risk aversion.

Total production is given by the linearly homogeneous production function $y_t = AF(H_t, L_t)$,

[6] This assumption can be relaxed. In fact, we have also simulated some examples where the elasticity of intertemporal substitution is equal to the inverse of the coefficient of relative risk aversion ρ, but the determination of voting equilibria becomes more complicated.

where H_t is the number (mass) of high skilled and L_t the number of low skilled workers in period t. The parameter A reflects technology. The production function satisfies $F_H, F_L > 0, F_{HH}, F_{LL} < 0$, and $F_{HL} \geq 0$, where subscripts denote partial derivatives. Since we focus on one generation out of an endless overlapping generations model, the high skilled and low skilled consist of young individuals of generation t, as well as the old of generation $t-1$. There are

$$H_t = pN_{t-1}$$

high skilled in period t, where N_{t-1} denotes the successful students from the previous generation. There are

$$L_t = (1-p)N_{t-1} + (1-N_{t-1}) + (1-N_t) = 1 - H_t + 1 - N_t$$

low skilled in period t, i.e., those of the current period who do not study, plus those who either have not studied or not studied successfully in the previous period. We assume profit maximizing firms and perfectly competitive labour markets. Therefore, workers are paid their marginal product in each period, and the wages for high skilled and low skilled, w_H and w_L are given by:

$$w_H = AF_H \tag{2}$$

$$w_L = AF_L. \tag{3}$$

Since $F_{HL} \geq 0$, increasing the number of high skilled will reduce the high skilled wage and increase the low skilled wage (since the number of low skilled falls). Likewise, increasing the number of low skilled will decrease the low skilled wage and increase the high skilled wage. This is one important channel through which education finance affects household preferences.

2.2 Financing Schemes

In this paper we analyse four different financing schemes for higher education: a pure loan scheme (PL), a traditional tax-subsidy scheme (TS), a graduate tax scheme (GT) and income contingent loans (IC).

Pure loan scheme. Consider first the PL scheme. Here, all students are eligible for a loan to cover the direct education costs e. This implies that the credit constraint is never binding. Letting $EU(\omega_i)$ denote the expected utility of studying and $U(\omega_i)$ the (certain) utility of not studying, the endowment of the household who is just indifferent between letting its child study or not, $\hat{\omega}^{PL}$, is implicitly defined by

$$\begin{aligned} EU^{PL}(\hat{\omega}^{PL}) &= pu(\hat{\omega}^{PL} - e + \delta w_H) + (1-p)u(\hat{\omega}^{PL} - e + \delta w_L) & (4) \\ = U^{PL}(\hat{\omega}^{PL}) &= u(\hat{\omega}^{PL} + (\gamma + \delta) w_L). & (5) \end{aligned}$$

We assume that the loan scheme is "pure" in that the interest to be paid equals the market interest rate. Students pay their education costs e (they receive a loan of e in the first period and repay the loan plus interest, e/δ in the second period) and obtain a wage w_H if successful and w_L if unsuccessful.[7] Non-students obtain the wage w_L in both periods (where again first period length is a fraction γ of the second). Since all loans are repaid in period 2, government financing occurs only on paper, that is, government subsidies prepay for the loans of credit constrained students, but the government's intertemporal budget constraint always balances. Therefore, we do not explicitly model subsidies or tax payments, since in fact each student pays for her own education costs.

Since we assume decreasing absolute risk aversion, all households with endowment larger than $\hat{\omega}^{PL}$ will let their children study and all others won't. The number of students under PL is then $N^{PL} = 1 - G(\hat{\omega}^{PL})$.

Traditional tax-subsidy scheme. In the TS scheme, the fraction s of the costs of studying is covered by the government. These public expenditures are financed by a proportional tax levied on the endowments of all households.[8] In purely fiscal terms, this system redistributes from non-students to students, since non-students pay taxes but do not directly benefit from subsidies towards higher education. However, they may benefit indirectly through higher wages (Johnson, 1984).

[7] Implicitly, we assume that even unsuccessful students will be able to repay their loans. In the benchmark simulations, this poses no problem since the unskilled wage always exceeds the loans to be repaid including accrued interest. In the sensitivity analysis where we vary the elasticity of substitution (see Table 3), the unskilled wage does fall below the repayable loan in two cases. We have also simulated the PL system by assuming that the maximum loan to be repaid cannot exceed the unskilled wage, with defaults covered by a tax on the successful graduates. Doing so leads to relatively small changes in majorities. These results are available on request.

[8] García-Peñalosa and Wälde (2000) analyse a quite similar set-up of education finance with lump-sum taxes but argue that a tax on current income seems like a more natural scheme. See also De Fraja (2001).

Households whose child goes to college obtain the following expected utility

$$EU_i^{TS} = pu((1-t^{TS})\omega_i - (1-s^{TS})e + \delta w_H) \; + \; (1-p)u((1-t^{TS})\omega_i - (1-s^{TS})e + \delta w_L), \quad (6)$$

where s is the subsidy rate and t the income tax rate, and the superscript TS denotes the financing scheme.

Households whose children do not pursue higher education achieve utility

$$U_i^{TS} = u((1-t^{TS})\omega_i + (\gamma+\delta)w_L). \quad (7)$$

To ensure a balanced budget, total tax revenue must cover subsidies to all students:

$$t^{TS}\omega \;=\; s^{TS}eN^{TS}, \quad (8)$$

where N^{TS} is the fraction (or number, since total population is set to one) of students and $\omega = \int_0^\infty \omega_i g(\omega_i)d\omega_i$ denotes average income.

Households decide whether or not to let their child study by comparing EU_i^{TS} and U_i^{TS}. Then, the number of students will be determined by the endowment level $\hat{\omega}^{TS}$, where the expected utility of studying equals the utility level for a non-student, if this endowment is larger than the net costs of studying. This endowment is implicitly defined by:

$$EU_i^{TS}(\hat{\omega}^{TS}) \;=\; U_i^{TS}(\hat{\omega}^{TS}). \quad (9)$$

If, on the other hand, the household with income $\hat{\omega}_i^{TS}$ is credit constrained, the equilibrium number of students is given by all those with income above $\bar{\omega}^{TS}$, which is the income level that just covers net education costs:

$$\bar{\omega}^{TS} = \frac{(1-s^{TS})}{(1-t^{TS})}\,e. \quad (10)$$

The equilibrium number of students is then given by:

$$N^{TS} = 1 - G(\tilde{\omega}^{TS}) \quad \text{with} \quad \tilde{\omega}^{TS} = \max\{\hat{\omega}^{TS}, \bar{\omega}^{TS}\}. \quad (11)$$

Graduate tax scheme. Under the GT scheme, every student takes out a loan from the government in period 1. In addition, government subsidises part of the education costs and finances these subsidies by issuing public debt. The debt is repaid in period 2 by a tax on successful graduates. Hence, this system is entirely self-financing and does not require any funding from general taxation.[9]

Consequently, the GT system redistributes from successful to unsuccessful graduates (García-Peñalosa and Wälde, 2000). It also provides insurance against the risk of failure to graduate.

The expected utility level of a household whose child studies under GT is

$$EU_i^{GT} = pu(\omega_i - (1 - s^{GT})e + \delta(1 - t^{GT})w_H) + (1 - p)u(\omega_i - (1 - s^{GT})e + \delta w_L), \quad (12)$$

whereas households with non-students realise utility

$$U_i^{GT} = u(\omega_i + (\gamma + \delta)w_L). \quad (13)$$

Since the expenses for loans distributed in the first period will not be covered until graduation, i.e. the identification of lucky and unlucky students in period 2, government finances educational grants through public debt. The government budget constraint is:

$$\delta t^{GT} w_H p N^{GT} = s^{GT} e N^{GT}, \quad (14)$$

where the left side of equation (14) reflects discounted tax revenue. As can be seen, only successful students pN are taxed to finance the education expenditures granted to the entire cohort of students.

