UNIVERSITY TUITION SUBSIDIES AND STUDENT LOANS: A QUANTITATIVE ANALYSIS

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Abstract

We use a calibrated macroeconomic model to examine the different effects of university tuition and student loan policies aimed at improving access to public higher education. Student loans that condition repayment on future income substantially improve access. The significant fiscal cost of such loans can be offset by reducing current tuition subsidies, without significantly impairing access. The impact of such policies on graduation rates is smaller than on enrolment rates and even the most effective measures leave a very large gap between rich and poor. None of these policies has a significant effect on the economy's total output.

1. INTRODUCTION

Governments facing fast-growing demand for broader access to subsidized public higher education are finding they cannot maintain the quality of a rapidly expanding university system without raising taxes. Wishing to avoid this, many are contemplating, or have already implemented, reductions in tuition subsidies which are often coupled with student loan programs aimed at easing liquidity constraints, and in many of these programs repayment of the loan is conditioned on future income so as also to absorb some of the risk of a university education.

Those who oppose such steps warn that raising tuition undermines the role of the university as an instrument of social mobility but professional economic opinion generally supports these policies, arguing that it is inadequate access to credit rather than the level of tuition that deters worthy but disadvantaged students from enrolling in higher education. Tuition subsidies, the argument goes, introduce an inefficient distortion of incentives while student loans directly address the problem of insufficient liquidity without wasting resources that could otherwise be channeled to better purposes. Moreover, as access to higher education is regulated not only by tuition but also by academic requirements, the students who benefit most from tuition subsidies generally come from higher-income families, so that current subsidies are regressive in effect. The aim of this paper is to gauge the relative importance of these different effects by simulating different combinations of tuition subsidies and student loans within a

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calibrated macro model and quantifying their effect on access to higher education, on fiscal cost, and on aggregate measures of efficiency, income distribution and intergenerational income mobility.

The need for simulation arises because of the limited empirical evidence we have on these issues. We have no systematic evidence of the effect of these policies on efficiency: what we know about their effect on access draws largely on raw international comparisons, and fiscal costs can be seen to vary widely among countries. We know, for example, that Australia and New Zealand, despite adopting cost-based tuition and income-contingent loan programs, maintain tertiary enrolment rates that are as high as or higher than countries such as Denmark, France, Germany, Ireland and Sweden, which charge little or no tuition (OECD, 2003, Table C2.1).[1] However, these countries´ education systems differ in many other ways too, which must cloud the comparison. In the United States, where university tuition is substantially higher, and funding arrangements are less comprehensive, econometric analysis indicates that liquidity constraints have little effect on college enrolment rates (Carneiro and Heckman, 2002; Cameron and Taber, 2004), though access to the most prestigious—and most expensive—programs remains strongly conditioned on socioeconomic background.

The fiscal costs of student loan programs exhibit considerable variation. Recovery rates are far from perfect even in well-run programs due to interest rate subsidies, administrative costs, and loan default. Barr (2004, p. 241) estimates that "in the United Kingdom a third of all money lent to students is not repaid" and Ziderman and Albrecht (1995) reach similar conclusions. Chapman and Ryan's (2005) estimate for Australia is lower, between 15% and 25%. Experience with loan programs in newly industrializing countries varies even more widely, with some, notably Hong Kong, administering relatively low-cost loan programs while in others, such as Thailand, loan recovery rates are so low as to render their loan programs effectively equivalent to tuition subsidies (Ziderman, 2004).[2]

Several recent studies have used calibrated simulations to assess the impact of tuition and loan policies,[3] and we continue in this vein, defining and calibrating a decision-based, general equilibrium, macro model with a centralized system of higher

[1] On Australia's Higher Education Contribution Scheme (HECS), see Department for Education Science and Training (2004) and Chapman and Ryan (2005) among others; on funding of higher education in New Zealand, see Ministry of Education/Tertiary Education Commission (2003). For an overview of higher education funding in various countries see (UK) Department for Education Services (2004). On higher education funding reform in Great Britain, patterned on Australia's HECS, see House of Commons (2004) and Barr and Crawford (2005).

[2] Both Hong Kong's and Thailand's programs score high in reaching needy candidates. Ziderman (2004) also describes less successful programs in South Korea, the Philippines and China.

[3] Among these are Heckman, Lochner and Taber (1998), Keane and Wolpin (2001), Caucutt and Kumar (2003), Akyot and Athrea (2005), Gallipoli, Meghir and Violante (2006), Garriga and Keightley (2007) and Lochner and Monge-Naranjo (2008).

education, which we use to simulate different tuition and loan policies. However, several key assumptions set our model apart from earlier efforts.[4]

First, we condition both enrolment and graduation on academic achievement. Thus higher education acts as a "double filter" (Arrow, 1973) in which academic tests imperfectly correlated with true ability regulate both admissions and graduation. Prospective students who meet academic entry requirements decide whether to attend university or not, and graduation is a stochastic variable positively correlated with ability.[5] This captures the importance of non-monetary barriers to access: even when liquidity constraints are resolved, academic admission standards must be met to gain entry; and even if admission standards are waived there is no point attending university unless there is a good chance of graduating. Both filters limit the improvement in access that can be achieved through tuition and loan policies;[6] and graduation requirements limit the potential efficiency loss that results from allowing students with a weak prior record of academic achievement to enrol in higher education.

The endogenous determination of wages in the model departs from previous treatments in two important ways. First, the marginal products of skilled and unskilled labor, on which individual wages are based, are derived from a nested CES production function in which capital equipment is a close substitute for unskilled labor but not for skilled labor. This follows Krussel et al.'s (2000) empirical analysis and allows us to capture what we believe is an essential point which simpler functional forms miss: the fall in the education premium is checked by increases in the stock of capital equipment making up for the decline in the share of unskilled labor.[7] Absent such a mechanism, a

[4] The higher-education system described in our model, in which university attendance is a discrete choice rather than a continuous decision on the quantity of education purchased, is nearer to the more centralized, public systems of higher education operating in most European countries, Canada, Australia, New Zealand and Israel, which charge uniform tuition across institutions that offer similar quality, than to higher education in the United States, which is offered in a much wider range of unregulated qualities and prices. (But previous efforts geared to modeling higher education in the United States, while possibly allowing students to choose the quantity of education they acquire ignore the wide range of quality and prices available; cf. Lochner and Monge-Naranjo, 2008; Caucutt and Kumar, 2003; Akyol and Athreya, 2005. The quality-price dimension seems crucial for assessing access in the United States.) Our central assumptions regarding the importance of academic tests in determining both entry and graduation—the economy's ability to substitute capital equipment for unskilled labor, and the combined role of human capital and signaling in determining wages—are valid for both types of system.

[5] Modeling the production of skills through higher education as a function of material resources and student effort is beyond the scope of this paper. Costrell (1993, 1994) and Betts (1998) model the effect of admissions and graduation policies on student effort, and Garriga and Keightly (2007) offer a quantitative analysis of college behavior as a multi-period risky investment in which students decide how many credits to take and how much effort to invest in their completion. However, there are as yet no reliable empirical estimates of academic production functions that link university inputs and output, largely because of the difficulty of measuring university output (Ehrenberg, 2004).

[6] The practical significance of this point is illustrated by Bratti et al.'s (2008) empirical study, which shows that the expansion of higher education in Italy had limited effect on inequality in achievement precisely because greater access, while significantly raising enrolment rates, had a much smaller effect on the probability of graduating.

[7] Studies of higher education that do not take this effect into account include Heckman, Lochner and Taber (1998), who argue that ignoring general equilibrium effects overestimates the enrolment response to a tuition subsidy by an order of magnitude as increases in enrolment will be dampened by a

large expansion of higher education should result in a substantial fall in the education premium, which has not been the case in the last three decades.[8]

In addition, we assume that individual wages ultimately reflect not only the specific ability of individual workers but also the average productivity of skilled and unskilled labor respectively, as employers cannot immediately discover individual productivity. This attributes a signaling effect to higher education in addition to its role in building human capital.[9] As such an effect imputes negative externalities to education, it implies that a market solution without the use of academic filters to regulate access to higher education and graduation is not "first best" even when students pay full tuition costs (Gilboa and Justman, 2005).

Another important feature of our model is our detailed analysis of intergenerational mobility. Broader access to higher education independent of parental background is at the core of the public debate on financing higher education and is widely viewed as a social goal in its own right, not only in terms of its effect on the distribution of income.[10] To gauge the effect of different policies on social mobility we model ability and parental income as following a joint bivariate lognormal distribution, which we calibrate to empirical observations and then follow in our simulations the impact of different policies on the enrolment and graduation rates of prospective students stratified by parental income quintiles, and on an aggregate measure of intergenerational income mobility.

Liquidity constraints play a central role in the model. Following Becker (1975) and Cameron and Taber (2004) among others, we assume that absent government intervention, students from poor families face a higher rate of interest in financing their education than do students from more affluent homes, and this also constrains their spending on consumption while they are studying. This captures the flexibility of the liquidity constraint that families face in funding higher education and the restrictions that both formal and informal lenders typically place on the uses to which students can apply borrowed funds, and yields a monotonically increasing relationship between initial human capital before higher education and both enrolment and graduation rates.[11]

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consequent decline in the wage premium; and Caucutt and Kumar (2003) and Akyol and Athreya (2005), who see the main benefit of tuition subsidies in lowering the college premium, which reduces risk.

[8] Other work has emphasized the role of skill-biased technological change in maintaining the education premium (e.g., Bartel and Sicherman, 1999).

[9] There is extensive evidence that education contributes to individual earnings through both channels. See Weiss (1995) for an early review of the empirical evidence.

[10] The literature that examines the link between aspects of the parents' socioeconomic status and their children's educational achievements includes recent work by Cameron and Heckman (1998, 2001), Ellwood and Kane (2000), Keane and Wolpin (2001), Carneiro and Heckman (2002), Restuccia and Urruria (2004), Justman and Gilboa (2006) and Belley and Lochner (2007). Earlier work is reviewed by Haveman and Wolfe (1995).

