Optimal Student Financial Aid Policies and Parental Income*

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Abstract

We study the optimal design of student financial aid policies. We find that optimal financial aid is sharply declining in parental income. This strong progressivity is very robust to different parameter choices and holds for different welfare criteria, assumptions on credit markets and merit based elements. It also holds independently of whether the progressivity of the income tax is chosen optimally or at its current level. Finally, we show that a larger degree of progressivity can even be implemented in a simple Pareto improving way: our results suggest that an increase in financial aid for low parental income children is likely to be self-financing through higher tax revenue in the future. Efficient policies favor social mobility.

JEL-**classification:** H21, H23, I22, I24, I28

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1 Introduction

Most governments provide significant financial aid to college students. At one extreme, in Scandinavian countries college students pay low or no tuition fees and in addition receive grants because of generous public subsidies for higher education. In the US, students bear a larger burden of tuition costs; still federal and spending on grants to college students exceeded 55 billion dollars for the academic year 2014-2015. Most countries additionally target low income students with their policies. In the US, federal spending on the Pell Grant program for low income students exceeded 30 billion in 2014-2015 and has grown by over 80% in the last 10 years.[1] Despite their importance and potential implications for growth, income inequality, and social mobility, there is surprisingly little research on the normative side on financial aid policies.[2] The contribution of this paper is to explore the optimal design of financial aid policies and clarify the main underlying trade-offs.

We begin by characterizing optimal financial aid policies theoretically. Our modeling approach emphasizes the need-based aspect of student aid – we ask how grants to college students should vary with parental income.[3] Our analysis is sufficient statistic in nature so we keep the model as general as possible at this stage without imposing many restrictions on the underlying heterogeneity in the population (Chetty 2009), and express the optimal policies as a function of empirically estimable parameters.[4] We additionally provide conditions under which expansions of existing financial aid systems could be self-financing by future higher tax revenue.

We implement our model empirically to characterize the desirability of progressive financial aid policies in the US. To this end, we estimate and calibrate the structural parameters of the model, stressing the importance and interaction of parental income and ability to explain the selection into college and heterogenous returns to college graduation. We validate our approach by replicating quasi-experiments on the effects of student financial aid expansions and parental income on enrollment. Our model also implies returns for marginal students similar to existing estimates from quasi-experiments.

We have two main results. First, we find that optimal financial aid policies are strongly progressive. For example, in our preferred specification the subsidy level drops by 80% moving from 10th percentile of the parental income distribution to the 95th percentile. The strong progressivity is very robust and holds for for a broad range of different parameter choices: different tax functions, welfare criteria, and assumptions on credit markets. Second, our estimates suggest that increases in financial aid for low-income students, approximately in the first parental income tercile, are self-financing by increases in future tax-revenue, implying that targeted financial aid expansions could be Pareto improving free-lunch policies. Both results point

[1] See Trends in Student Aid, College Board: `http://trends.collegeboard.org/student-aid/highlights`

[2] We review the existing literature, including the positive literature on the empirical effects of financial aid reform, below.

[3] The approach is more general and can be extended to condition financial aid policies on other observables like academic merit or jointly on the combination of parental income and academic merit. In fact we exploit the model flexibility later to compare different kind of financial aid policies.

[4] The sufficient statistic approach has been applied extensively in the optimal social insurance literature and optimal taxation, (Chetty and Finkelstein 2013, Piketty and Saez 2013). Maybe surprisingly, it has not been used a lot to characterize education and financial aid policies, although governments are heavily involved in the subsidization of education and the stakes in terms of governments' budgets are large. A recent exception is Lawson (2016).

out that financial aid policies for students are a rare case where there is no equity-efficiency trade-off: education policies which lead to a cost effective distribution of aid to help students pay for the cost of college and increase affordability are also in line with redistribute concerns and social mobility.

The paper has three major parts. In the first step in Section 2, we build the framework and characterize how financial aid should optimally vary with parental income. The marginal gain from increasing financial aid for a given parental income level is proportional to the *fiscal externality* it creates. The fiscal externality results from the increase in future tax revenue, which is determined by the returns of college attendance for marginal students as well as the mass of marginal students who are induced to attend college. The latter number has been estimated in numerous studies for different policy reforms in the US (see Castleman and Long (2016) for a recent contribution or Deming and Dynarski 2009 for a survey). The marginal cost of increasing financial aid for a given parental income level is proportional to the amount of inframarginal students – those who would attend even in the absence of the reform. The marginal cost is further scaled down by the welfare weight placed on students from the parental income group.[5] Equating marginal costs and benefits yields an easy interpretable formula for the optimal financial aid level at each parental income level.