The determination of the number of students proceeds like in the TS scheme. It is given by $N^{GT} = 1 - G(\tilde{\omega}^{GT})$ with $\tilde{\omega}^{GT} = \max\{\hat{\omega}^{GT}, \bar{\omega}^{GT}\}$, where again $\hat{\omega}^{GT}$ denotes the household who is indifferent between letting its child study or not and $\bar{\omega}^{GT} = (1 - s^{GT})e$ is the household whose income just suffices to pay (net of subsidy) education costs.

Income contingent loans. Under the IC system, every student is entitled to a loan from the government in period 1, but only lucky students have to pay back their loans in period 2. The loans of unsuccessful students – who number $(1 - p)N$ – are borne by

[9]This definition of a graduate tax follows García-Peñalosa and Wälde (2000). On the other hand, Del Rey and Racionero (2006), following the terminology of Chapman (2006), call this type income-contingent loans with risk-pooling. In the generally known graduate tax system, there is no specific link between tax revenues and the costs of higher education, but we keep the definition for reasons of comparability.

the entire population via a general tax.[10] The expected utility level for a household whose child studies is

$$EU_i^{IC} = pu(\omega_i - e + \delta(1 - t^{IC})w_H) + (1 - p)u(\omega_i - (1 - s^{IC})e + \delta(1 - t^{IC})w_L), \quad (15)$$

and if the child does not study, household utility is

$$U_i^{IC} = u(\omega_i + (\gamma + \delta(1 - t^{IC}))w_L). \quad (16)$$

Note that for successful students, the subsidy cancels out because the loans received have to be repaid in full in period 2.

The government budget constraint in the IC system is:

$$\delta t^{IC}(pN^{IC}w_H + (1 - p)N^{IC}w_L + (1 - N^{IC})w_L) = (1 - p)N^{IC}s^{IC}e. \quad (17)$$

The left hand side is tax revenue, which comes from three sources: lucky students pN, unlucky students $(1 - p)N$ and non-students $(1 - N)$. The right hand side shows public expenditure for education, which consists of the loans to the unlucky that are not funded.

Again, the equilibrium number of students is given by $N^{IC} = 1 - G(\tilde{\omega}^{IC})$ with $\tilde{\omega}^{IC} = \max\{\hat{\omega}^{IC}, \bar{\omega}^{IC}\}$, where these thresholds are defined as before.

3 Equilibrium

We assume that our game has the following structure: at the first stage, households decide about the financing scheme, at the second stage the equilibrium subsidy is determined within each system by majority voting. And finally, households decide whether to let their child study or not at stage 3. As usual, this game is solved by backward induction.

3.1 Education Decision

Let us first look at the last stage. Having observed the equilibrium subsidy rates for every scheme s^k with $k \in \{TS, GT, IC, PL\}$ (the subsidy level under PL is zero by definition) and the resulting number of students $N(s^k)$, determined by the political voting process in stage 2, households decide about the education of their children. As described before,

[10] Chapman (2006) and Del Rey and Racionero (2006) call this type of student support income contingent loans with risk sharing.

students will be all children of households whose expected utility of studying exceeds the utility of not studying and who are not credit constrained. All those who either do not want to study or cannot study because of credit constraints will work in both periods.

Households are myopic in that they treat the number of students as given, but the equilibrium number of students results from the joint decisions of all households, and is given by

$$N^k = 1 - G(\max\{\bar{\omega}^k, \hat{\omega}^k\}). \tag{18}$$

Note that under PL, the credit constraint is irrelevant as every potenetial student is eligible to receive a loan. Hence, $\bar{\omega}^{PL} = 0$.

3.2 Equilibrium Subsidy Rates

At stage 2, the subsidy level is determined within a given education finance scheme by simple majority voting. Each household votes for her preferred subsidy rate within system $k \in \{TS, GT, IC\}$.

A household with endowment level ω_i will vote for its optimal subsidy s_i^k, which maximizes utility, subject to the relevant budget constraint. A majority voting equilibrium must satisfy the condition that there is no majority favouring a subsidy different from the equilibrium subsidy s^k.

Using the results from the previous stages, we can write the subsidy rate for any system k as $s^k(t)$, where $s^k(t)$ has to satisfy the relevant budget constraint. Likewise, wages can be written as $w_H(t), w_L(t)$, which result from substituting the equilibrium number of students, $N^k(t)$ in (2) and (3). We can then write the utility a household obtains if its child studies, $EU^k(t)$ or does not study, $U^k(t)$ as

$$\begin{aligned} U^k(t) &= u_n(\omega_i, (\gamma + \delta) w_L(t), t) \\ EU^k(t) &= p u_{ss}(\omega_i, \delta w_H(t), s(t), t) + (1-p) u_{sn}(\omega_i, \delta w_L(t), s(t), t), \end{aligned}$$

where subscripts ss, sn refer to the utility of households with successful and unsuccessful students.

Differentiation shows how these utilities react to an increase in t:

$$\frac{dU^k}{dt} = (\gamma+\delta)\frac{\partial u_n}{\partial w}\frac{dw_L}{dt} + \frac{\partial u_n}{\partial t}, \tag{19}$$

$$\begin{aligned}\frac{dEU^k}{dt} &= \delta p\frac{\partial u_{ss}}{\partial w}\frac{dw_H}{dt} + p\frac{\partial u_{ss}}{\partial s}\frac{ds}{dt} + p\frac{\partial u_{ss}}{\partial t} \\ &+ \delta(1-p)\frac{\partial u_{sn}}{\partial w}\frac{dw_L}{dt} + (1-p)\frac{\partial u_{sn}}{\partial s}\frac{ds}{dt} + (1-p)\frac{\partial u_{sn}}{\partial t}. \end{aligned} \tag{20}$$

Each household will in general have two different optimal tax rates, one where the child studies, and one where she does not. When the child does not study, equation (19) shows that there are two effects on household utility: the direct effect, which occurs if the household has to pay taxes in the corresponding regime (as under TS and IC) shown by the last term on the right, and the indirect effect on the low skilled wage. This effect depends on how increasing taxes and subsidies changes the number of students versus non-students and hence, skilled and unskilled wages.

If the child studies, there is also a direct effect of a higher tax on household utility, and additionally the effect of the higher subsidy received by students (the second terms on the first and second line on the right of (20)). Further, the wage effect is split in two: with probability p, the child will succeed and receive the high skilled wage, and with probability $1-p$ she will not succeed and receive the low skilled wage (see the first terms on the first and second line on the right of (20)). The household will vote for whichever tax rate maximises its utility. The voting equilibrium is then determined by the aggregation of households' preferences via majority voting. Since the determination of equilibrium tax rates can be somewhat involved, we leave its description for the several systems to the numerical simulation in the next section.

3.3 Equilibrium Financing Scheme

At the first stage, households vote for a financing scheme. In so doing, they take into account the resulting equilibrium subsidy rate and the equilibrium number of students. We assume pairwise voting over alternatives. The equilibrium system is then defined as that system which beats all others in pairwise voting.

4 Numerical Simulation

In this section, we simulate the model numerically. We calibrate our numerical example to broadly fit relevant parameters from Germany.