[11] Many recent studies model liquidity constraints as a cap on student lending. However, as Lochner and Monge-Naranjo (2008) point out, absent a restriction on consumption, this implies a negative link between ability and investment in higher education (for empirically observed values of the inter-temporal elasticity of substitution), which contradicts the positive link observed in the data. They resolve this by combining a credit cap with the stipulation that student loans cannot be used to finance

The benchmark we use to calibrate the model is based on the Israeli economy and its centralized higher education system, which offers three- and four-year bachelor degrees at a fixed level of annual tuition. Tuition is proportionately comparable to that in public universities in the United States, Great Britain, Australia and New Zealand, with full tuition for a degree costing roughly half the average annual salary of a high school graduate, or about one third of annual per capita GDP. There is no way of precisely separating teaching costs from research at a university, but taking the budgeting practices of Israel's Council of Higher Education as a guideline, we assume that tuition covers about half of university teaching costs. Admissions are regulated by academic criteria and calibrated in the model to approximate current enrolment and graduation rates in Israel. There is no significant student loan program, and liquidity constraints in the benchmark case are set to approximate the distribution of student enrolment by parents' socioeconomic status.

After calibrating the model we simulate different combinations of tuition levels and student loan policies, and compare their effects. The policies we consider are the benchmark case of partial tuition subsidies without student loans; student loans that cover tuition and living expenses coupled with the current levels of tuition subsidies; student loans without tuition subsidies; and student loans with contingent repayment, which forgive some or all of the debt incurred depending on the student's wage income, combined with partial tuition subsidies and with no tuition subsidies. Each policy is evaluated assuming it is applied over the time required for a full turnover of the labor force, and in each case we calculate enrolment and graduation rates by parents' income quintile as a direct measure of access; the intergenerational correlation of income as an aggregate measure of income mobility; the Gini coefficient of lifetime wage income and the college wage premium as indicators of wage inequality; indices of aggregate output and variation in aggregate utility as indicators of efficiency; loan recovery rates; and the tax rate required to cover tuition subsidies and unpaid loans.

Previewing the results of these simulations, we find that student loans in themselves have only a small positive effect on access to higher education, though providing student loans allows tuition subsidies to be removed with little adverse effect on access, thus freeing fiscal resources for other worthwhile purposes or enabling a reduction of taxes. Absorbing some of the risk of higher education by conditioning repayment of student loans on the student's income after entering the workforce substantially improves access for students from low-income families, increasing both enrolment rates and, to a lesser degree, graduation rates. This supports Akyol and Athreya’s (2005) emphasis on the importance of risk aversion as an inhibiting factor that limits access to higher education. Nonetheless, the scope for improvement is limited, and differences in enrolment and graduation rates between students from different socioeconomic backgrounds remain large. The high fiscal cost of contingent repayment of loans can be offset by removing tuition subsidies with little sacrifice of access.

The general increases in graduation rates caused by student loans leads to a fall in wage inequality, and generally has a positive effect on total output, but these effects are

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non-schooling-related consumption. Our introduction of academic filtering further reinforces the positive link, in our model, between pre-college ability and enrolment.

proportionally so small as to be dwarfed by important elements ignored in our analysis including the costs of administering the program, the scope for abuse, the extent of incomplete information among college candidates, and the role of non-economic factors in education decisions. The effect of these policies on aggregate utility, as an imperfect general indicator of welfare, is generally even smaller in proportional income-equivalent terms and indeterminate.

Our general approach builds on two important economic perspectives on education: macroeconomic analyses of how the accumulation of human capital affects intergenerational mobility and wage inequality (e.g., Becker and Tomes, 1979; Loury, 1981; Bénabou, 1996; Durlauf, 1996; Hassler and Rodriguez-Mora, 2000) to which we add structural detail; and more structured analyses of higher education (Arrow, 1973; Stiglitz, 1975; Danziger, 1990; Loury and Garman, 1993; Fernandez and Gali, 1999; Epple, et al., 2003) which we place in a general equilibrium context. The issues we consider here are closely related to work by Bertocchi and Spagat (2004) and Checchi et al. (1999) on the impact of education systems on income inequality and social mobility; to empirical analyses of the impact of different funding schemes on access to higher education, such as Keane (2002) and Chapman and Ryan (2005), and Barr's (2004) integrative essay; and more directly to calibrated analyses of student loans and tuition subsidies by Heckman, Lochner and Taber (1998), Keane and Wolpin (2001), Caucutt and Kumar (2003), Akyol and Athreya (2005), Gallipoli, Meghir and Violante (2006), Garriga and Keightley (2007) and Lochner and Monge-Naranjo (2008). None of these incorporates academic barriers to entry and graduation or uses an aggregate production function with different elasticities of substitution between capital and skilled and unskilled labor or allows that higher education has a signaling effect in the labor market. Finally, the basic structure of the model developed in this paper draws on our earlier calibrated analysis of university admission standards (Gilboa and Justman, 2005).

The paper is organized as follows: in Section 2 we describe the model; in Section 3 we calibrate it; in Section 4 we compare different funding policies as they affect access, distribution, mobility, output, welfare and fiscal costs; and Section 5 concludes. In an appendix we fill in some of the technical details and present sensitivity analyses.

2. THE MODEL

We define a model in which parents automatically bequeath innate abilities to their children and invest economic resources in their early development. Children then reach young adulthood with a record of prior achievement, which indicates their academic potential. A centralized system of higher education regulates admissions on the basis of this prior indicator.[12] Those offered admission decide whether to enrol, pay tuition, and

[12] The present analysis focuses on tuition policies, and so holds fixed an admissions criterion similar to that generally applied in Israel's higher education system. This criterion is income-neutral. Gilboa and Justman (2005) focus on academic admissions requirements and consider also income-based affirmative action admissions policies that favor applicants from low-income households. The two types of policy could be combined in the model without difficulty, as described in note 16 below.

lose paid employment while they study. In the benchmark case, these costs are funded through the family at an interest rate that decreases with parental income. Those who choose to study and then successfully graduate earn a degree that opens the door to employment in skilled jobs; those without degrees work in unskilled jobs. Workers earn a wage equal to a weighted average of their own marginal product value and of the average marginal product value of their occupation—skilled or unskilled. Young adults anticipate their future wages in deciding whether to study or not, and we focus on equilibria in which their anticipations are realized.

2.1 The household, before higher education

Consider an economy with a continuum of households, each comprising a parent and child, and take parents' after-tax income as exogenously given.[13] Denote the lifetime disposable income of the parent in household i by y_i, and assume it is distributed lognormally in the population with mean μ_y and variance σ_y^2, $\ln y_i \sim N(\mu_y, \sigma_y^2)$. Denote by a_i the unobservable "innate ability" of the child in household i and assume that it is positively correlated with parental income:[14]

(1) $\ln a_i = \ln y_i + u_{ai}$,

where u_{ai} is an independent, normally distributed disturbance term with zero mean and variance σ_{ua}^2.

The child's pre-college level of human capital h_i is determined by her innate ability and by additional parental investment, b_i :

(2) $\ln h_i = A + \alpha \ln a_i + \delta \ln b_i$,

where A, α, γ, and δ are constants. Assuming parents' investment in their child's cognitive development is proportional to income,[15] $b_i = \xi y_i$, we have after substitution

(3) $\ln h_i = A + \delta \ln \xi + (\alpha + \delta) \ln y_i + \alpha u_{ai}$,

which implies that $\ln h_i$ is also normally distributed, with mean and variance

[13] We will assume a balanced budget constraint, for completeness. However, as the higher education funding policies on which our analysis focuses have a very small effect on government spending, for practical purposes, tax rates can be ignored (and as we show in a sensitivity analysis). In Israel the total government higher education budget, for teaching and research, is about 0.8% of GDP, and assuming half of that is for teaching, total government spending on teaching in higher education amounts to 0.4% of GDP, which is about 1% of tax revenues. Moreover, one could argue that fluctuations in the government's higher education spending are generally not translated into variation in the tax rate but rather affect other budget items, such as repayment of public debt.

[14] This correlation stems from genetic or cultural factors, which "money can't buy". In Justman and Gilboa (2006) we show that even in *kibbutzim* (communal villages) there is a substantial positive correlation between children's test scores and their parents' education— which in the general population is positively correlated with earnings.

[15] This implicitly assumes that parents' investment of economic resources in their children's early development cannot be financed by borrowing against their children's future income—this is a capital market imperfection that cannot be resolved—and that investment in education is independent of children's ability (this holds if the elasticity of substitution between consumption and education equals one).

(4) $\mu_h = A + \delta \ln \xi + (\alpha + \delta)\, \mu_y$,

(5) $\sigma_h^2 = (\alpha + \delta)^2 \sigma_y^2 + \alpha^2 \sigma_{ua}^2$.

We assume that individuals know their own human capital h_i but that university admissions officers have access only to a stochastic entry score t_i that summarizes their record of prior achievement, and which is positively correlated with h_i:

(6) $t_i = \ln h_i + u_{ti}$,

where u_{ti} is an independent, normally distributed disturbance term with zero mean and variance σ_{ut}^2. After substitution we have

(7) $t_i = A + \delta \ln \xi + (\alpha + \delta) \ln y_i + \alpha u_{ai} + u_{ti}$,

so that t_i is also normally distributed, with the same mean as h_i but larger variance:

(8) $\mu_t = A + \delta \ln \xi + (\alpha + \delta)\, \mu_y = \mu_h$,

(9) $\sigma_t^2 = (\alpha + \delta)^2 \sigma_y^2 + \alpha^2 \sigma_{ua}^2 + \sigma_{ut}^2$.