In the second step, our empirical analysis quantifies the model in Section 4. We use data from the National Longitudinal Survey of Youth 1979 and 1997 (henceforth, NLSY79 and NLSY97). Our empirical approach focuses on heterogeneity in three dimensions and their correlations: parental income, ability determined before college and preferences for college attendance. Parental income matters as it is strongly linked to parental transfers during college; heterogeneity in ability is important as it is it allows for heterogenous returns to college attendance, in particular, it plausible that marginal students are expected to have different returns than inframarginal ones, moreover this returns should differ across the parental income distribution. We estimate the joint distributions of parental income, ability determined before college and preferences for college attendance, which pin down the relevant parameters/sufficient statistics as described in the theoretical part. Our quantitative model can replicate key patterns on how college education varies with parental income and a measure of ability for young adults. Further, our model yields returns to college that are in line with the empirical literature (Card 1999, Oreopoulos and Petronijevic 2013, Zimmermann 2014) and can replicate quasi-experimental studies.[6]

The quantitive analysis yield the result that the optimal subsidy is strictly decreasing in parental income. The result is surprisingly robust to the social welfare function, the existence or non-existence of borrowing constraints, and other parameters. In particular, we find that even for a government purely interested in maximizing tax revenue, progressive financial aid is the best policy. It might have been expected that fiscal returns to financial aid programs

[5]The marginal cost is multiplied by $(1-x)$ where x is the societal value placed on more dollar in the hand of the respective group of students.

[6]A number we target is that a $1,000 dollar increase in college grants for all students induces an increase in the share of individuals that hold a college degree by 1.5 percentage points. A number that is the average in the empirical literature surveyed by Kane (2006) and Deming and Dynarski (2009). Further, we find that a $1,000 dollar increase in parental income triggers a 0.08 percentage points increase in college graduation. A number that is in line – though slightly smaller – with Hilger (2016). The latter number was not a target for our calibration.

are higher for higher parental income levels, as those children are thought of as being better prepared for college and having higher returns. This will indeed be true in our model. However, this effect is clearly dominated by the fact the at higher income level much more students are inframarginal for any education or tax system. As a result, optimal subsidies are progressive and the fiscal returns to financial aid expansions are significantly higher for low income children.

The third major part of the article also takes into account the optimal design of income taxes. Despite the large underlying degree of heterogeneity in the model, we can solve for the fully optimal schedule in the spirit of Mirrlees (1971). First, this exercise is motivated by the fact that higher and more progressive taxes are a complement to financial aid. It is hence important to know how endogenously chosen optimal taxation affects financial aid policies. Second, it allows the government to directly tackle redistributional concerns by progressive taxation instead of redistributing through progressive financial aid. We theoretically characterize optimal tax policies in Section 3 and quantitatively in Section 6. The main result is that optimal financial aid policies are unchanged compared to the case with exogenous taxes: the optimal system features high progessiveness and a high negative dependence on parental income. Although optimal taxes are significantly higher and more progressive than the current system, the main result does not get overturned. The intuition here is again that the fraction of inframarginal students is significantly higher for high-income children for basically any tax system.

This paper contributes to the literature studying the optimal design of human capital policies. This has been done in different contexts. Stantcheva (2015) characterizes optimal history-dependent tax and human capital policies in a dynamic life-cycle model. Bovenberg and Jacobs (2005) consider a static model with a continuous education choice and emphasize that education subsidies and taxes are complements, calling them "Siamese Twins". In Findeisen and Sachs (2016), we show how history-dependent labor wedges can implemented with an income-contingent education loan system. Lawson (2016) uses a sufficient statistic approach to characterize optimal uniform tuition subsidies for all college students. Our work is also complementary to Abbott, Gallipoli, Meghir, and Violante (2016) and Krueger and Ludwig (2013, 2016) who study education policies computationally in very rich overlapping-generation models. We contribute in this paper by developing a new framework to analyze how education policies should depend on parents' resources and also trade-off merit-based concerns.[7] We are able to characterize optimal financial aid and tax policies theoretically despite allowing for a large amount of heterogeneity and tightly connect our theory directly to the data, by estimating the relevant parameters ourselves.

When characterizing optimal taxes, we show how our formula is an extended version of the well known Diamond (1998) formula. Since college enrollment is modeled as a binary choice, our formal approach is similar to other optimal tax papers with both, intensive and extensive margin, as in Saez (2002).[8] More generally, our work is connected to the optimal taxation literature surveyed in Piketty and Saez (2013) and dynamic extensions to characterize more complex policies (Golosov, Tsyvinski, and Werquin 2015). Finally, the paper is also related

[7]Gelber and Weinzierl (2015) study how tax policies should take into account that the ability of children is linked to parents' resources.