4.1 Specification

We use a CRRA utility function:

$$u = \frac{1}{1-\rho} c^{1-\rho} \text{ for } \rho \neq 1, \tag{21}$$

where ρ is the coefficient of relative risk aversion. Hence, we have decreasing absolute and constant relative risk aversion. In the benchmark simulation, we set $\rho = 2$, which seems an empirically plausible value. We also set the discount rate to $\delta = 0.85$.[11] The production function is assumed to be of the CES type:

$$y = A(\alpha H^{\beta} + (1-\alpha)L^{\beta})^{\frac{1}{\beta}} \text{ for } \beta \neq 0 \tag{22}$$

where A describes technological knowledge and is set to $A = 100$, α is set to 0.5, and $\sigma = 1/(1-\beta)$ is the elasticity of substitution. In the benchmark, we use $\beta = -0.1$, which corresponds to an elasticity of substitution $\sigma = 0.909$.

Note that the resulting wages for high and low skilled correspond to lifetime income. The factor $\gamma < 1$ represents the fraction of the period of study to the working life of students, and in the benchmark simulation, we set $\gamma = 0.3$.

The costs of education are measured in 1,000 Euros and are set to $e = 35$.[12] These expenditures reflect all indirect costs such as accomodation, food, books as well as direct costs of studying.[13]

The financial endowment is distributed according to a lognormal-distribution, $\ln \omega_i \sim \mathcal{N}(\mu, v)$ with $\mu = 3.8$ and $v = 0.8$. This results in average endowment $\omega = 61.559$

[11]This value for δ is actually a bit too high, given that it reflects discounting over the two periods of life. However, choosing a lower discount factor generally results in corner solutions where, for instance, all households prefer GT over IC. Results are available upon request.

[12]The value for e comes from *OECD Education at a Glance 2008*, where Table B1.1a. shows annual expenditures on all tertiary education per student for Germany in 2005 of \$ 12.446 (weighted with PPP) multiplied by 3 years duration for higher education.

[13]Strictly speaking, living costs should be compared to the alternative living costs in case where the individual does not study.

Table 1: Equilibrium values for baseline example

	TS	**GT**	**IC**	**PL**
N	0.57	0.46	0.50	0.37
s	0.5621	0.6371	1.0164	–
t	0.2026	0.3733	0.1001	–
w_H	77.57	95.38	87.74	111.93
w_L	31.64	25.17	27.64	20.96
$(w_H - w_L)/w_L$	1.45	2.78	2.17	4.34

and median endowment $\omega^m = 44.701$, with income measured in thousand euros. This distribution is a mix of the data for income distribution and wealth distribution as an exact definition of the sources of financial support is difficult.[14]

Finally, the success probability is set to $p = 0.77$, which seems to correspond well to the proportion of beginning students who graduate with a university degree.[15]

Using these functional forms and parameters, we solve the model numerically for the equilibrium number of students within each system and then determine households' optimal policy parameters for each system. We then study how equilibrium policy parameters are determined. Results are presented in the next subsection.

4.2 Baseline Results

We first characterize the equilibria for all four schemes, and then consider the choice between regimes in the next subsection. Table 1 shows the equilibrium values for the four systems, TS, GT, IC and PL, under our benchmark parameters. Note that for this specification, credit constraints never bind in any financing scheme.

[14]We take the data from *Die wirtschaftliche und soziale Lage der Studierenden in der Bundesrepublik Deutschland 2006 - 18.Sozialerhebung des Deutschen Studentenwerks* and *Deutsches Institut für Wirtschaftsforschung*.

[15]See again *OECD Education at a Glance 2008*, Table A4.1. As emphasised above, since the risk of unemployment of low-skilled employment for college graduates is generally low, this seems to be a good approximation of the probability of finding a skilled job.

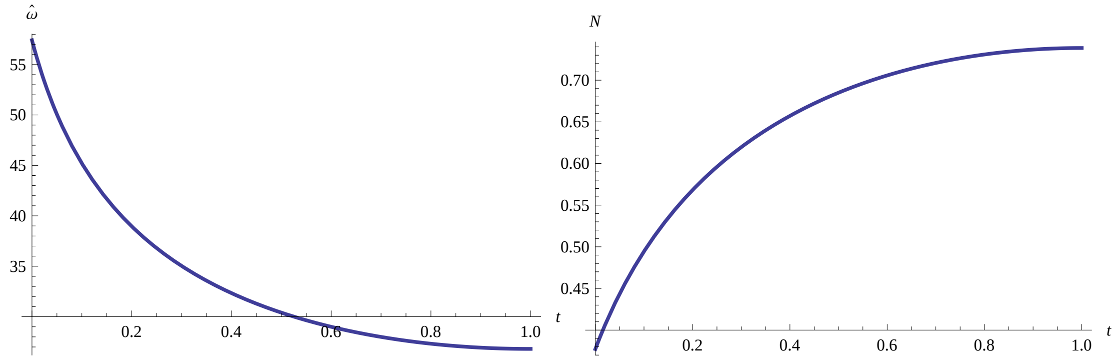

Figure 1: Marginal student and number of students under TS

PL. The results for the PL system are shown in the last column of Table 1. Computing the value of the endowment of the household who is indifferent between studying or not studying, we find $\hat{\omega}^{PL} = 57.409$, which translates into a number of students of $N^{PL} = 0.37$. Thus, about 37% of all households choose to go to college. Previewing the results from the other systems in Table 1, we find that the number of students under PL is lower than under the other systems. This is not surprising, given that there are no subsidies and no insurance against failure in this system. As a result, the skill premium is rather large: the high skilled wage is $w_H = 111.93$ and the low-skilled wage $w_L = 20.96$, which gives a skill premium, $(w_H - w_L)/w_L$, of 434%.

TS. We next turn to the TS system. Here and for the other systems, we first compute the number of students and the endowment of the marginal student for discretely varying tax rates. We then interpolate functions $N(t)$ and $\hat{\omega}(t)$ relating the endogenous variables to the tax rate, which are shown in Figure 1. We then substitute back these functions into the utility functions and determine households' optimal tax rates. The figures show that increasing the tax rate (and subsidy rate) increases the number of students. This makes intuitive sense, since subsidies increase the utility of studying relative to not studying.

As a result, the skill premium falls with the tax rate: Figure 2 shows that the high skilled wage falls and the low skilled wage rises with the tax rate.

Let us then analyse the determination of equilibrium taxes or subsidies. As is often the case in voting problems of this type, the equilibrium tax rate (if it exists) does not necessarily correspond to the optimal tax rate of the household with the median endowment, since preferences satisfy neither single peakedness nor single crossing. Indeed, voting under