2.2 Higher education

There is a centralized system of higher education in the economy that offers a single degree. It specifies a threshold θ for the observable entry score t_i as an academic requirement for admission.[16] Students who meet this requirement and choose to enrol, pay an annual tuition fee P (which may or may not cover the full cost of education). In order to graduate, they must attend school for T_e years and earn a passing grade $\underline{s}$, where grades are a stochastic function of human capital:

(10) $s_i = \ln h_i + u_{si}$

and u_{si} is an independent, normally distributed disturbance term with mean zero and variance σ_{us}^2. Substitution shows that s_i is normally distributed with mean and variance

(11) $\mu_s = \mu_t = \mu_h$,

(12) $\sigma_s^2 = (\alpha + \delta)^2 \sigma_y^2 + \sigma_{ua}^2 + \sigma_{us}^2$.

Students who fail to attain a passing grade drop out of school after T_d years and enter the labor market as non-graduates performing unskilled jobs; failure occurs before the full course of study is completed, $T_d < T_e$, so only partial tuition and living costs are

[16] A more general form of admission criteria, considered in Gilboa and Justman (2005), is $\phi t_i + (1 - \phi) \ln y_i \geq \theta$, where $\phi > 1$ yields income-based affirmative action policies that favor applicants from lower-income households, and $\phi = 1$ yields a purely "merit-based" criterion that ignores parental income. To focus here on the effect of tuition policies we hold fixed a merit-based admissions criterion.

incurred. Graduation opens the door to skilled jobs.[17]

Whether or not the student graduates successfully, there are tuition and living costs to be funded, and we assume in the benchmark case that the capital market for funding them is imperfect. Students may be able to fund some of these costs through part-time work but are dependent on their parents for substantial support, whether from the parents' own resources or from external sources for which the parent co-signs. We assume that this dependence constrains students' borrowing for consumption while they study—whether through formal constraints set by external lenders or implicit constraints which parents place on their children while they support them. To simplify the analysis we ignore earnings from part-time employment while studying at university, and set annual consumption while at university exogenously (and uniformly) equal to c_0; hence, annual financing needs are $P + c_0$. We assume that the cost of financing these needs is a decreasing function of parental income, so that students from lower-income homes face higher financing costs. This may stem from the lower (opportunity) cost of funding this expense by reducing savings as opposed to the higher (out-of-pocket) cost of incurring additional debt; or from the higher expected recovery costs that lenders may anticipate when lending to parents with less liquid assets. Denote by $r(y_i)$ the rate of interest paid by a household with parental income y_i, and assume that it is weakly decreasing in income with

$$(13) \qquad r(y_i) \geq r_0 \ ,$$

where r_0 is the market rate of interest, and strict inequality holds at least for lower incomes.

It follows from the preceding exposition that the four variables ln y, ln h, t and s share a joint multivariate normal distribution. Straightforward calculation yields the following correlation between pairs of variables:

$$(14a) \qquad \rho_{yt} = (\alpha + \delta)\, \sigma_y / \sigma_t \ ,$$

$$(14b) \qquad \rho_{ys} = (\alpha + \delta)\, \sigma_y / \sigma_s \ ,$$

$$(14c) \qquad \rho_{yh} = (\alpha + \delta)\, \sigma_y / \sigma_h \ .$$

$$(14d) \qquad \rho_{hs} = \sigma_h / \sigma_s \ ,$$

$$(14e) \qquad \rho_{ht} = \sigma_h / \sigma_t \ ,$$

$$(14f) \qquad \rho_{ts} = \sigma_h^2 / [\sigma_t\, \sigma_s] \ .$$

[17] As discussed in note 4 above, graduation is a dichotomous variable—employers do not look at grades, and do not distinguish between those who fail at college and those who do not enroll. The model could be extended to allow graduation to enhance human capital by a variable factor of $\beta > 1$, so that a person entering college with human capital h_i graduates with human capital βh_i, where β is a function of university inputs. However, it is not possible to identify β from macro data when skilled and unskilled labor are distinct factors of production; and identifying it from micro data would require an econometric estimate of the production function of higher education, on which there is little agreement (Ehrenberg, 2004). The absence of a quantitative empirical link between education quality and the cost of education also prevents us from using the model to explore related issues of optimal quality in higher education.

2.3 Production and wages

We assume that production in the economy is undertaken by a continuum of identical firms producing a single homogeneous good using the same constant-returns-to-scale production function. Aggregate output equals

(15) $Y = F(H_u, H_s, K)$,

where H_u is the unskilled human capital of nongraduates, H_s is the skilled human capital of graduates and K is the stock of capital equipment. Let w_u denote the average wage per unit of unskilled human capital, w_s the average wage per unit of skilled human capital, and p the rental cost of a unit of capital equipment.[18] We assume that employers cannot fully or immediately observe individual human capital, hence a worker i in occupation k ($k = u, s$) earns a pre-tax income y_{ki} that is proportional to individual ability, h_i, and the average ability of workers in her occupation, denoted h_k :

(16) $y_{ki} = w_k [\upsilon h_i + (1 - \upsilon) h_k]$,

where $0 < \upsilon < 1$. This is consistent with the general empirical finding (see Jencks, 1972, among others) that measured cognitive ability has little effect on earnings at early ages, exercising its greater influence later in the life cycle. The cost of tuition subsidies and of incomplete recovery of contingent loans, when offered, is funded by a proportional tax on wage income, at the tax rate τ.[19]

Except for the decision to study, the supply of labor is inelastic.[20] An individual who does not attend college works for T_u years; a graduate studies for T_e years and works for $T_s = T_u - T_e$ years; and one who studies but fails to graduate studies for T_d years and works for $T_f = T_u - T_d$ years.

2.4 The decision to study

Assume that the lifetime utility V of individual i is a discounted integral of temporal utility U at the subjective discount rate η , where temporal utility $U = U(c_{it})$ is an increasing concave function of consumption by individual i at time t. Individuals seek to maximize their expected utility given their anticipation of future skilled (graduate) and unskilled (nongraduate) wage rates and of average skilled and unskilled human capital, and we assume that all individuals share the same anticipated values,

[18] In general, factor prices may vary over time. For simplicity, we limit our analysis to an equilibrium in which individuals anticipate stationary factor prices.

[19] We assume that the government is able to offer (non-contingent) student loans at the market rate of interest at no extra cost through an infrastructure of tax collection which allows it to recover debts at a lower variable cost than that in the private sector.

[20] Gallipoli, Meghir and Violante (2006) show that allowing a variable supply of labor increases wage inequality among households.

(17) $\omega = (w_s^e, w_u^e, h_s^e, h_u^e, \tau)$.

Consider first a person who does not attend university. To simplify the analysis, assume that the borrowing rate of interest she faces is no lower than η and that her lending rate is no higher than η so that she has no incentive to shift income from one period to the next. Then her lifetime utility conditioned on her human capital h_i and on ω, *is* given by

$$(18)\qquad V_u(h_i,\omega) = \int_0^{T_u} U((1-\tau)w_u^e[\upsilon h_i + (1-\upsilon)h_u^e])e^{-\eta t}dt \quad .$$

Next, consider skilled workers who attend university and incur a debt to cover their tuition and living expenses. The size of the debt upon graduation and entry into the workforce depends on parental income and equals

$$(19)\qquad B_s(y_i) = \int_0^{T_e} (P + c_0)e^{-r(y)t}dt \quad .$$

Assume that once the individual is in the workforce, this debt can be refinanced at the uniform interest rate r_0 to be repaid in a continuous constant stream of

(20) $R_s(y_i, h_i, \omega) = \gamma_s(h_i, \omega)\, B_s(y_i)\, r_0 \,/\, (1 - e^{-r_0(T_u - T_e)})$,

where $\gamma_s(h_i, \omega) \leq 1$ is strictly less than one when repayment of student loans is contingent on income and graduate i's income $y_{si} = w_s\,[\upsilon\, h_i + (1 - \upsilon)\, h_s]$ falls below the relevant threshold. The lifetime utility of a skilled worker, conditioned on her human capital, on parental income, and on anticipated ω is then

$$(21)\qquad V_s(y_i,h_i,\omega) = \int_0^{T_e} U(c_0)e^{-\eta t}dt + \int_{T_e}^{T_u} U((1-\tau)w_s^e[\upsilon h_i + (1-\upsilon)h_s^e] - R_s(y_i,h_i,\omega))e^{-\eta t}dt \ .$$

Similarly, an individual who enrolls in university but fails to graduate incurs a debt of

$$(22)\qquad B_f(y_i) = \int_0^{T_f} (P + c_0)e^{-r(y)t}dt \quad ,$$

which is repaid in a continuous constant stream of

(23) $R_f(y_i, h_i, \omega) = \gamma_u(h_i, \omega)\, B_f(y_i)\, r_0 \,/\, (1 - e^{-r_0(T_u - T_f)})$,

where $\gamma_u(h_i, \omega) \leq 1$ is as above, for unskilled workers. Her expected lifetime utility, similarly conditioned, then equals

(24) $$V_f(y_i,h_i,\omega)=\int_0^{T_d}U(c_0)e^{-\eta t}dt+\int_{T_d}^{T_u}U((1-\tau)w_u^e[\upsilon h_i+(1-\upsilon)h_u^e]-R_f(y_i,h_i,\omega))e^{-\eta t}dt\ .$$

A person with an entry score $t_i \geq \theta$ that meets the admissions requirement will choose to enrol in higher education if it increases her expected lifetime utility, taking into account her probability of graduating, conditioned on her human capital h_i, her parent's income y_i, and anticipated ω (see Appendix B for a derivation of the joint distribution of $\ln h_i$ and s_i given $\ln y_i$ and t_i). Denoting the cumulative density function of s conditioned on h_i by $G(s \mid h_i)$, $G(\underline{s} \mid h_i)$ is the probability that a student with human capital h_i will fail to graduate if she enrols, and $1 - G(\underline{s} \mid h_i)$ is the probability that she succeeds. A prospective student expects to gain from attending college if her expected lifetime utility if she enrolls is greater than her lifetime utility if she does not enrol:

(25) $$V_u(h_i,\omega)\ \leq\ G\left(\underline{s}\mid h_i\right)V_f(y_i,h_i,\omega)\ +\ \left(1-G\left(\underline{s}\mid h_i\right)\right)V_s(y_i,h_i,\omega)\ .$$

2.5 Equilibrium

We assume that each cohort has measure one; that all capital, labor and product markets are competitive, except for the funding of education and imperfect observation of human capital; and that the supply of capital equipment is perfectly elastic at the exogenous price p.[21] We focus on an equilibrium in which the value of the marginal product of each of the factor inputs equals its price or wage; all anticipations are realized; markets clear; the distribution of human capital across graduate and non-graduate labor in each cohort is the same; and the government's budget is balanced.