[8]Kleven, Kreiner, and Saez (2009) consider the extensive margin of secondary earners, Scheuer (2014) considers the occupational choice margin, Saez (2002) and Jacquet, Lehmann, and Van der Linden (2013) consider the labor force participation margin and Lehmann, Simula, and Trannoy (2014) consider migration.

to many empirical papers, from which we take the evidence to gauge the performance of the estimated model. Those papers are discussed in detail in Section 4.

Our framework makes some simplifying assumptions, which may restrict the generality of our results. First, we abstract from explicitly modeling heterogeneity in college types and majors. Implicitly, sorting of students into different colleges and majors is captured by the estimated differences in returns. Large changes in financial aid policies may change that sorting, and it is conceivable that it would increase the desirability of progressive financial aid if lower income students will select into higher value-added but more expensive institutions. Second, we consider only direct subsidies and do not change student loan policies. However, we show that the issue of loans is slightly orthogonal to the question of progressivity: the policy implications concerning the progressivity do not change if the government in addition provides to opportunity to borrow. Third, we rule out that higher subsidies lead to strategic tuition increases by universities. This may reduce the desirability of public financial aid on average but should only have an impact on the optimal progressivity if it leads to stronger tuition increases for expansion in financial aid for low income children. Further, this should only mute the positive effects in the sense that private colleges respond, where only about 40% of all 4-year college students are enrolled (Snyder and Dillow 2013).

We progress as follows. In Section 2 we develop the model and study optimal policies. Section 3 continues the theoretical part and adds optimal taxation. In Section 4 we describe our calibration and estimation approach and discuss the relationship to previous empirical work. Section 5 presents optimal financial aid policies and Section 6 considers the jointly optimal education and tax policies. In Section 7 we discuss the robustness of our results with respect to college dropout and general equilibrium effects on wages. Section 8 concludes.

2 Model and Optimal Financial Aid Policies

The model characterizes optimal financial aid policies for college students. We start by stressing the need-based component of financial aid and derive optimal policies as a function of parental income. Optimal policies will be a function of a set of estimable parameters. In particular, the elasticity of college graduation rates w.r.t. to changes in financial aid generosity, the returns for marginal students, and the fraction of inframarginal students will be the key forces driving the most important results. Subsequently, we also allow the government to condition financial aid policies on other observables like academic merit or jointly on the combination of parental income and academic merit.

In the model, individuals start life as high school graduates and decide whether to obtain a college degree. If an individual decides against a college degree, she directly enters the labor market. The decision to enroll into college will depend on a vector of characteristics X. For example, potential students may be aware of their returns to college and these returns are likely to be heterogenous. It could also capture geographical origins, endurance or any other aspect that influences the decision to study. In addition to the sources of heterogeneity in X, parental income I can determine the college decision. We stress this dimension as an extra parameter because of our strong focus on the need-based element of student financial aid. Parental income I is strongly associated with parental transfers during college. Parental transfers matter for two

reasons. First, parental transfers matter because of (potentially binding) borrowing constraints. Second, parental transfers act as a price subsidy because parents make transfers contingent on the educational decision.

The model also incorporates uncertainty about labor market outcomes. We start with a simple two period version of the model with an education period and a labor market period. It is inconsequential for the interpretation of the optimal financial aid formulas, as they also hold if taxable incomes and wages change over the life cycle.

2.1 Individual Problem

Individuals graduate from high-school and are characterized by a vector X and the (permanent) I income of their parents. A certain type (I, X) is also labeled by j. They face a binary choice at the beginning of the model: enrolling into college or not. Assume that life after the college entry decision lasts T years, college takes T_e years and individuals' yearly discount factor is β. Then we can think of $\beta^{C1} = \sum_{t=1}^{T_e} \beta^{t-1}$ and $\beta^{C2} = \sum_{t=T_e+1}^{T} \beta^{t-1}$. If a young individual j enrolls, her expected lifetime utility is:

$$\beta^{C1} U^C(c_j^C; I, X) + \beta^{C2} \int_\omega U^W\left(c_{jw}^W, y_{jw}^W; w, I, X\right) dG^C(w|I, X).$$

$U^C(c_j^C; I, X)$ denotes utility during the college years. It depends on consumption c_j^C during those years, and level of consumption will depend on the realization of $j = (I, X)$. For example higher parental income is strongly associated with higher parental transfers during college. I and X can also have a direct utility effect of attending college; for example empirical studies have found a strong correlation between parents' and children's educational attainment, conditional on parental income. This would be captured by the direct effect of X.

The wage w is drawn from a conditional distribution function $G^C(w|I, X)$. X can include, for example, a measure of ability, which leads to heterogeneous returns to college. Empirical paper have stressed the importance of complementarity between ability measures and college education, which can be flexibly captured by $G^C(w|I, X)$. Consumption and taxable income during the working life are c_{jw}^W and y_{jw}^W. They depend on the wage draw, as well as the type from the previous period. Parental income I may still influence consumption and labor supply during adulthood, for example, as it determines the need for student loans during college, which are paid back over the working life.