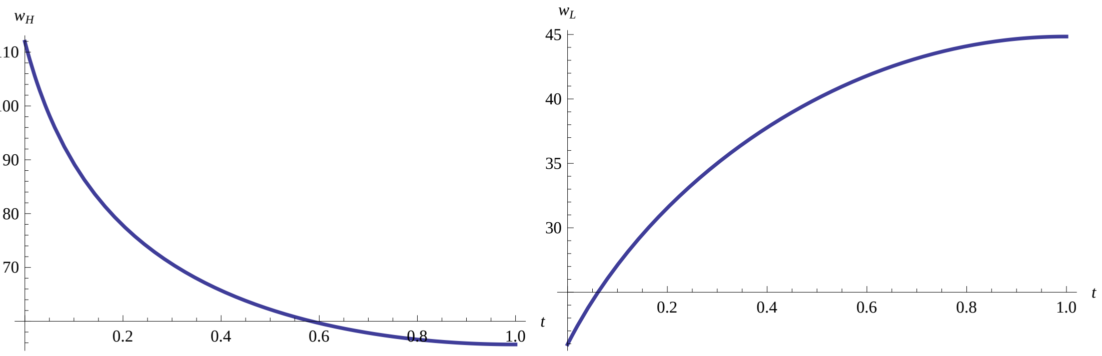

Figure 2: Skilled and unskilled wages under TS

the TS system is a classic candidate for an "ends against the middle" (EATM) equilibrium (see Epple and Romano 1996). Intuitively, this could occur for the following reason: A household's choice of tax rate depends on whether, at a particular tax rate, the household wants its child to study or not. There are some households, who, at their preferred tax rate, do not want their child to study, and they consequently vote for a tax rate, say $t_N(\omega_i)$ (N for not studying), which is decreasing in income. This is intuitive, since the benefit of increased unskilled wages accrues to all households, while the financing costs increase with income. At some endowment, say, $\underline{\omega}$, the household is just indifferent between studying or not, at *its preferred tax rate*. Richer households then vote for a tax rate, say, $t_S(\omega_i)$, at which they prefer to study. Again, these tax rates are declining in income. Intuitively, this is due again to the fact that financing costs increase with income (and in addition, marginal utility is decreasing in income). But, at each income level, $t_S(\omega_i) > t_N(\omega_i)$: the optimal tax rate is higher if one were to study, because of redistribution from non-students to students. Hence, since the optimal tax rate discretely jumps upwards at $\underline{\omega}$, optimal tax rates are not monotonic in income, and the median voter theorem may not hold.

If an equilibrium exists, the median voter might then not be the median income household. Figure 3 portrays this possibility. The EATM equilibrium obtains when the decisive voter has income ω' such that

$$G(\omega') + G(\omega'') - G(\underline{\omega}) = \frac{1}{2}, \tag{23}$$

where the voters with income ω' and ω'' have the same optimal tax rate t', but one of them prefers to study at this tax rate (ω'') and the other one (ω') does not. This may be an equilibrium since there are fifty percent of households who prefer higher tax rates than t',

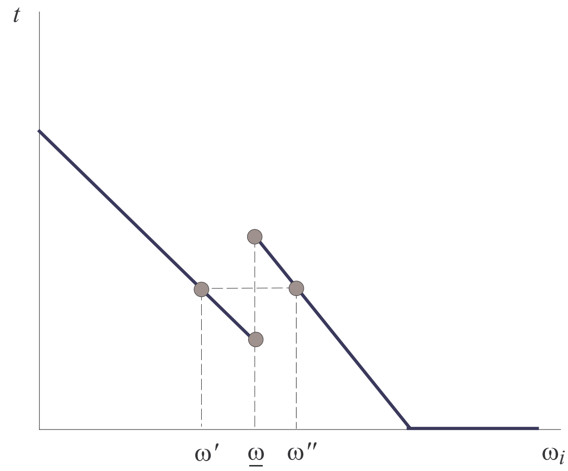

Figure 3: Possible equilibrium under TS

namely those with $\omega_i < \omega'$ and those with $\underline{\omega} < \omega_i < \omega''$.[16]

A necessary condition for the EATM equilibrium to occur is that the median income lie in the interval $[\omega_1, \omega_2]$, where $t(\omega_1) = t_S(\underline{\omega})$ and $t(\omega_2) = t_N(\underline{\omega})$, see Figure 4. Indeed, if $\omega_m < \omega_1$, those fifty percent of voters who are poorer than ω_m prefer a higher tax rate and the other fifty percent a lower tax rate, so the equilibrium tax rate is $t(\omega_m)$.[17] An analogous argument holds if $\omega_m > \omega_2$. In our benchmark example, we find $\underline{\omega} = 34.345$, and this voter has optimal tax rate conditional on studying or not of $t_S(\underline{\omega}) = 0.3289$ and $t_N(\underline{\omega}) = 0.3155$. The median income household's optimal tax rate is $t(\omega_m) = t_S(\omega_m) = 0.2026 < t_N(\underline{\omega})$, so that this is the equilibrium tax rate. The corresponding subsidy rate is 0.5621, or 56% of the costs of studying.

This results in a number of students $N^{TS} = 0.57$, which is actually the highest of any of the systems. The skill premium is correspondingly low: the skilled wage is $w_H = 77.57$, the unskilled wage $w_L = 31.64$, and the implied skill premium is 145%.

[16]Failure of single peakedness and single-crossing implies that the condition in (23) is necessary but not sufficient for an equilibrium. Indeed, one has to check 'by hand' whether there exist other tax rates which command a majority against the equilibrium candidate tax rate identified by condition (23).

[17]Again, we have to check whether another tax rate may beat the optimal tax rate of the median income household, but in our simulations we find this not to be the case.

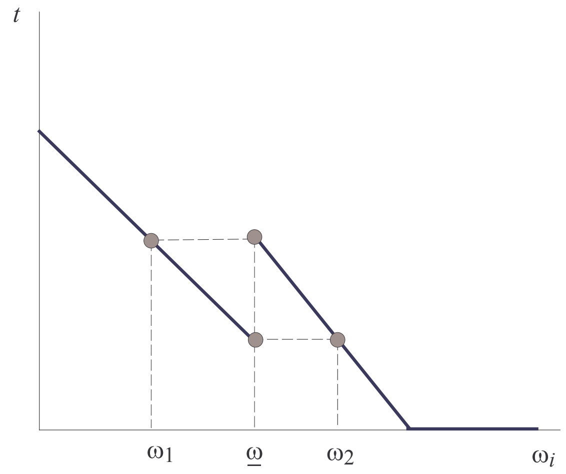

Figure 4: Possible equilibrium under TS (2)

GT. We now turn to the GT system, using the same procedure as described above. Here, the functions $N(t)$ and $\hat{\omega}(t)$ are not monotonically increasing as for TS, but inversely U-shaped or U-shaped as shown in Figure 5. The reason can be seen as follows: let $\Delta^{GT}(\hat{\omega}^{GT}, t) \equiv EU^{GT}(\hat{\omega}^{GT}, t) - U^{GT}(\hat{\omega}^{GT}, t)$ be the utility difference between studying or not studying for the marginal household under GT. Differentiating shows that, since Δ^{GT} is decreasing in $\hat{\omega}$, the income of the marginal household rises with t if Δ^{GT} rises with t. Appendix A shows that this is the case if $(1-t)w_H < w_L$, which will be the case once the tax rate is high enough. Intuitively, when the tax rate is close to one, studying becomes unattractive since the graduates bear the entire tax burden.