To set out these conditions explicitly, let $g(y, h, t, s)$ denote the joint density of y, h, t and s and assume that the admission criterion θ and the graduation threshold $\underline{s}$ are given. Let $\psi(y,\omega)$ denote the set of values of h for which (25) holds for candidates with parental income y, given the vector of anticipated values ω; these are the values of h for which candidates with parental income y, anticipating ω, choose to attend college.[22] Then the share of graduates in a cohort, given a vector of anticipated values ω, is

(26) $$\varphi_s(\omega)=\int_{-\infty}^{\infty}\int_{h\in\psi(y,\omega)}\int_{\theta}^{\infty}\int_{\underline{s}}^{\infty}g\left(y,h,t,s\right)ds\,dt\,dh\,dy\ .$$

The share of those who enter university but fail is

[21] In effect we are assuming that changes in the proportion of skilled workers are gradual enough for capital to adjust without a change in its price.

[22] It seems intuitively plausible that for every value of y_i there should be a unique threshold level of human capital $\underline{h}(y_i,\omega)$ that satisfies (25) with equality, such that individual i applies to study in higher education if and only if $h_i \geq \underline{h}(y_i,\omega)$. However, we were not able to prove this generally and did not use it in the numerical solution of the model, though we found it always held.

(27) $$\varphi_f(\omega) = \int_{-\infty}^{\infty} \int_{h\in\psi(y,\omega)} \int_{\theta}^{\infty} \int_{-\infty}^{\underline{s}} g\left(y,h,t,s\right) ds\, dt\, dh\, dy \ .$$

The share of those who do not attend university, either because they choose not to or because they do not meet the entry requirement, is the remainder[23]

(28) $\varphi_n(\omega) = 1 - \varphi_s(\omega) - \varphi_f(\omega)$.

It follows that the measure of skilled workers in the workforce in equilibrium is $T_s\ \varphi_s(\omega)$; the measure of unskilled workers who enrolled in higher education but failed to graduate is $T_f\ \varphi_f(\omega)$; and the measure of unskilled workers who did not enrol in higher education is $T_u\ \varphi_n(\omega)$.

Similarly, the total human capital of skilled workers in equilibrium is

(29) $$H_s(\omega) = T_s \int_{-\infty}^{\infty} \int_{h\in\psi(y,\omega)} \int_{\theta}^{\infty} \int_{\underline{s}}^{\infty} h\, g\left(y,h,t,s\right) ds\, dt\, dh\, dy \ ,$$

so that the average human capital of a skilled worker is

(30) $h_s(\omega) = H_s(\omega) / [T_s\ \varphi_s(\omega)]$.

The total human capital of unskilled workers who attended higher education but failed is

(31) $$H_f(\omega) = T_f \int_{-\infty}^{\infty} \int_{h\in\psi(y,\omega)} \int_{\theta}^{\infty} \int_{-\infty}^{\underline{s}} h\, g\left(y,h,t,s\right) ds\, dt\, dh\, dy \ .$$

The total human capital of unskilled workers who did not attend higher education is

(32) $$H_n(\omega) = T_u \left[\int_{-\infty}^{\infty} \int_{h\notin\psi(y,\omega)} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} h\ \ g\left(y,h,t,s\right) ds\ dt\ dh\ dy + \int_{-\infty}^{\infty} \int_{h\in\psi(y,\omega)} \int_{-\infty}^{\theta} \int_{-\infty}^{\infty} h\ \ g\left(y,h,t,s\right) ds\ dt\ dh\ dy \right] .$$

Consequently, the total human capital of unskilled workers equals

(33) $H_u(\omega) = H_n(\omega) + H_f(\omega)$,

[23] $\varphi_n(\omega) = \int_{-\infty}^{\infty} \int_{h\notin\psi(y,\omega)} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} g\left(y,h,t,s\right) ds\, dt\, dh\, dy + \int_{-\infty}^{\infty} \int_{h\in\psi(y,\omega)} \int_{-\infty}^{\theta} \int_{-\infty}^{\infty} g\left(y,h,t,s\right) ds\, dt\, dh\, dy$

and their average level of human capital is

(34) $h_u(\omega) = H_u(\omega) / [T_f \varphi_f(\omega) + T_u \varphi_n(\omega)]$.

An equilibrium is then a vector $\omega^* = (w_s^*, w_u^*, h_s^*, h_u^*, \tau^*)$ and a stock of capital equipment, K^*, such that

(35) $h_s(\omega^*) = h_s^*$,

(36) $h_u(\omega^*) = h_u^*$,

(37) $\frac{\partial F}{\partial H_s}(H_u(\omega^*), H_s(\omega^*), K^*) = w_s^*$,

(38) $\frac{\partial F}{\partial H_u}(H_u(\omega^*), H_s(\omega^*), K^*) = w_u^*$,

(39) $\frac{\partial F}{\partial K}(H_u(\omega^*), H_s(\omega^*), K^*) = p$,

and the government budget is balanced.

3. CALIBRATION

Calibrating the model to observed empirical variables allows us to derive a quantitative indication of how changes in the financing of higher education affect access, mobility, distribution, output, and fiscal cost. Our benchmark is the Israeli economy with its centralized higher education system. Tuition subsidies cover about half of teaching costs and the government does not offer a comprehensive student loan program. (A summary of calibration values is presented in Table 1.)

We describe aggregate production by a nested constant elasticity of substitution (CES) function:

(41) $Y = A\{\nu(H_u)^{\psi} + (1-\nu)[\lambda(K)^{\varsigma} + (1-\lambda)(H_s)^{\varsigma}]^{\psi/\varsigma}\}^{1/\psi}$,

and adopt the elasticities estimated by Krusell et al. (2000) for the United States economy, $\zeta = -0.495$, and $\psi = 0.401$, which imply an elasticity of substitution of 1.67 between skilled and unskilled labor, and between capital equipment and unskilled labor, and an elasticity of substitution of 0.67 between capital equipment and skilled labor.[24]

[24] We use Krusell et al.'s estimates only for the elasticities. The other parameters of the production function are calibrated to Israeli data. There are no estimates of these elasticities for the Israeli economy but we believe the values derived from the United States economy provide a better approximation of Israel's advanced industrialized economy than the more easily estimated logarithmic form.

Thus capital equipment is a substitute for unskilled labor and a complement of skilled labor. The remaining parameters are scaling parameters, which are calibrated to Israel's business sector in 2003. The (gross) return on investment in capital equipment is set equal to p = 12%. Wages are determined as an equally weighted average of own human capital and the average human capital of similarly skilled workers, $\upsilon = 0.5$ (in our sensitivity analysis we simulate the model for $\upsilon = 0.4$ and $\upsilon = 0.6$).

Income, human capital, entry scores and course grades—ln y, ln h, t and s—are assumed to follow a multivariate normal distribution,[25] the parameters of which are related to observed empirical values as follows:

- The mean and variance of the logarithm of parental income, μ_y and σ_y^2, are derived from the distribution of net household income in Israel in 2003.[26]
- The marginal distributions of entry scores and course grades are assumed to be standardized normal, with $\mu_t = \mu_s = 0$ and $\sigma_t^2 = \sigma_s^2 = 1$. This implies that the logarithm of human capital μ_h also has zero mean.
- The correlation ρ_{yt} between parental income and entry scores is set equal to 0.25, which is within the range of empirical estimates of the correlation between parental income and pre-college aptitude test scores.[27]
- The correlation between parental income and course grades is assumed to be the same as between parental income and entry scores:[28] $\rho_{ys} = \rho_{yt} = 0.25$.
- The correlation between entry scores and course grades ρ_{ts} is calibrated to estimated correlations between pre-college aptitude test scores and first-year college grades,[29] and set equal to 0.5.

The remaining entries of the variance-covariance matrix—σ_h^2, σ_{hy}, σ_{ht}, and σ_{hs}—are then calculated directly from these values (see Appendix A for details of the derivations).

We assume that graduation requires four years of study, $T_e = 4$;[30] total tuition for the degree equals about one half of the annual salary of an unskilled worker, which we spread over four years; and annual living expenses while studying equal one third of the average wage of an unskilled worker. A student who fails is assumed to study for half the time, $T_d = 2$, and pay half the tuition.[31] The total working life of a graduate after graduation is $T_s = 40$; hence $T_f = 42$ and $T_u = 44$. We posit an annual household

[25] The multivariate normal distribution provides a tractable framework for parametrizing the joint distribution of these variables. The assumption that income follows a lognormal distribution is common in empirical work, though other assumptions are clearly possible (see, e.g., Harrison, 1981).

[26] Mean gross monthly income per household in 2003 was NIS 10,385, and median income was NIS 9,200 (Statistical Abstract of Israel, 2005, Table 5.31).

[27] These vary between 0.17 and 0.3 (Hearn 1991; Owen 1985; Alwin and Thornton 1984; Paulhus and Shaffer 1981).

[28] This is an arbitrary determination: because of the wide variation in grading standards, it does not seem reasonable to calibrate ρ_{ys}, the correlation in the population at large, to empirical correlations between parental income and college grade-point averages.

[29] *Cf.* Bridgman, McCameley-Jenkins and Ervin (2000) and Kennet-Cohen, Bronner and Oren (1998).