The problem of a college graduate with parental income I and vector X becomes:

$$V^C(I, X; \mathcal{G}(I), T(.)) = \max_{c_j^C, c_{jw}^W, y_{jw}^W} \beta^{C1} U^C(c_j^C; I, X) + \beta^{C2} \int_\omega U^W\left(c_{jw}^W, y_{jw}^W; w, I, X\right) dG^C(w|I, X)$$

subject to

$$\forall\, w: \; c_{jw}^W = y_{jw}^W - T(y_{jw}^W) - (1+r)L$$

and

$$c_j^C = tr^C(I) + \mathcal{G}(I) - C + L,$$

and

$$L \leq \bar{L}.$$

$T(.)$ are taxes on earnings. $tr^C(I)$ is the transfer function mapping parental income into transfers received when going to college. Students can take loans L with some interest r. Potentially, there may be an exogenous borrowing limit on loans taken out given by $\bar{L}$. During college, students receive transfers depending on parental income. The government runs a financial aid program $\mathcal{G}(I)$ which subsidizes college costs based on financial needs. C represents the tuition cost of attending college.

Expected utility of a high-school graduate entering the labor market directly is:

$$\beta^H \int_\omega U^H\left(c^H_{jw}, y^H_{jw}; w, I, X\right) dG^H(w|I,X),$$

where $\beta^{hs} = \beta^{co1} + \beta^{co2}$ captures the length of the labor market period of high school graduates. The wage realization is drawn from a different conditional distribution $G^H(w|I,X)$, but is allowed to depend on attributes in X, importantly ability should be expected to influence wages also for high-school graduates. We will from now refer to all individuals not attending college as high-school graduates. The problem of a high-school graduate with parental income I and vector X becomes:

$$V^H(I,X;T(.)) = \max_{c^H_{jw}, y^H_{jw}} \beta^H \int_\omega U^H\left(c^H_{jw}, y^H_{jw}; w, I, X\right) dG^H(w|I,X)$$

subject to

$$\forall\ w:\ c^H_{jw} = y^H_{jw} - T(y^H_{jw}) + tr^H(I).$$

So a high-school graduate solves a static problem under this formulation. Note we also allow for the possibility that high-school graduates receive financial support from their parents $tr^H(I)$. We observe positive transfers in the data also for working high-school graduates and the majority of these transfers happen at the beginning of the working life.

Each type (I,X) decides to attend and college or not, comparing $V^C(I,X)$ and $V^H(I,X)$.

2.2 Government Problem and Optimal Policies

We now characterize the optimal level of financial aid function $\mathcal{G}(I)$ for a given tax function. We denote by $F(I)$ the unconditional parental income distribution, by $K(I,X)$ the joint c.d.f. and by $H(X|I)$ the conditional one; the densities are $f(I)$, $k(I,X)$ and $h(X|I)$. The support of I and X are $\mathbb{R}_+$ and χ. The government assigns Pareto weights $\tilde{k}(I,X) = \tilde{f}(I)\tilde{h}(X|I)$ which are normalized to integrate up to one. The objective of the government is:

$$\max_{\mathcal{G}(I)} \quad \int_{\mathbb{R}_+} \int_\chi \max\{V^C(I,X), V^H(I,X)\} \tilde{k}(I,X) dIdX \tag{1}$$

s.t. to the budget constraint:

$$\int_{\mathbb{R}_+}\int_{\chi}\beta^{C1}\mathcal{G}(I)\mathbb{1}_{V^C\geq V^H}k(I,X)dIdX = \int_{\omega}\int_{\mathbb{R}_+}\int_{\chi}\beta^{H}T(y^H_{jw})\mathbb{1}_{V^C<V^H}k(I,X)dIdXdG^H(w|I,X)$$
$$+\int_{\omega}\int_{\mathbb{R}_+}\int_{\chi}\beta^{C2}T(y^C_{jw})\mathbb{1}_{V^C\geq V^H}k(I,X)dIdXdG^C(w|I,X),$$

where $\mathbb{1}_{V^C<V^H}$ and $\mathbb{1}_{V^C\geq V^H}$ are indicator functions capturing the education choice for each type (I,X). The budget constraint simply equates government spending on financial aid to tax revenues. We label ρ as the multiplier on the budget constraint and assume the government shares the same discount factor as the agents.

Before we derive optimal education subsidies, we ease the upcoming notation a little bit and define the share of college students at parental income level I as follows:

$$F^C_I = \int_{\chi}\mathbb{1}_{V^C\geq V^H}h(X|I)dX.$$

Relatedly, we define the mass of people with attributes X going to college conditional on parents' income I as $h^c(X|I)$.