Here, the pivotal voter under GT is the household with the median endowment. The preferred tax rate conditional on not studying is identical for all households at $t_N(\omega_i) = 0.3559$ (which is the tax rate that maximises the low skilled wage). For all households with income above $\underline{\omega}^{GT}$, they prefer the tax rate $t_S(\omega_i)$ which is decreasing in income. This follows because with decreasing risk aversion richer households demand less insurance against the risk of failure, and hence, the optimal subsidy rate falls with income. Further, at $\underline{\omega}^{GT}$, the optimal tax rate jumps downward: $t_S(\underline{\omega}^{GT}) < t_N(\underline{\omega}^{GT})$. Hence, optimal tax rates are monotonically decreasing in income and we find that the median income household is

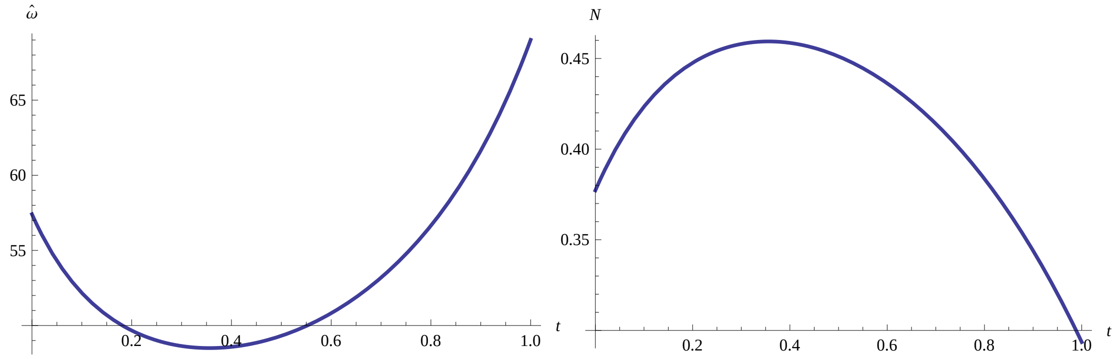

Figure 5: Marginal student and number of students under GT

decisive.[18]

The equilibrium values for GT are shown again in Table 1. The equilibrium tax rate is 0.3733 and the subsidy rate 0.6371. The equilibrium number of students, $N^{GT} = 0.4593$ is lower than under TS, which implies a higher skill premium. We find that the skilled wage is $w_H = 95.38$, the low skilled wage $w_L = 25.17$, which gives a skill premium of about 278%.

IC. Finally, we turn to the IC system. As shown in Figure 6, both functions $N(t)$ and $\hat{\omega}(t)$ are (inversely) U-shaped as already shown for GT. Again, the pivotal voter is the household with median endowment. Like under GT, the optimal tax rate conditional on not studying is identical for all households. Preferred tax rates $t_S(\omega_i)$ for those who prefer $t_S(\omega_i)$ to $t_N(\omega_i)$ are strictly lower than $t_N(\omega_i)$ and decreasing in income. Again, the median income household is decisive.

Table 1 shows the equilibrium values for IC. We find a relatively low tax rate, of 10% and a subsidy rate of 102%. This is possible because the tax base includes all students and non-students, whereas under GT the tax base includes only the successful students. The number of students, $N^{IC} = 0.50$, exceeds that under GT. This can be explained by the fact that redistribution from non-students to students makes studying more attractive, despite the fact that unsuccessful students are subsidised less than under GT. However, the high subsidy rate and low tax rate more than compensate for this. We find skilled wages $w_H = 87.74$, unskilled wages of $w_L = 27.64$ and a skill premium of 217%.

[18] Again, we check for the possibility that some other tax rate may be majority preferred to the optimum of the median income household and find this is not the case.

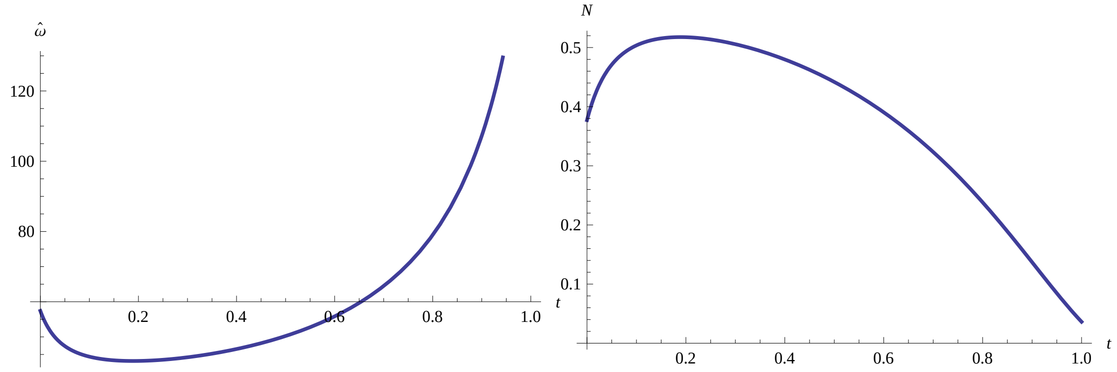

Figure 6: Marginal student and number of students under IC

4.3 Comparison of Regimes

We now proceed to the comparison of the four financing systems by pairwise majority voting.

We start with the choice between TS and GT. Figure 7 plots the differences in indirect utility between GT and TS. Analysing the utility difference shows that all households with income larger than 36.717, or 59.71% of the voting population prefer GT over TS. Thus a majority supports GT. Interestingly, poorer households who do not study under either system tend to prefer TS over GT, even though they do not pay taxes under the GT system. However, the general equilibrium effects imply that TS makes studying attractive, which pushes up unskilled wages. Hence, the poor prefer to subsidize studying through the TS system (see also Johnson (1984)). While under GT, the rich have to relinquish the implicit subsidy from the non-students, they still prefer the GT system since skilled wages are higher, and in addition the GT system provides insurance against the risk of failure.[19]

Next, we look at household preferences between TS and IC, depicted in Figure 8. The results here parallel those of the GT-TS comparison: TS yields higher unskilled wages. For the poor, this is beneficial, even though they have to pay taxes under both the TS and IC system. For the rich, again, there is the positive wage effect and the insurance effect under IC. In sum, the majority for the IC system, 62.94%, is, somewhat larger than the majority for GT over TS.

These results cast some doubt on redistributional arguments for the introduction of graduate taxes or income contingent loans. In fact, if wages are endogenous and subsidies

[19]With some probability, these students will receive the low skilled wage.

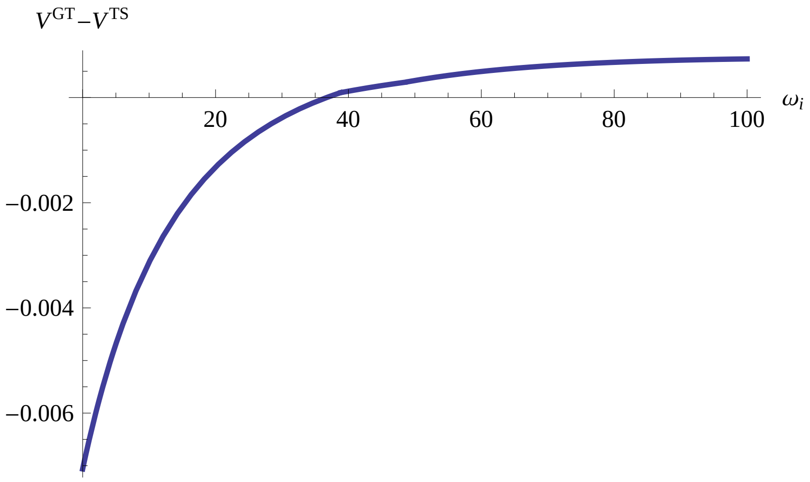

Figure 7: Comparison between GT and TS

chosen by majority voting, our results do not support the usual reverse redistribution argument. Instead, the poor prefer the TS system against either GT or IC.