[30] Arts and sciences degrees are three year programs; engineering, accounting and law are four-year programs (to accreditation). Of course, many students take longer to complete their studies.

[31] This accords with Stinebrickner and Stinebrickner's (2007) finding that the median time to dropping out is two years.

discount rate of η = 6% and assume that the temporal utility function has a constant coefficient of relative risk aversion (CRRA) equal to 1.2, that is, $U(c) = -c^{-0.2}$ (in our sensitivity analysis we simulate the model for CRRA values of 1.05 and 1.35).

In calibrating the benchmark case we set the admissions threshold equal to $\theta = -0.2$, that is, one fifth of a standard deviation below the mean, and set the final pass score $\underline{s}$ equal to 0, the mean score in the population as a whole.[32] Education costs, beyond the government subsidy, are self-financed in the benchmark case at an interest rate that decreases with household income y:

$$r(y) = 0.06 + 0.06\, y_m / y \quad , \tag{42}$$

where y_m is median income (in our sensitivity analysis we simulate the benchmark case for six other interest rate schedules; the interest rate schedule is relevant only for the benchmark case). The interest rate in subsequent periods is $r_0 = 0.06$, which is the same as the subjective inter-temporal discount rate. This yields an enrolment share in higher education of 41.4%, which is slightly lower than the first-year enrolment share in tertiary education in Israel, 43.6%; and a share of graduates equal to 27.1%, slightly higher than the share of graduates in Israel's workforce, which is about 25% (Statistical Abstract of Israel, 2005, Table 14.7).

The ratio we obtain of the average wage of nongraduates to that of graduates is 0.4, which is lower than the ratio of 0.54 observed in the workforce of the wages of workers with less than a college education to that of workers with a college education or more, (Statistical Abstract of Israel, 2005, Table 12.42).[33] This can be seen as reflecting added advantages of a college degree, such as more stable employment and social status. The Gini coefficient of lifetime wage income we obtain equals 0.217, which is lower than observed values of the Gini coefficient computed for annual income. This can be attributed to our use of permanent income to calculate the Gini coefficient in the calibrated model, which is less variable than annual income used in empirical calculations,[34] and to the simple occupational structure of our model, which allows only two skill levels. We measure relative social mobility through the intergenerational correlation of the logarithm of incomes between parents and their children. It equals 0.389 in the benchmark case, which is well within the range of values obtained for advanced industrialized economies.[35] Figure A1 in Appendix C compares the

[32] Admissions in Israel are generally "merit-based" with very little affirmative action.

[33] We were not able to calibrate the model with the lower, observed, wage ratio. This is consistent with skilled jobs having other advantages besides better pay, such as higher social status and better working conditions.

[34] Lillard (1977) found that the Gini coefficient for annual earnings is 50 percent larger than for lifetime income, which suggests that our benchmark calibration is roughly consistent with observed values.

[35] This last measure is closely related to the most commonly used measure of intergenerational mobility—the elasticity of income with respect to parental income. If ε denotes the intergenerational earnings elasticity obtained from a simple regression of sons' log earnings y on fathers' log earnings x, s_y and s_x respectively denote their sample standard deviations, and r_{xy} denotes their correlation coefficient, then $r_{xy} = \varepsilon\, s_x / s_y$ (Johnston, 1972, p. 34). Thus if the variances in log earnings are about the same for parents and their children, the two are roughly equal (Solon, 2002). We use the correlation

cumulative distribution function of children's wage income in equilibrium in the benchmark case with the parents' distribution of income. The dichotomous occupational structure assumed in the model induces a bimodal density function.

The distribution of college enrolment shares by quintile of parental income in the benchmark case is presented in the first column of Table 2. The second column presents the distribution of enrolment rates in Israel 2003 by the socioeconomic quintile of the student's local authority of residence (Statistical Abstract of Israel, 2005, Table 8.36). Graduation rates by parents' income quintile are presented in the third column of the table. These enrolment and graduation rates, obtained in the benchmark case, appear also in the first column of Table 3, as a reference point for comparison to other policies, with the summary measures of access, inequality, mobility, output and fiscal cost, discussed above.

4. SIMULATION OF ALTERNATIVE FUNDING POLICIES

We now apply our calibrated model to simulate different university funding policies:

- removing liquidity constraints by offering loans at preferred market rates to cover tuition and living expenses during studies;
- removing tuition subsidies; and
- offering contingent loans that reduce individual risk by allowing repayment to depend on future income.

We gauge the incremental effect of these policies on access to higher education, fiscal cost, income distribution, intergenerational mobility, and output, after a full turnover of the labor force. Access is measured through enrolment and graduation rates by quintiles of parental income; fiscal cost is measured as an index in relation to fiscal cost in the benchmark case; distribution is measured as the Gini coefficient of lifetime labor income; (relative) mobility is measured as the intergenerational correlation of income; and output is measured as an index, in relation to the benchmark case. In addition we provide a measure of aggregate welfare computed, for each policy *j*, as the proportional change in incomes in the benchmark case required to achieve the same aggregate utility that policy *j* achieves.[36] Admission standards and academic graduation requirements are held fixed throughout.

4.1 Removing liquidity constraints and raising tuition

We begin by considering the impact of first removing liquidity constraints and then raising tuition, and compare the results to the benchmark case. When liquidity

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of log incomes to measure relative mobility, rather than the earnings elasticity, in order to distinguish more clearly between mobility and distribution. For other approaches to measuring social mobility see the survey by Fields and Ok (1999), who observe that "the mobility literature does not provide a unified discourse of analysis".

[36] Let $\mathbf{y}_{ij}$ be the vector of annual incomes of individual *i* under policy *j*, where $j = 0$ denotes the benchmark case, and let $V(\mathbf{y}_{tj})$ be her indirect lifetime utility. Then the welfare entry in Table 3 for policy *j* is the value ξ that solves $V((1+ \xi)\, \mathbf{y}_{t0}) = V(\mathbf{y}_{tj})$.

constraints are resolved, we assume that tuition and living costs can be financed at the uniform interest rate $r_0 = 0.06$, irrespective of parental income. The first three columns of Table 3 present the impact of the following policies: the benchmark case, in which 50% of tuition is subsidized and liquidity is constrained; the same tuition subsidies combined with (noncontingent) government student loans that remove liquidity constraints; and removal of tuition subsidies, resulting in a doubling of tuition, combined with (noncontingent) government student loans. The top rows of Table 3 presents enrolment and graduation rates by quintile for each of these policies; and the bottom rows present aggregate enrolment and graduation rates, the ratio of nongraduate to graduate income, the Gini coefficient of lifetime income,[37] the intergenerational correlation of incomes, an index of total output, an income-equivalent indicator of the change in aggregate utility (defined above), and the fiscal cost of higher education, presented both as a tax rate and as an index of fiscal cost. We assume that there is full recovery of loans and ignore administrative costs.

A comparison of the first two columns in Table 3 shows that resolving liquidity constraints marginally improves access: it causes a general increase in enrolment and graduation rates, with the relative increase decreasing as parental income rises. The slight increase in the total share of graduates in the workforce leads to a small increase in the ratio of unskilled to skilled wages, which slightly reduces inequality. The intergenerational correlation of income, an indicator of immobility, varies very slightly in the same direction as the Gini coefficient: a smaller gap between unskilled and skilled wages renders higher education less effective in promoting relative income mobility. The slight increase in total output is negligible given that we ignore administration costs, and the increase in total utility is also very small in income-equivalence terms. The small rise in fiscal costs reflects a small increase in enrolment in subsidized higher education.

Raising tuition is often an important component of reform of higher education finance, either supplementing public spending on higher education or replacing it. The third column in Table 3 shows the result of removing tuition subsidies, which causes tuition fees to double, while offering student loans. Comparing it to the benchmark we find small declines in enrolment and graduation rates, with the largest declines occurring in the higher-income quintiles, indicating that if liquidity constraints are resolved, tuition can be substantially increased with little effect on access to higher education. The removal of tuition subsidies results in a sharp relative decline in fiscal cost, though the computed decline overstates actual gains as it assumes perfect loan recovery and costless administration. The changes in output and in aggregate utility are negligible.

4.2 Contingent repayment of loans

[37] These values are considerably smaller than empirical Gini coefficients of wage income. We made no attempt to adjust this as our measures should be lower: Where empirical measures of inequality are based on annual income our measure is based on permanent income. It should be smaller, as it averages out both year to year fluctuations in income and variation in annual income among people with similar lifetime earnings profiles who are at different stages of their lives.

The observation that individuals are risk averse and governments can efficiently pool risk has led many higher education funding programs implemented in recent years to incorporate an element of insurance. Typically, repayment in each year is limited to a fixed fraction of income with no repayment below a given income threshold, until either the debt is repaid or a pre-determined number of years have passed, at which point any outstanding debt is forgiven. Our model assumes that perfect consumption smoothing is possible, so the timing of repayment is irrelevant, and only the fraction repaid matters. To fix ideas, we assume that individuals earning less than 0.75 of average income pay nothing, those earning 1.25 times average income repay their loans in full, and those in-between repay on a linear scale (e.g., individuals earning average income repay half their debts).[38]

The fourth column of Table 3 assumes that such loans are offered while tuition subsidies remain at the benchmark level of 50%, while the fifth column assumes that tuition subsidies are removed. The results shown in column 4 demonstrate the substantial positive effect of student loans with contingent repayment on access: in the lowest parental-income quintile they increase enrolment rates by more than a third and graduation rates by a quarter, compared to the rates achieved through an uninsured student loan program. Higher quintiles also gain, but relative gains decrease with parental income and the lowest two quintiles also have the highest absolute gains. The insurance implicit in such loans substantially increases the share of graduates in the workforce, which reduces inequality, raises output, and reduces relative income mobility. The recovery rate is within the range 75-85% quoted by Chapman and Ryan (2005) for Australia. The fiscal cost of the program is almost doubled because of the added cost of forgiven loans and the expansion of subsidized higher education.