The marginal impact on welfare of an increase in financial aid $\mathcal{G}(I)$ is given by:

$$\underbrace{\frac{\partial F^C_I}{\partial \mathcal{G}(I)}\times \Delta T(I)}_{\text{Fiscal Externality}} \;-\; \underbrace{F^C_I(1-W^C_I)}_{\text{Mechanical Effect}}, \tag{2}$$

where $\Delta T(I)$ is the expected fiscal externality (Hendren 2014) from going to college for an average marginal individual with parental income I. Formally it is given by

$$\Delta T(I) = \frac{\int_{\chi}\mathbb{1}_{H_j\to C_j}\Delta T_j dX h^c(X|I)}{\int_{\chi}\mathbb{1}_{H_j\to C_j}h^c(X|I)dX}$$

where $\mathbb{1}_{H_j\to C_j}$ takes the value one if individual j is marginal in her college decision with respect to a small increase in financial aid and ΔT_j is the expected fiscal externality of an individual of type j:

$$\Delta T_j = \frac{1}{\beta^{C1}}\int_{\omega}\left(\beta^{C2}T(y^C_{jw})g^C(w|I,X) - \beta^H T(y^H_{jw})g^H(w|I,X)\right)dw - \beta^{C1}\mathcal{G}(I).$$

The first term in (2) captures the fiscal benefits of more financial aid. The reform will trigger enrollment from a certain set of students from income level I, those who were close to the margin on enrolling before the reform. This gives rise to the expected increase in tax payment per student type j.

The second term in (2) captures the mechanical aspect of the reform: for all inframarginal students at the parental income level in question, the government has to spend one more Dollar

since it is impossible to just target marginal students by the reform. The marginal costs are scaled down by the welfare weights on students

$$W_I^C = \frac{\tilde{f}(I)}{f(I)} \frac{\int_{\mathcal{X}} \mathbb{1}_{V^C \geq V^H} U_c^C(c_j^C; I, X) \tilde{h}(I|X) dX,}{\rho}$$

where U_c^C is the marginal utility of consumption and ρ is the marginal value of public funds – thus, W_I^C is the money-metric marginal social welfare weight (Saez and Stantcheva 2016).

For the grant to be at its optimal level, (2) must be set to zero, which yields:

$$\underbrace{\frac{\partial F_I^C}{\partial \mathcal{G}(I)} \times \Delta T(I)}_{\text{Marginal Benefits}} = \underbrace{F_I^C(1 - W_I^C)}_{\text{Marginal Costs}} \tag{3}$$

The LHS of (3) captures the benefits of increasing financial and the RHS the costs. Optimal financial aid is increasing in the effectiveness of increasing college attendance measured by $\frac{\partial F_I^C}{\partial \mathcal{G}(I)}$; such behavioral responses have been estimated in the literature exploiting financial aid reforms, see the discussion in Section 4.3. This behavioural effect is a policy elasticity as discussed in Hendren (2015). This effect is weighted by the fiscal externality created, i.e. the increase in tax payments. Intuitively, the size of the fiscal externality will depend on the returns to college for marginal students, another parameter which has been estimated in different contexts in prior work.

Optimal financial aid is decreasing in the number of inframarginal students, capturing the cost of financial aid, and increasing in the value placed on college students' welfare.

The formula is a sufficient statistic formula, providing intuition for the main trade-offs underlying the design of financial aid. It is valid without taking a stand on the functioning of credit markets for students, the riskiness of education decisions or the exact modeling how parental transfers are income influenced by parental income. Changes in those factors would influence the parameter $\frac{\partial F_I^C}{\partial \mathcal{G}(I)}$, for example, a tightening in borrowing constraints should increase the sensitivity of enrollment especially for low income students.

Notice that the essence of the main trade-offs are unchanged if taxable incomes change over the life-cycle. This affects the calculation of the term T_j which then reflects the difference in discounted present values of yearly tax payments over the life-cycle. Additionally, if wages change stochastically over the life-cycle, the fiscal externality still reflects differences in expected tax payments for the group of marginal students.

The Role of Parental Income How should we expect that the optimal $\mathcal{G}(I)$ varies with parental income I? On the one hand one should expect a larger effect of increases in financial aid on attendance decisions for low income kids. The size of the fiscal externality T_j is closely related to the returns for marginal students from a parental income group. Ex-ante it is not clear how this term should vary with I. The education literature has stressed the complementarity between early childhood human capital investments (Carneiro and Heckman 2002) and found evidence for higher educational returns for children from households with higher income (Altonji and Dunn 1996). It is plausible that this complementarity is also important

for marginal students, which suggests higher returns for higher levels of I. On the other hand, papers using instrumental variables to estimate returns for marginal students for different kind of policy changes have found relatively large returns (compared to OLS estimates), which is sometimes attributed to high returns for children from economically disadvantaged backgrounds Oreopoulos and Petronijevic 2013).