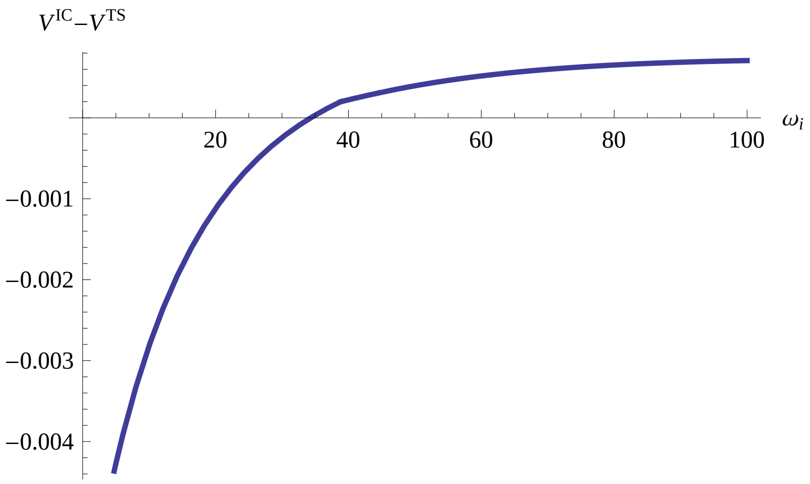

Figure 8: Comparison between IC and TS

The utility difference between GT and IC is shown in Figure 9. We find that all households with income below 67.898 prefer IC. This makes for a majority for IC over GT of 69.93%. At first sight, wealthy students might be thought to prefer IC, since there the non-students have to pay taxes. Also, the IC system provides a larger subsidy at a lower tax rate than GT. Nonetheless, rich students prefer GT because it yields higher skilled wages.

Conversely, the poor prefer IC even though they have to pay taxes. Yet the unskilled wage is higher under IC, so the poor actually prefer this system to the GT system.

The comparison between GT and IC also shows the importance of general equilibrium effects. For instance, García-Peñalosa and Wälde (2000) show that for large enough subsidy rates, a GT system would be preferable to an IC system on the grounds that it implies more insurance against risk, even though the expected income of students is higher under IC. Our example shows, however, that if subsidies are endogenously determined in the political process, the subsidy under IC can be larger than under GT. This tends to increase insurance. On the other hand, the tax on the non-successful students tends to increase the difference in income between successful and unsuccessful students. In the example, we find that IC leads to higher expected income for students but a higher variance of income. Hence, in fact there is somewhat less insurance than under GT. This insurance aspect of GT would be especially valuable for students from middle-income families with relatively large risk aversion (since absolute risk aversion is decreasing in income).

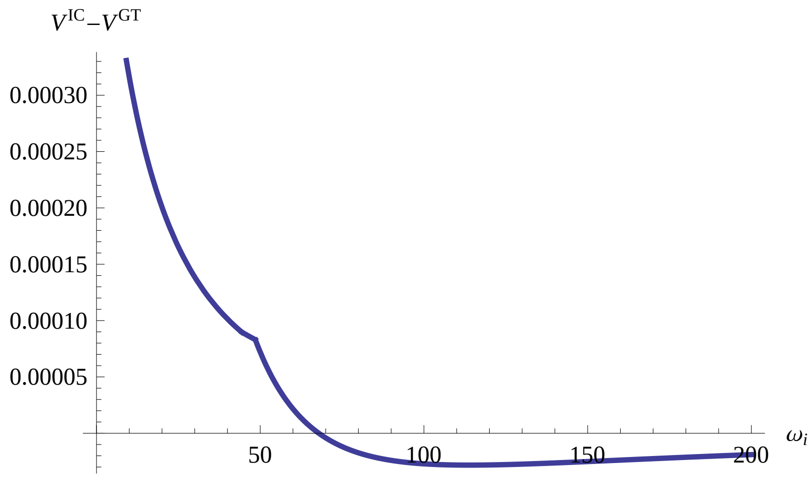

Figure 9: Comparison between GT and IC

At last we analyse the preferences over the PL system against GT, IC, and TS. As can be seen in Figures 11 and 12 only households with a high financial endowment vote for PL over either IC or GT. There are large majorities against PL of 78.74% for GT and 77.59% for IC. For poorer students the insurance function of IC and GT outweighs the taxes they have to pay. Very rich students on the other hand, have a sufficiently low degree of risk aversion that they benefit from the absence of subsidies under PL. For the poor non-students, PL is not attractive even though under this system they do not have to subsidise students. The same, of course, is true under GT, so non-students prefer the system with higher unskilled wage, which is GT. They also prefer IC over PL, however, even though they have to pay taxes, because here the low skilled wage under IC is even higher than under GT. The majority for TS over PL is somewhat lower at 65.48%. While non-students benefit from the high unskilled wage under TS, the middle class students benefit from redistribution from non-students and rich students under TS, even though they receive lower skilled wages if successful. The rich students who pay most under TS obviously have a preference for PL. This finding again shows that the TS system may not be regressive, as argued by Johnson (1984) and others: if subsidies were abolished and students had to pay their own way, the rich, not the poor, would stand to gain.

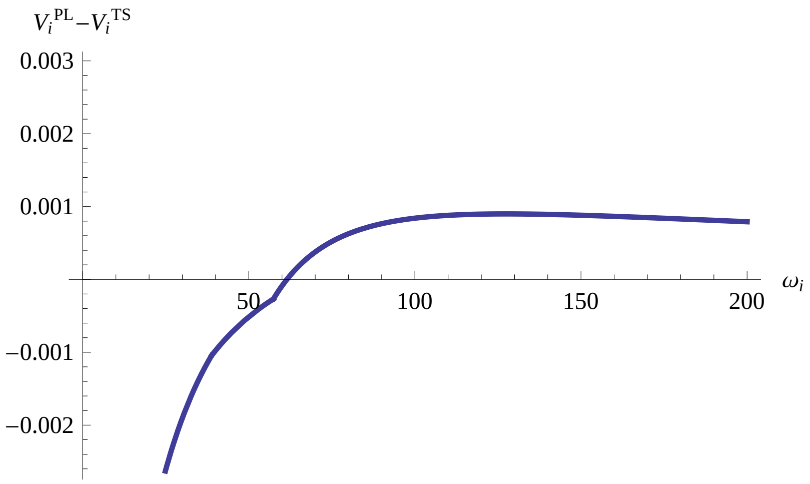

Figure 10: Comparison between TS and PL

In summary, in the benchmark example, IC beats all other systems and would be chosen in a pairwise majority vote among the four systems. The PL system loses against all others. Note also that IC beats TS and PL, and the majority for GT over IC is relatively small, so one may immediately think that varying parameters would change the majorities. In the next subsection, we explore to what extent this is the case.

4.4 Sensitivity Analysis

In this subsection, we study the effects of varying parameters on the equilibrium of our model. Here, we present variations of the coefficient of relative risk aversion, the elasticity

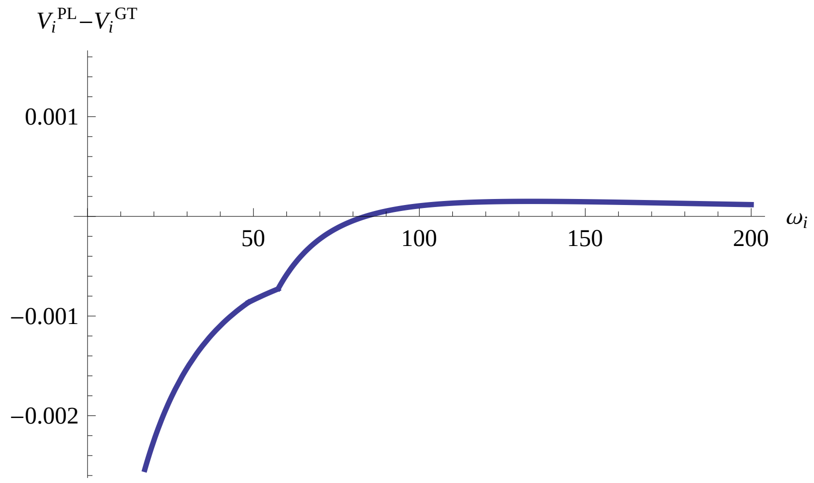

Figure 11: Comparison between GT and PL

of substitution and the parameters of the income distribution. Risk aversion is obviously important since the systems insure against the risk of failure to different degrees. The elasticity of substitution is important for how low skilled wages react to an increase in the high skilled population. The income distribution plays a decisive role in political-economic models of redistribution with linear income taxes (see Borck, 2007, for a survey).