In the fifth column of Table 3, where the same loans are combined with a removal of tuition subsidies, we find again that resolving liquidity constraints allows removal of tuition subsidies with very little effect on access, while substantially reducing fiscal cost. Combining these loans with a removal of tuition subsidies leaves government spending at the benchmark level while achieving large relative gains in both enrolment and graduation rates in the lowest income quintile. The large overall increase in enrolment and graduation rates narrows the gap between skilled and unskilled wages and reduces wage inequality as measured by the Gini coefficient of lifetime wage income. The small gain in output of 0.8% over the benchmark case reflects the government's innate advantage in spreading risk, though again it ignores the administrative costs of the program, its possible administrative inefficiencies and any abuse of the system.

The tradeoffs implicit in choosing between these various policies are illustrated in Figure 1, which graphs the college enrolment rate for the lowest quintile of parental income *versus* fiscal cost, for the five policies in Table 3. There are three policies on the

[38] We also examined a more generous insurance schedule: allowing individuals earning less than average income to pay nothing, requiring those earning at least 50% above average income to repay their loans in full, while those in-between repay on a linear scale. This yields a lower recovery rate of about two thirds, which substantially increases the fiscal cost of the loan program while offering little improvement in access or in any of the aggregate measures of equity and efficiency.

optimal (upper left-hand) frontier: offering student loans while charging full tuition achieves a large reduction in fiscal cost with a very slight reduction in access; offering insured student loans while charging full tuition achieves a large improvement in access with little change in fiscal cost; and offering insured student loans while maintaining current tuition subsidies achieves a small further improvement in access while substantially increasing fiscal cost.

4.3 Sensitivity analysis

To test the robustness of our conclusions we conducted sensitivity analyses and re-computed Table 3 under alternative assumptions, which are presented in Appendix D. First, we varied the relative influence of human capital and signaling on wages. We originally calibrated the model to a value of $\upsilon = 0.5$, where υ is the relative weight of individual human capital in determining wages, and now re-ran it for values of $\upsilon = 0.4$ and 0.6. The results, presented in Tables A1 and A2, show that these variations do affect demand for higher education: a smaller impact of own human capital on wages—i.e., a larger signaling effect—results in increased demand for access to higher education, raising enrolment and graduation rates across the board. However, these parameter changes do not affect our policy comparisons. It still holds that removing tuition subsidies while offering (noncontingent) government student loans reduces fiscal costs with very little impact on access, while offering insured loans and removing tuition subsidies markedly improves access, compared to the benchmark case, with little change in fiscal costs, thus describing the same policy tradeoff frontier as Figure 1. Additionally, as in the principal calibration, none of these policies has much effect on aggregate output or utility.

Next we varied the coefficient of relative risk aversion (CCRA), which we originally calibrated to a value of 1.2, testing alternative values of 1.05 and 1.35, results of which are presented in Tables A3 and A4. As might be expected, lowering the CCRA raises enrolment and graduation rates and slightly raises fiscal costs, while raising the CRRA has the opposite effect, but these effects are small and the quantitative conclusions are again unchanged.

We also varied the interest rate structure of private lending for higher education to test its effect on the benchmark case. In the original calibration we assumed the interest given in equation (42). We now re-ran the model assuming a piecewise linear rate. The results shown in Table A5 compare 6 different schedules to the benchmark case (the interest rates are not relevant when student loans are offered). The general similarity is apparent and our conclusions remain intact. Finally, we ran the model for a fixed (zero) tax rate, assuming that changes in spending on education do not result in variation of the tax rate but rather are absorbed as changes in other budget items. The results shown in Table A6 are very similar to those in Table 3, indicating that the tax rate can be ignored (and the model streamlined) without substantively affecting the results.

5. CONCLUSION

In this paper we constructed a macro-model of an economy with skilled and unskilled labor and a centralized system of higher education that trains skilled labor, which we then used to simulate different university tuition and student loan policies. We considered the effect of providing student loans at preferred interest rates, of doubling tuition, and of conditioning repayment of the loans on students' income when they enter the workforce.

We found that student loans in themselves have only a small positive effect on access to higher education but they enable tuition to be raised substantially with little adverse effect on access for students from low-income homes. Allowing repayment of loans to depend on future income absorbs some of the risk of higher education and substantially improves access. And if tuition is increased at the same time, a large improvement in access can be achieved without increasing fiscal cost above its current level. Increased access, resulting in larger numbers of graduates, causes a fall in the college wage premium and thus in wage inequality. At the same time, intergenerational relative income mobility, as measured inversely by the correlation in income across generations, declines very slightly despite the improvement in enrolment and graduation rates. Loans with contingent repayment generate small increases in total output, in our simulation results, but these effects are relatively small compared to the large relative impact of these policies on access and fiscal cost, and given the many factors from which our analysis abstracts are at best a weak indication of actual efficiency gains.

Finally, we note that even loans with contingent repayment combined with subsidized tuition leave substantial differences in enrolment and graduation rates between students from different socioeconomic backgrounds. By the time students reach college age much has already been determined; larger improvements in social mobility require intervention at earlier ages.

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Table 1
Calibration values

Description of variable	*Value*	*References and notes*
Elasticity of substitution between (unskilled labor) and (capital equipment and skilled labor)	1.67	Krussel et al. (2000)
Elasticity of substitution of between capital equipment and skilled labor	0.67	
Return on investment in equipment, p (gross)	12%	
Weight of own human capital in wage, υ	0.5	Also tested: $\upsilon = 0.4, 0.6$
Mean of the log of parental income, μ_y	Calibrated to net household income in Israel, 2003; see note 24	
Variance of the log of parental income, σ_y^2		
Mean of entry scores and grades, μ_t and μ_s	0	Standardized normal
Variance of entry scores and grades, σ_t^2 and σ_s^2	1	
Corr between parents' income and entry scores, ρ_{yt}	0.25	See references in note 27
Corr between parents' income and grades, ρ_{ys}	0.25.	Assumed equal to ρ_{yt}; n. 28
Corr between entry scores and grades, ρ_{ts}	0.5	See references in note 29
μ_h, σ_h^2, σ_{hy}, σ_{ht}, and σ_{hs}	Calculated, see Appendix A for details	
Years of study to graduation, T_e	4	
Years of study, to discontinuing studies, T_d	2	
Tuition, per year, P	w_u / 8	Calibrated to Israeli tuition
Annual living expenses in college, c_0	w_u / 3	Subjective estimate
Graduate's working life, T_s (years)	40	
Admissions threshold, θ	–0.2	Enrolment rate
Graduation requirement, $\underline{s}$	0	Graduation rate
Best interest rate for consumer loans, r_0	6%	
Coefficient of relative risk aversion (CRRA)	1.2	Also tested: 1.05, 1.35
Annual household discount rate, η	6%	Set equal to r_0

Table 2
Distribution of enrolment and graduation shares: Benchmark simulation *versus* observed values

Quintile	Enrolment rate by parent's income quintile (benchmark model)	Enrolment rate by local authority's socioeconomic ranking (observed)	Share of graduates by parent's income quintile (benchmark model)
I	18.4%	23.4%	11.0%
II	31.4%	28.5%	19.5%
III	42.2%	42.1%	26.3%
IV	51.0%	52.5%	33.7%
V	64.7%	63.0%	45.8%
Total	41.4%	43.6%	27.1%

Table 3

Enrolment and graduation rates by quintile, and aggregate indicators of access, inequality, mobility, output and fiscal cost under different tuition and loan policies

	Quintile	*Benchmark* 50% tuition subsidy No student loans	50% tuition subsidy Student loans	No tuition subsidy Student loans	50% tuition subsidy Contingent repayment	No tuition subsidy Contingent repayment
Enrolment shares by parents' income quintile	I	18.4%	20.0%	18.1%	28.2%	27.2%
	II	31.4%	33.0%	30.7%	41.6%	40.6%
	III	42.2%	42.3%	40.1%	50.1%	49.3%
	IV	50.1%	51.7%	49.7%	58.1%	57.4%
	V	64.7%	64.9%	63.4%	68.7%	68.3%
Graduation shares by parents' income quintile	I	11.0%	11.7%	10.8%	15.0%	14.6%
	II	19.5%	20.2%	19.1%	23.7%	23.3%
	III	26.3%	26.8%	25.8%	30.0%	29.7%
	IV	33.7%	34.1%	33.1%	36.7%	36.4%
	V	45.8%	45.8%	41.2%	47.4%	47.3%
Enrolment rate in higher education		41.4%	42.2%	40.2%	49.1%	48.4%
Share of graduates in the workforce		27.1%	27.6%	26.7%	30.4%	30.1%
Ratio of non-graduate to graduate income		0.389	0.397	0.383	0.442	0.437
Gini coefficient of lifetime income		0.217	0.214	0.219	0.197	0.199
Intergenerational income correlation		0.367	0.369	0.366	0.387	0.377
Aggregate output index (Benchmark = 100)		100.0	100.1	99.9	100.8	100.8
Change in aggregate utility (see text)		—	-0.51%	-0.38%	-0.80%	-0.79%
Loan recovery rate		—	100%	100%	81.7%	82.0%
Tax rate		0.29%	0.30%	0	0.57%	0.29%
Fiscal cost index		100	103	0	196	99