The RHS of (3) points towards progressive optimal policies given the well-documented correlation between college attendance and parental income (Chetty et al. 2014 AER P&P): the higher parental income, larger the share of inframarginal students. Additional welfare weights should be plausibly assumed to be decreasing in parents' resources. Our empirical model which we estimate in the next section will shed light on the quantitative importance and magnitudes of these different forces,

Beside the fully optimal level, we will use our empirical model for a related but different question: to what extent could small reforms to the current US financial aid be self-financing through higher future tax-revenue? We see that as an interesting complementary question for at least two reasons. First, it may be easier to implement small reforms to the existing current federal financial aid system. Second, it points out if there are potential Pareto improving free-lunch policy reforms on the table which are independent of the underlying welfare function.

Setting W_I^C to 0 to focus on fiscal magnitudes, we can rewrite (2) as:

$$R(I) = \frac{\frac{\partial F_I^C}{\partial \mathcal{G}(I)} \Delta T(I)}{F_I^C} - 1$$

This expression can be interpreted as the rate of return on one dollar invested in additional college subsidies at income level I. If it takes the value .2, it says that the government gets \$1.20 in additional tax revenue for one marginal dollar invested into college subsidies. If it is -.5, it implies that the government gets 50 Cents back for each dollar invested.

It is plausibly of more practical relevance to consider reforms which increases financial aid up for students whose parents' income is below some level I^*. For such a reform the fiscal effect is:

$$R^*(I) = \frac{\int_0^I \frac{\partial F_I^C}{\partial \mathcal{G}(\tilde{I})} \Delta T(\tilde{I}) d\tilde{I}}{\int_0^I F_I^C(\tilde{I}) f(\tilde{I}) d\tilde{I}} - 1, \tag{4}$$

which is simply the aggregation of the fiscal externalities divided by the fraction of inframarginals up to income level I.

2.3 Merit-Based Policies

Our approach is more general and can be extended to condition financial aid policies on other observables like academic merit or jointly on the combination of parental income and academic merit. In fact in our empirical application we will allow the government to also target financial aid policies on a signal of academic ability. We take that factor out of the vector X and label it θ. For notational simplicity, we will still call the vector without θ X; in this case X includes all factors influencing the college decision except for parental income and the measure of academic

ability. How would $\mathcal{G}(\mathcal{I}, \theta)$ optimally vary with ability? Optimality would still be described by (3) with the only difference that the terms would have to be evaluated at for the respective ability group.

How should we expect optimal financial aid expect to vary with academic ability, holding parental income fixed? At first glance, one may expect that the optimal grant $\mathcal{G}(\mathcal{I}, \theta)$ is increasing in θ as the returns to college education should increase in θ, which boosts the fiscal externality. By conditioning on ability directly, the government can implicitly guarantee that marginal students have a certain minimum expected return to college attendance, circumventing some of the potential problems of a pure need-based system. Working against this is that higher ability students are likely more inframarginal in their decision: i.e. they opt for college in any financial aid system. Our empirical model will shed light on this first question, which has no clear theoretical answer. A second question is: does the possibility of targeting policies to academic ability increase or decrease the need-based component of optimal financial aid, conditional on the merit-based component? Again the answer lies in the empirical evaluation of how the semi-elasticity of enrollment, the share of inframarginal and returns for marginal students change across the joint distribution of the variables.

3 Optimal Taxation

Our previous analysis hinted at the importance of income taxation for the design of optimal financial aid policies. We now extend the model to allow the government to also chose income taxation optimally. We consider this is an important extension for three reasons. First, as the last section has shown, higher and more progressive taxes are a complement to financial aid. The average level and also the progressivity of financial aid are hence closely related to the design of taxes.[9] Second, financial aid conditioning on parental resources is partly a redistribution device, captured by the welfare weights in formula (3). When we allow the government to redistribute directly with non-linear taxes, we can analyze how much of the progressivity of financial aid is driven by the desire to ex-ante redistribute. Finally, we can theoretically and empirically analyze how taxes themselves may distort education decisions, a channel analyzed in a prominent paper by Trostel (1993).[10]

We build on the large literature following Mirrlees (1971) and the modern literature originating with Diamond (1998) and Saez (2001) expressing optimal tax schedules in terms of observables (see Piketty and Saez (2013) for a review). Our model can stay very general in terms of the underlying heterogeneity, while still preserving tractability.