First, we increase ρ from 2 to 2.5. This increased risk aversion will make studying less attractive, other things equal. In the PL system, the number of students consequently falls from 38% in the baseline case to 33%. Consequently, skilled wages rise and unskilled wages fall. However, in the other systems, there will be a response through changed subsidies. Indeed, the subsidy rate increases in all systems, reflecting the increased demand for insurance. Tax rates rise as well. As a result, the equilibrium numbers of students change by relatively little (compare the first column of Table 2 with Table 1). The effects on the voting equilibrium are mostly relatively small as well. Support for PL against all systems decreases somewhat.

Increased risk aversion would tend to increase the demand for insurance, and one would tend to think that this increases support for those systems that provide more of it. In fact, the majority for GT over TS increases from 60 to 61% and that for IC over TS from 63% to 64%. However, the majority of IC over GT increases from 70% to 77%. This despite the fact, as mentioned above, that the variance of incomes for students is larger under IC than under GT. However, the increased risk aversion actually reduces the difference in those

Table 2: Sensitivity analysis

System	N	w_H	w_L	s	t	$(w_H - w_L)/w_H$
			$\rho = 2.5$			
TS	0.58	76.24	32.24	0.6297	0.2349	1.36
GT	0.45	96.26	24.92	0.6905	0.4101	2.86
IC	0.50	87.53	27.72	1.0549	0.1044	2.16
PL	0.33	123.53	18.66	–	–	5.62
			$m = 3.7$			
TS	0.57	77.99	31.46	0.5646	0.2269	1.48
GT	0.46	95.63	25.10	0.6525	0.3837	2.81
IC	0.50	87.68	27.66	1.0275	0.1014	2.17
PL	0.36	115.54	20.19	–	–	4.72
			$v = 0.9$			
TS	0.59	74.62	33.00	0.6273	0.2170	1.26
GT	0.46	95.36	25.18	0.6838	0.3742	2.79
IC	0.50	87.74	27.64	1.0164	0.1002	2.17
PL	0.38	110.99	21.16	–	–	4.24

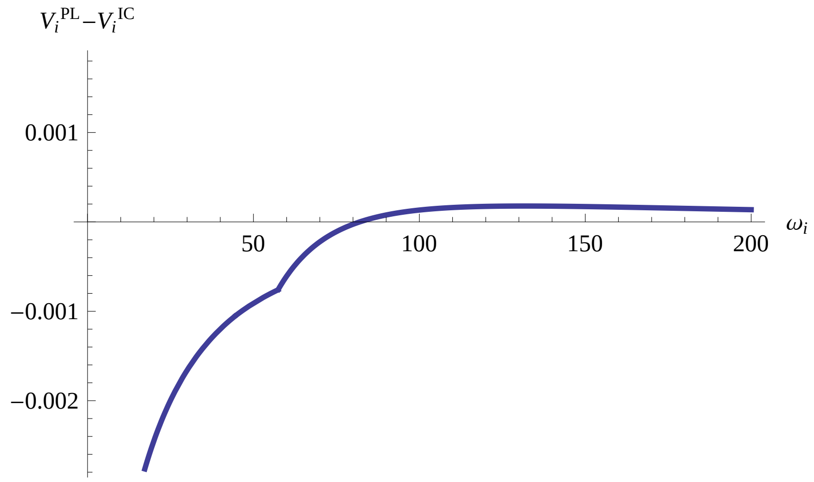

Figure 12: Comparison between IC and PL

variances between IC and GT. In fact, as can be seen from Table 3, the skilled wage rises under GT with increasing ρ whereas it falls under IC. Therefore, the majority of IC over GT actually rises.

Next, we look at the effect of varying the parameters of the income distribution. We first decrease m to 3.7. This leaves the skewness unchanged, but decreases both mean and median income. As the table shows, the effect on the numbers of students and wages does not seem huge. However, there is a clear political effect: since the median voter gets poorer, she votes for a higher tax rate under TS. Since the average tax base has fallen, however, the subsidy rate under TS rises only very slightly. This makes TS less attractive. Consequently, we find that the majorities for GT and IC over TS increase to 61% and 65%.

Now, we look at what happens when we make the distribution more skewed by increasing v to 0.9. While median endowment stays constant, this increases mean income. Again, the results do not change dramatically in terms of the number of students and wages under the several systems. Again, however, there is an interesting political effect: since the tax base rises with higher v, the median voter now benefits more from redistribution and votes for a higher tax rate. Since the average tax base has increased, this strongly increases the subsidy rate. The result is to increase support for TS. We find that the majority for GT over TS shrinks to 51% and the majority of IC over TS shrinks to 55%. Increasing v even further eventually leads to a majority for TS over GT and IC. Thus, a reform of higher education finance to a graduate tax or income contingent loans is more likely, the lower

Table 3: Sensitivity analysis (2)

System	N	w_H	w_L	s	t	$(w_H - w_L)/w_H$
			$\sigma = 0.999$			
TS	0.63	103.87	49.52	0.5770	0.2356	1.10
GT	0.55	119.39	42.11	0.7066	0.3203	1.84
IC	0.59	112.11	45.31	1.1178	0.0860	1.47
PL	0.46	137.54	35.71	–	–	2.85
			$\sigma = 1.11$			
TS	0.70	144.39	77.13	0.5954	0.2730	0.87
GT	0.64	157.50	68.92	0.8464	0.2849	1.29
IC	0.67	150.46	73.11	1.3105	0.0763	1.06
PL	0.56	174.27	60.65	–	–	1.87
			$\sigma = 0.77$			
TS	0.45	47.91	12.95	0.5586	0.1554	2.70
GT	0.28	72.41	7.93	0.6291	0.5416	8.13
IC	0.33	63.79	9.32	0.8443	0.1214	5.84
PL	0.24	80.22	6.90	–	–	10.62

per capita income or the more equal the income distribution is.

Finally, we vary the elasticity of substitution. To do this, we calibrate parameters A and α using the procedure described by Klump and de La Grandville (2000) (see Appendix B for further details). We use the same parameters for the calibration of A and α than in the previous subsection, namely $A = 100$ and $\alpha = 0.5$. We then solve the PL system for $\beta = -0.1$ and find the benchmark values of L_H^0 and L_U^0. Using these, we then calibrate α and A as described in Appendix B. The results are described in Table 3. We use four values of β: -0.1 (the starting value, corresponding to $\sigma = 0.909$), -0.0001 (which approximates the Cobb-Douglas case with $\sigma = 0.999$), 0.1 ($\sigma = 1.111$) and -0.3 ($\sigma = 0.77$).

We would expect the variation of β to affect the skill premium. From (22), we can write the skill premium as

$$\ln\left(\frac{w_H}{w_L}\right) = \ln\left(\frac{\alpha}{1-\alpha}\right) - \frac{1}{\sigma}\ln\left(\frac{H}{L}\right). \tag{24}$$

If $H > L$, increasing σ increases the skill premium, for given share of the high skilled, and conversely, when $H < L$, increasing σ reduces the skill premium. Second, increasing the share of high skilled obviously decreases the skill premium, but less so the larger is the elasticity of substitution. In fact, what we find is that the combined effect is that in all systems, more families will send their children to university when σ increases, which decreases the equilibrium skill premium.