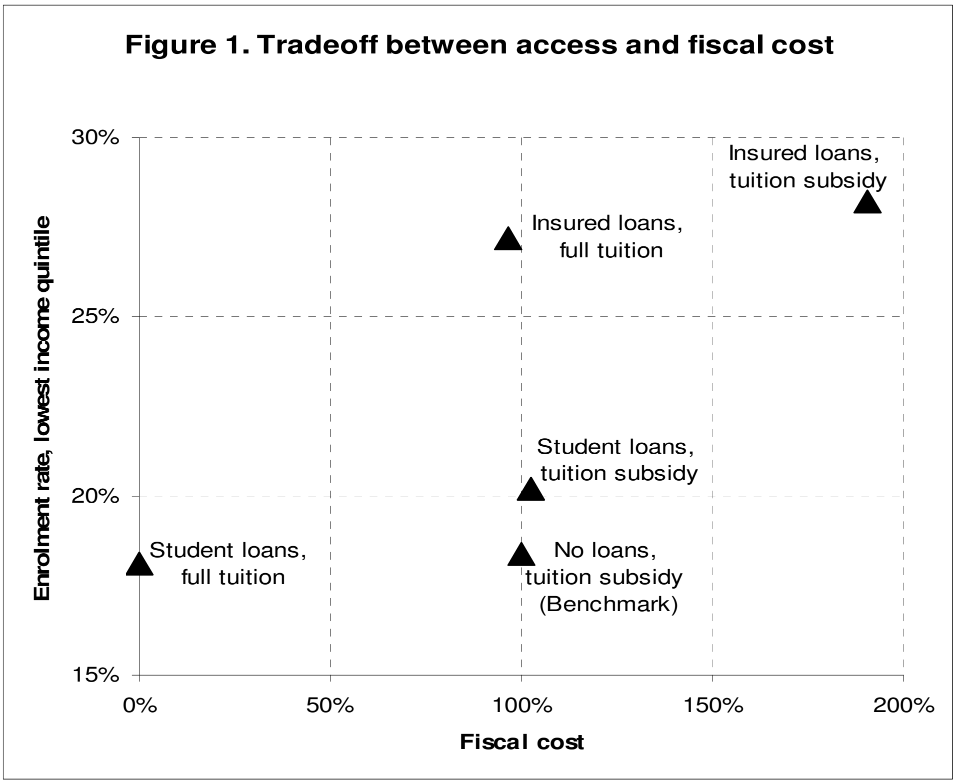


Figure 1. Tradeoff between access and fiscal cost
Enrolment rate, lowest income quintile
30%
25%
20%
15%
0%
50%
100%
150%
200%
Fiscal cost
Insured loans, tuition subsidy
Insured loans, full tuition
Student loans, tuition subsidy
Student loans, full tuition
No loans, tuition subsidy (Benchmark)

Appendix

A. The variance-covariance matrix of ln h_i, s_i, ln y_i and t_i

The missing elements of the variance-covariance table are the elements incorporating the unobserved variable ln h_i, the logarithm of human capital.

From equation (15a) we obtain

(A.1) $\alpha + \delta = \rho_{yt}\ \sigma_t / \sigma_y$,

and substituting this in equation (15c) gives

(A.2) $\rho_{yh} = \rho_{yt}\sigma_t / \sigma_h$,

implying that

(A.3) $\text{cov}\ (y, h) = \rho_{yh}\sigma_y\sigma_h = \rho_{yt}\sigma_y\sigma_t = 0.181$

after substituting the calibration values from the text. From equation (15f)

(A.4) $\sigma_h^2 = \rho_{ts}\sigma_t\sigma_s = 0.5$,

and from equation (15d)

(A.5) $\text{cov}(h,s) = \rho_{hs}\sigma_h\sigma_s = \sigma_h^2 = \rho_{ts}\sigma_t\sigma_s = 0.5$.

Similarly, from equation (15e)

(A.6) $\text{cov}(h,t) = \rho_{ts}\sigma_t\sigma_s = 0.5$.

Thus all the elements of the variance-covariance matrix can be expressed as functions of the observed correlations and variances.

B. The conditional joint distribution of ln h_i and s_i given ln y_i and t_i

Given parental income and the prior test score, the joint conditional distribution of the logarithm of human capital and the final exam score have expectations

$$E(\ln h_i \mid \ln y_i, t_i) = E(\ln h) + \frac{1}{(1-\rho_{yt}^2)}\left[\frac{\rho_{yt}(\ln y_i - E(\ln y))}{\sigma_y}(\sigma_t - \sigma_s\rho_{ts}) + (\frac{\rho_{ts}\sigma_s}{\sigma_t} - \rho_{yt}^2)(t_i - E(t))\right] ,$$

$$E(s_i \mid \ln y_i, t_i) = E(s) + \frac{\sigma_s}{(1-\rho_{yt}^2)}\left[\frac{(\ln y_i - E(\ln y))}{\sigma_y}(\rho_{ys} - \rho_{ts}\rho_{yt}) + \frac{(t_i - E(t))}{\sigma_t}(\rho_{ts} - \rho_{ys}\rho_{yt})\right] ,$$

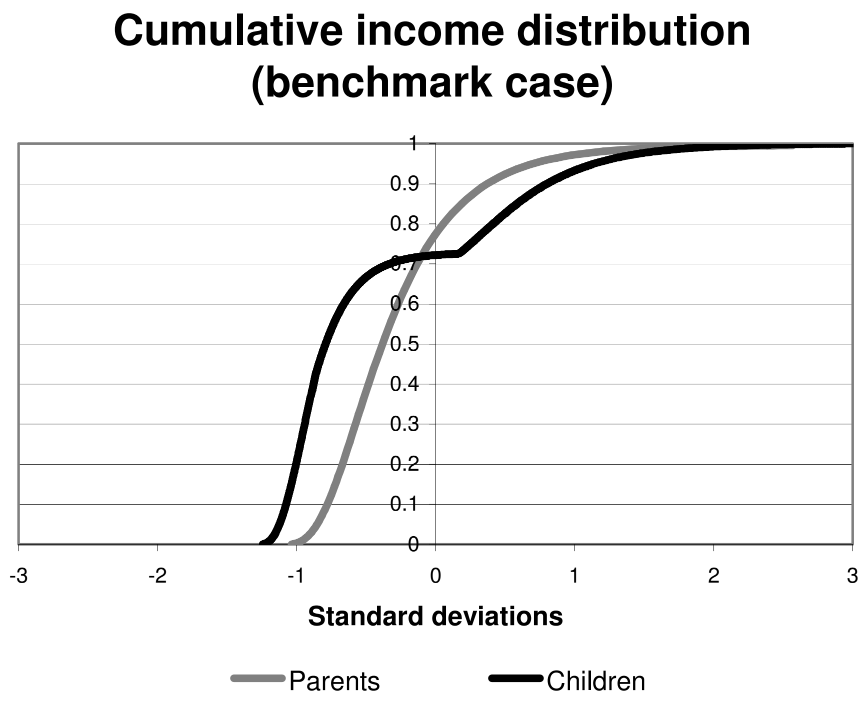
and variance-covariance matrix

$$\sigma^2_{\ln h_i \mid \ln y_i, t_i} = \rho_{ts}\sigma_t\sigma_s - \frac{\rho_{yt}^2\sigma_t}{(1-\rho_{yt}^2)}(\sigma_t - \rho_{ts}\sigma_s) - \frac{\rho_{ts}\sigma_t\sigma_s}{(1-\rho_{yt}^2)}\left(\frac{\rho_{ts}\sigma_s}{\sigma_t} - \rho_{yt}^2\right) ,$$

$$\sigma^2_{s_i \mid \ln y_i, t_i} = \sigma_s^2 - \frac{\rho_{ys}\sigma_s^2}{(1-\rho_{yt}^2)}(\rho_{ys} - \rho_{ts}\rho_{yt}) - \frac{\rho_{ts}\sigma_s^2}{(1-\rho_{yt}^2)}(\rho_{ts} - \rho_{ys}\rho_{yt}) ,$$

$$\mathrm{cov}(\ln h_i, s_i \mid \ln y_i, t_i) = \rho_{ts}\sigma_t\sigma_s - \frac{\rho_{ys}\rho_{yt}\sigma_s}{(1-\rho_{yt}^2)}(\sigma_t - \rho_{ts}\sigma_s) - \frac{\rho_{ts}\sigma_t\sigma_s}{(1-\rho_{yt}^2)}\left(\frac{\rho_{ts}\sigma_s}{\sigma_t} - \rho_{yt}^2\right) .$$

C. Cumulative income distributions



D. Sensitivity analysis

Table A1. Signaling effect $\upsilon = 0.4$
Enrolment and graduation rates by quintile, and aggregate indicators of access, inequality, mobility, output and fiscal cost under different tuition and loan policies

	Quintile	*Benchmark* 50% tuition subsidy No student loans	50% tuition subsidy Student loans	No tuition subsidy Student loans	50% tuition subsidy Contingent repayment	No tuition subsidy Contingent repayment
Enrolment shares by parents' income quintile	I	20.2%	21.9%	19.8%	30.4%	29.4%
	II	33.5%	35.1%	32.7%	43.6%	42.7%
	III	43.1%	44.4%	42.1%	51.8%	51.0%
	IV	52.6%	53.4%	51.4%	59.3%	58.8%
	V	65.7%	65.9%	64.6%	69.3%	69.1%
Graduation shares by parents' income quintile	I	11.8%	12.5%	11.6%	15.8%	15.4%
	II	20.4%	21.1%	20.1%	24.3%	24.0%
	III	27.2%	27.7%	26.7%	30.5%	30.3%
	IV	34.5%	34.8%	34.0%	37.1%	36.9%
	V	46.2%	46.3%	45.7%	47.6%	47.6%
Enrolment rate in higher education		42.8%	44.0%	41.9%	50.6%	50.0%
Share of graduates in the workforce		27.9%	28.4%	27.5%	30.9%	30.7%
Ratio of non-graduate to graduate income		0.401	0.409	0.395	0.451	0.447
Gini coefficient of lifetime income		0.199	0.197	0.202	0.181	0.183
Intergenerational income correlation		0.343	0.345	0.342	0.353	0.352
Aggregate output index (Benchmark = 100)		100	100.1	99.9	100.7	100.7
Change in aggregate utility (see text)		—	-0.12%	-0.06	-0.54%	-0.54%
Loan recovery rate		—	100%	100%	80.1%	80.3%
Tax rate		0.30%	0.31%	0	0.60%	0.32%
Fiscal cost index		100.0	102.4	0	199.1	104.7