The planner's problem is the same as in (1) with the difference that the planner also optimally chooses the income tax schedule $T(\cdot)$. Notice that the formula for optimal financial aid policies is unaltered. We allow the tax function $T(\cdot)$ to be arbitrarily nonlinear in the spirit of Mirrlees (1971). We restrict the tax function to be only a function of income and to be independent of the education decision. This tax problem can either be tackled with a variational or tax perturbation approach (Piketty 1997, Saez 2001, Golosov, Tsyvinski, and Werquin 2014, Jacquet

[9]Bovenberg and Jacobs (2005) was the first paper to emphasize this complementarity. They study a case with a continuous education choice in which the optimal education subsidy rate is equal to the tax rate.

[10]See Abramitzky and Lavy (2012) for recent quasi-experimental evidence on the negative effect of redistributive taxation on education investment.

and Lehmann 2016) or with a restricted mechanism design approach for nonlinear history-independent income taxes that we explore in Findeisen and Sachs (2015b).

Assumption Preferences $U^H\left(c^H_{jw}, y^H_{jw}; w, I, X\right)$ and $U^W\left(c^W_{jw}, y^W_{jw}; w, I, X\right)$ imply no income effects on labour supply.

As we show in Appendix A.1, the optimal marginal tax rate can be expressed as:

$$\frac{T'(y^*)}{1-T'(y^*)} = \frac{1}{\varepsilon_{y^*,1-T'}} \times \left(\text{Haz}(y^*)\left(1-\mathcal{W}(y^*)\right) + \frac{\int_{\mathbb{R}_+} \xi(\mathcal{I}, y)\Delta T(\mathcal{I}) dF(I)}{h(y^*)y^*} \right)$$

where

$$\text{Haz}(y^*) = \frac{\int_{y^*}^{\infty} h(y)dy}{h(y^*)y^*}$$

and

$$\begin{aligned} h(y^*) =& \beta^{C2} \int_{\mathbb{R}_+} \int_{\mathcal{X}} T(y^C_{jw}) \mathbb{1}_{V^C \geq V^H} k(I,X) g^C(w|I,X) dIdX \\ &+ \beta^H \int_{\mathbb{R}_+} \int_{\mathcal{X}} T(y^C_{jw}) \mathbb{1}_{V^C \leq V^H} k(I,X) g^C(w|I,X) dIdX. \end{aligned}$$

Note that $\text{Haz}(y^*)$ and $h(y^*)$ are basically the Hazard ratio (Saez 2001) and the density of income, only adjusted by period length. $\mathcal{W}^{co}(\omega)$ and $\mathcal{W}^{hs}(\omega)$ are money metric average social welfare weights of students and college graduates with wage ω. $\varepsilon_{y^*,1-T'}$ is the local labor supply elasticity along a nonlinear tax schedule (Jacquet and Lehmann 2016). To capture the college responses to taxes, we define

$$\xi(\mathcal{I}, y) = \frac{1}{f(I)} \frac{\partial F^C_I}{\partial T(y)},$$

which is the semi-elasticity of enrollment with respect to the absolute tax at income y.

First, note that this formula holds for optimal as well as for suboptimal college subsidies. It differs from the seminal formula of Diamond (1998) in two respects. First of all, it is adjusted for period length and discounting. Second, the term

$$\int_{\mathbb{R}_+} \xi(\mathcal{I}, y)\Delta T(\mathcal{I}) dF(I)$$

shows up in the numerator. The formula is therefore related to the formulas of Saez (2002) and Jacquet, Lehmann, and Van der Linden (2013), where the extensive margin is due to labor market participation, or Lehmann, Simula, and Trannoy (2014) where the extensive margin captures migration.[11] In these papers, the extensive margin is an unambiguous force towards lower marginal tax rates whenever workers pay more taxes than non-workers (or individuals that are on the margin of emigrating pay positive taxes). In contrast, the endogeneity of college enrollment does not necessarily lead to lower marginal tax rates as the additional term

[11] Further papers are Scheuer (2014) where the extensive margin captures the decision to become an entrepreneur and Kleven, Kreiner, and Saez (2009) who consider the extensive margin of secondary earner to study the optimal taxation of couples.

is ambiguous in its sign. First, we do not know the sign of $\Delta T(\mathcal{I})$ in general. Second, we do not know whether higher taxes for individuals with $\omega > \omega^*$ indeed lead to lower college enrollment because of possibly counteracting income and substitution effects. Whereas higher taxes unambiguously decrease the return to college, an income effect on college enrollment might work in the opposite direction. Further, higher taxes decrease the opportunity costs from going to college in the form of foregeone earnings. In an earlier version of this paper, we distinguish these effects more formally. (Findeisen and Sachs 2015a, p.12)

Whether and to what extent the endogeneity of college enrollment leads to lower optimal marginal tax rates is thus a quantitative question.