The results of our exercise are shown in Table 3. For instance, in the TS system, the skill premium falls from 270% to 145%, 109% and 87% as β increases from -0.3 to -0.1, -0.0001 and 0.1. The same is true in the other systems. The fall in skill premium is least pronounced in the TS system. For instance, increasing β from -0.1 to 0.1 decreases the skill premium by about 30% in the TS system, while the decrease is between 44% and 63% for the other systems. There are also effects on the tax and subsidy rates. As β increases, the tax and subsidy rate increases under TS. For GT and IC, the tax rate falls and the subsidy rate rises. Thus, IC and GT should become more attractive with rising β on the account of increasing subsidies and falling taxes. However, the relatively strong fall in the skill premium should make them less attractive to students.

And lastly, the majority for or against one of the systems also depends on the identity of the median voter and the marginal voter, i.e. the household who is just indifferent between the two systems. The median voter does not study under any system for $\beta = -0.3$. She starts studying under TS and IC at $\beta = -0.1$, under GT at $\beta = -0.0001$, and lastly under PL for $\beta = 0.1$. The marginal voter for the choice between IC and GT is always a household with a child that studies. We find that increasing β monotonically increases support for GT over IC, as the marginal voter is made better off. For the choice between GT and TS, however, the marginal voter is a household whose child is a non-student under both systems for $\beta = -0.3$ and $\beta = -0.1$, student under TS only for $\beta = -0.0001$, and a student under both GT and TS for $\beta = 0.1$. As a consequence, going successively from $\beta = -0.3$ to $\beta = 0.1$, the majority for GT first increases slightly from 59.16% to 59.71%, then decreases to 59.28% and finally increases to 61.25%. A similar pattern holds for the comparison between IC and TS. The majorities between IC or GT and PL are extreme except for $\beta = -0.1$: for $\beta = -0.0001$ or $\beta = 0.1$, all households prefer GT or IC over PL, while conversely for $\beta = -0.3$ everyone prefers PL. In summary, the effects of varying the elasticity of substitution are relatively complex and may be non-monotonic.

5 Conclusion

We have studied the political determination of higher education finance. In particular, our interest was to analyse what factors might contribute towards reforming higher education finance from a traditional tax-subsidy scheme to income contingent loan schemes (also called income contingent loans with risk sharing) or graduate taxes (viz. income contingent loans with risk pooling). Because we have allowed for endogenous wage determination, general equilibrium feedback effects are present, which implies that comparative statics are mostly non-trivial. Nonetheless, under our assumptions, we find that majorities for GT or IC become larger when risk aversion rises, the elasticity of substitution rises (although this effect may be non-monotonic) or when the income distribution becomes less skewed, or median income falls for given skewness. In principle, one could test whether societies with different degrees of inequality or risk aversion, or different production technologies, have differing propensities to choose one or the other financing system.

There are some possible extensions of the model that come to mind. For one thing, we have assumed that the elasticity of intertemporal substitution is infinite. It may obviously be desirable to relax this assumption. A straightforward way to do this would be to assume a separable intertemporal utility function with the elasticity of intertemporal substitution being the inverse of the coefficient of risk aversion. We have actually computed examples with this specification, but do not report them here, since the determination of voting equilibria gets even more complex. Results, are, however, avaiable on request. Another way forward would be to allow for heterogeneous abilities (see Del Rey and Racionero, 2006). Doing this would be relatively straightforward, but combining income and ability heterogeneity would again complicate the determination of voting equilibria. Another interesting extension would be to allow for the possibility of moral hazard especially in the GT system. Individuals may not have the proper incentive to study successfully if they know that they will not have to repay their loans. This would reduce the incentives to vote for higher subsidies and would obviously affect the voting equilibrium.[20] Finally, an interesting question that we plan to pursue in future work is what happens if different countries choose different financing regimes, with students and possibly workers selecting into countries based on their preferences.

[20]See Nerlove (1975). Chapman (2006) argues that the moral hazard problem is less pronounced with income contingent loans (what he calls ICL with risk sharing).

Appendix

A Derivation of $d\hat{\omega}^{GT}/dt$

The income of the indifferent voter $\hat{\omega}^{GT}$ is implicitly defined by

$$\begin{aligned}\Delta^{GT}(\hat{\omega}^{GT},t) = EU^{GT}(\hat{\omega}^{GT},t) - U^{GT}(\hat{\omega}^{GT},t) = pu(\hat{\omega}^{GT} - e + \delta(1-(1-p)t)w_H) \\ + (1-p)u(\hat{\omega}^{GT} - e + \delta tpw_H + \delta w_L) - u(\hat{\omega}^{GT} + \delta w_L + (\gamma+\delta)w_L) = 0,\end{aligned} \tag{A.1}$$

use having been made of (14). Differentiating (A.1) gives

$$d\hat{\omega}^{GT}/dt = -(d\Delta^{GT}/dt)/(d\Delta^{GT}/d\hat{\omega}^{GT}),$$

where

$$\frac{d\Delta^{GT}}{d\hat{\omega}^{GT}} = pu'_{ss} + (1-p)u'_{sn} - u'_n \tag{A.2}$$

$$\frac{d\Delta^{GT}}{dt} = -\delta p(1-p)w_H(u'_{ss} - u'_{sn}), \tag{A.3}$$

where u'_n, u'_{ss}, u'_{sn} refer to the marginal utility of non-students, successful and unsuccessful students. Since decreasing absolute risk aversion implies that with small risk, $d\Delta^{GT}/d\hat{\omega}^{GT} > 0$, the sign of $d\hat{\omega}^{GT}/dt$ is given by sign of

$$sign(u'_{ss} - u'_{sn}) = sign(w_L - (1-t)w_H). \tag{A.4}$$

B Calibration of α and A

Our procedure follows Klump and de La Grandville (2000). Writing the production function in intensive form and the marginal rate of substitution, we have

$$y = A\left(\alpha\left(\frac{L_H^0}{L_U^0}\right)^{\beta} - \alpha + 1\right)^{\frac{1}{\beta}} \tag{A.5}$$

$$m = \frac{(1-\alpha)(L_H^0)^{1-\beta}(L_U^0)^{\beta-1}}{\alpha} \tag{A.6}$$

This system can be solved for A and α to give:

$$A = y_0 \left(\frac{L_U^0 m_0 (L_H^0)^\beta + L_H^0 (L_U^0)^\beta \left(\frac{L_H^0}{L_U^0}\right)^\beta}{L_U^0 m_0 (L_H^0)^\beta + L_H^0 (L_U^0)^\beta} \right)^{-1/\beta} \tag{A.7}$$

$$\alpha = \frac{L_H^0 (L_U^0)^\beta}{L_U^0 m_0 (L_H^0)^\beta + L_H^0 (L_U^0)^\beta}, \tag{A.8}$$

which are functions of L_H^0, L_U^0, y_0 and m_0. Using the benchmark values for L_H^0 and L_U^0, found by solving the PL system for $A = 100, \alpha = 0.5$ (see Table 3), we then substitute into (A.5) and (A.6) to find y_0 and m_0. Substituting these into (A.7) and (A.8) finally gives A and α as functions of β only. For our example, we get $A(-0.01) = 144.547, A(0.1) = 229.151$, $\alpha(-0.01) = 0.536, \alpha(0.1) = 0.58$.

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