Table A2. Signaling effect $\upsilon = 0.6$
Enrolment and graduation rates by quintile, and aggregate indicators of access, inequality, mobility, output and fiscal cost under different tuition and loan policies

		Benchmark 50% tuition subsidy	50% tuition subsidy	No tuition subsidy	50% tuition subsidy	No tuition subsidy
	Quintile	No student loans	Student loans	Student loans	Contingent repayment	Contingent repayment
Enrolment shares by parents' Income quintile	I	16.7%	18.1%	16.3%	26.4%	25.9%
	II	29.3%	30.7%	28.4%	39.8%	39.4%
	III	39.0%	40.1%	37.8%	48.6%	48.2%
	IV	49.1%	49.7%	47.7%	56.9%	56.5%
	V	63.5%	63.5%	62.0%	68.0%	67.8%
Graduation shares by parents' Income quintile	I	10.2%	10.8%	10.0%	14.3%	14.1%
	II	18.5%	19.1%	18.2%	23.0%	22.7%
	III	25.3%	25.8%	24.8%	29.4%	29.2%
	IV	32.9%	33.2%	32.2%	36.2%	36.0%
	V	45.2%	45.2%	44.6%	47.1%	47.0%
Enrolment rate in higher education		39.3%	40.2%	38.2%	47.7%	47.3%
Share of graduates in the workforce		26.3%	26.7%	25.7%	29.9%	29.6%
Ratio of non-graduate to graduate income		0.376	0.383	0.369	0.433	0.431
Gini coefficient of lifetime income		0.233	0.231	0.237	0.209	0.210
Intergenerational income correlation		0.386	0.389	0.386	0.392	0.392
Aggregate output index (Benchmark = 100)		100.0	100.2	99.8	101.0	101.0
Change in aggregate utility (see text)		—	-0.16%	-0.23%	-0.21%	-0.21%
Loan recovery rate		—	100%	100%	82.7%	82.9%
Tax rate		0.28%	0.29%	0	0.44%	0.26%
Fiscal cost index		100	102.0	0	237.4	93.3

Table A3. CRRA = 1.05
Enrolment and graduation rates by quintile, and aggregate indicators of access, inequality, mobility, output and fiscal cost under different tuition and loan policies

		Benchmark				
		50% tuition subsidy	50% tuition subsidy	No tuition subsidy	50% tuition subsidy	No tuition subsidy
	Quintile	No student loans	Student loans	Student loans	Contingent repayment	Contingent repayment
Enrolment	I	19.3%	21.1%	19.0%	29.0%	28.0%
shares by	II	32.5%	34.2%	31.8%	42.3%	41.4%
parents'	III	42.2%	43.5%	41.1%	50.8%	50.0%
income	IV	51.9%	52.7%	50.6%	58.5%	57.9%
quintile	V	65.4%	65.4%	64.0%	68.9%	68.6%
Graduation	I	11.4%	12.2%	11.2%	15.3%	14.9%
shares by	II	20.0%	20.7%	19.6%	23.9%	23.6%
parents'	III	26.8%	27.3%	26.3%	30.2%	29.9%
income	IV	34.1%	34.5%	33.6%	36.8%	36.6%
quintile	V	46.1%	46.1%	45.5%	47.5%	47.4%
Enrolment rate in higher education		42.0%	43.2%	41.1%	49.7%	49.0%
Share of graduates in the workforce		27.5%	28.0%	27.1%	30.6%	30.3%
Ratio of non-graduate to graduate income		0.396	0.403	0.389	0.446	0.441
Gini coefficient of lifetime income		0.214	0.211	0.217	0.196	0.197
Intergenerational income correlation		0.369	0.370	0.367	0.378	0.377
Aggregate output index (Benchmark = 100)		100.0	100.1	99.8	100.8	100.7
Change in aggregate utility (see text)		—	-0.10%	-0.38%	-0.82%	-0.82%
Loan recovery rate		—	100%	100%	81.3%	81.7%
Tax rate		0.30%	0.30%	0	0.57%	0.30%
Fiscal cost index		100	100	0	190	100

Table A4. CRRA = 1.35
Enrolment and graduation rates by quintile, and aggregate indicators of access, inequality, mobility, output and fiscal cost under different tuition and loan policies

		Benchmark				
		50% tuition subsidy	50% tuition subsidy	No tuition subsidy	50% tuition subsidy	No tuition subsidy
	Quintile	No student loans	Student loans	Student loans	Contingent repayment	Contingent repayment
Enrolment shares by parents' income quintile	I	17.4%	19.2%	17.1%	27.4%	26.7%
	II	30.3%	32.0%	29.5%	40.8%	40.2%
	III	40.0%	41.4%	38.8%	49.5%	49.0%
	IV	49.9%	50.8%	48.5%	57.6%	57.2%
	V	64.0%	64.2%	62.6%	68.4%	68.2%
Graduation shares by parents' income quintile	I	10.5%	11.3%	10.4%	14.7%	14.4%
	II	18.9%	19.7%	18.5%	23.4%	23.1%
	III	25.7%	26.4%	25.2%	29.7%	29.5%
	IV	33.3%	33.7%	32.6%	36.5%	36.3%
	V	45.5%	45.6%	44.8%	47.3%	47.2%
Enrolment rate in higher education		40.1%	41.3%	39.1%	48.5%	48.1%
Share of graduates in the workforce		26.6%	27.2%	26.2%	30.2%	30.0%
Ratio of non-graduate to graduate income		0.382	0.390	0.375	0.434	0.435
Gini coefficient of lifetime income		0.219	0.216	0.223	0.198	0.200
Intergenerational income correlation		0.366	0.368	0.364	0.377	0.376
Aggregate output index (Benchmark = 100)		100.0	100.2	99.8	101.0	100.9
Change in aggregate utility (see text)		—	-0.07%	-0.37%	-0.76%	1.86%
Loan recovery rate		—	100%	100%	82.9%	82.1%
Tax rate		0.29%	0.29%	—	0.56%	0.28%
Fiscal cost index		100	100	0	193	97

Table A5. Benchmark case with different forms of liquidity constraints

Enrolment and graduation rates by quintile, and aggregate indicators of access, inequality, mobility, output and fiscal cost under different tuition and loan policies

The interest rate is linear in the parent's income percentile from 0 to P_2 with the interest rate at P_1 equal to 12% and the interest rate at P2 and above equal to 6%.

	Quintile	P_1 = 40% P_2 = 80%	P_1 = 50% P_2 = 80%	P_1 = 30% P_2 = 70%	P_1 = 40% P_2 = 70%	P_1 = 20% P_2 = 60%	P_1 = 30% P_2 = 60%
Enrolment shares by parents' income quintile	I	16.6%	15.6%	17.6%	16.5%	17.9%	17.2%
	II	30.4%	29.7%	31.6%	30.7%	31.9%	31.5%
	III	41.1%	41.0%	42.3%	42.0%	42.6%	42.7%
	IV	51.7%	52.0%	52.5%	52.7%	52.5%	52.7%
	V	65.1%	65.4%	65.4%	65.5%	65.3%	65.4%
Graduation shares by parents' income quintile	I	10.1%	9.7%	10.6%	10.1%	10.8%	10.4%
	II	19.0%	18.7%	19.5%	19.1%	19.7%	19.5%
	III	26.3%	26.2%	26.8%	26.7%	26.9%	27.0%
	IV	34.1%	34.2%	34.4%	34.5%	34.4%	34.5%
	V	46.0%	46.1%	46.1%	46.1%	46.0%	46.1%
Enrolment rate in higher education		40.8%	40.6%	41.7%	41.3%	41.8%	41.7%
Share of graduates in the workforce		26.9%	26.8%	27.6%	27.2%	27.4%	27.4%
Ratio of non-graduate to graduate income		0.387	0.385	0.393	0.390	0.394	00.393
Gini coefficient of lifetime income		0.217	0.218	0.214	0.217	0.215	0.216
Intergenerational income correlation		0.366	0.366	0.368	0.367	0.368	0.368
Aggregate output index (Benchmark = 100)		100	99.9	100.1	100.06	100.1	100.1

Table A6. Fixed tax rate
Enrolment and graduation rates by quintile, and aggregate indicators of access, inequality, mobility, output and fiscal cost under different tuition and loan policies

		Benchmark				
		50% tuition subsidy	50% tuition subsidy	No tuition subsidy	50% tuition subsidy	No tuition subsidy
	Quintile	No student loans	Student loans	Student loans	Contingent loans	Contingent loans
Enrolment shares by parents' income quintile	I	18.4%	20.2%	18.1%	28.2%	27.2%
	II	31.4%	33.2%	30.7%	41.6%	40.6%
	III	41.2%	42.6%	40.1%	50.1%	49.3%
	IV	51.0%	51.9%	49.7%	58.1%	57.4%
	V	64.7%	64.9%	63.4%	68.7%	68.3%
Graduation shares by parents' income quintile	I	11.0%	11.8%	10.9%	15.2%	14.7%
	II	19.5%	20.3%	19.1%	23.8%	23.3%
	III	26.3%	26.9%	25.8%	30.1%	29.7%
	IV	33.7%	34.1%	33.2%	36.8%	36.4%
	V	45.8%	45.9%	45.2%	47.5%	47.3%
Enrolment rate in higher education		41.4%	42.4%	40.2%	49.1%	48.4%
Share of graduates in the workforce		27.1%	27.7%	26.7%	30.4%	30.1%
Ratio of non-graduate to graduate income		0.389	0.398	0.383	0.442	0.437
Gini coefficient of lifetime income		0.217	0.213	0.219	0.197	0.198
Intergenerational income correlation		0.367	0.369	0.366	0.377	0.377
Aggregate output index (Benchmark = 100)		100.0	100.2	99.9	100.9	100.8
Change in aggregate utility (see text)		—	-0.09%	-0.31%	1.61%	1.88%
Loan recovery rate		—	100%	100%	81.6%	81.9%
Fiscal cost index		100.0	102.3	0	190.8	96.7