4 Estimation and Calibration

We first explain how we concretely specify the model in Section 4.1. In Section 4.2 we explain how we quantify the model using micro data and information on current policies. In Section 4.3 we show in detail that the quantitative model performs very well in replicating patterns in the data and quasi-experimental evidence on returns to college and the elasticity of college education with respect to financial aid.

4.1 Empirical Model Specification

We now specify the concrete set-up for the empirical model. Concerning the underlying heterogeneity, we specify the vector X as (θ, κ), where θ is ability and κ are psychic costs. In the estimation, κ will also be allowed to depend on parental education. We assume that ability directly influences the wage distribution, i.e. we specify the wage distributions as $G^C(w|\theta)$ and $G^H(w|\theta)$. We assume these functions to be independent of parental income because we did not find a strong significant effect of parental income. In the modeling of psychic costs, we closely follow the structural education literature; see, among others, Cunha, Heckman, and Navarro (2005), Heckman, Lochner, and Todd (2006), Cunha, Karahan, and Soares (2011), Navarro (2011) and Johnson (2013). Psychic costs an be interpreted as a one-dimensional aggregate that captures factors that influence the decision to go to college beyond the budget constraint. We borrow the notion psychic costs from the empirical literature. They enter the model in a vary simple way: κ is just subtracted from lifetime utility if an individual goes to college. The value functions in case of college attendance is

$$V^C(I, \theta, \kappa; \mathcal{G}(.), T(.)) = \max_{c_j^C, c_{jw}^W, y_w^W} \beta^{C1} U^C(c_j^C) + \beta^{C2} \int_\omega U^W\left(c_{jw}^W, y_w^W; w\right) dG^C(w|\theta) - \kappa$$

subject to

$$\forall\, w: \; c_{jw}^W = y_{jw}^W - T(y_w^W) - (1+r)L$$
$$c_j^C = tr^C(I) + \mathcal{G}(.) - C + L,$$
$$L \leq \bar{L},$$

where j is a realization the triple (I, θ, κ). So we make the standard assumption that preferences over consumption and work are homogenous. Consumption in college differs because of

heterogeneity in parental transfers, financial aid receipt, and borrowing. We consider different cases if agents are facing binding borrowing constraints $\bar{L}$ or not. For high-school graduates:

$$V^H(I,\theta;T(.)) = \max_{c_w^H, y_w^H} \beta^H \int_\omega U^H\left(c_w^H, y_w^H; w\right) dG^H(w|\theta)$$

subject to

$$\forall\, w:\; c_w^H = y_w^H - T(y_w^H) + tr^H(I).$$

Note that the notation implies the fact that taxable income y only depends on w because of Assumption 1. We assume the utility function to be of the following form for both high-school and college graduates.

$$\frac{\left(C - \frac{\left(\frac{y}{w}\right)^{1+\varepsilon}}{1+\varepsilon}\right)^{1-\gamma}}{1-\gamma}.$$

During college, l is set to 0. We choose $\varepsilon = 2$, which implies a compensated labor supply elasticity of .5[12] The value of the curvature parameter γ matters for the elasticity of the college education decision. We set $\gamma = 1.85$ as this implies an elasticity in the mid range of estimates from the empirical literature. We comment on that more in Section 4.3.

An important simplifying assumption we make is that we abstract from the direct modeling of labor supply behavior over the life-cycle, as we are mostly interested in getting the net-present value of the fiscal externalities over the life-cycle right. This is achieved by using annuity values of the average discounted sums of income, as we describe below. Such simplifications are also commonly made in other calculations, calculating the lifetime present value effects of policies on earnings in the literature, for example, Kline and Walters (2016) and Chetty, Friedman and Rockoff (2014). Under our assumptions of no income effects, this simplification should be of no consequence for the quantitative results. If there are wealth effects on labor supply, a student debt channel could potentially affect our optimal policy results. Suppose changes in financial aid change the borrowing behavior and the amount of student debt carried over. This would differentially affect the labor supply behavior of low-income children with higher debt relative to high-income children with low debt. This effects would probably be mostly present at the beginning of the working life.

We assume that college takes 4.5 years (i.e. $T_e = 4.5$) and assume that individuals spend 43.5 or 48 years on the labor market depending on whether they went to college. The choice of 4.5 years for degree completion corresponds to the average years to graduation we observe in the NLSY97, which is 4.57 years. This lines up well with numbers from other sources, for example, from the National Center for Education Statistics (NCES).[13] We set the risk free interest rate to 3%, i.e. $R = 1.03$ and assume that individuals' discount factor is $\beta = \frac{1}{R}$.

Table 1: Quantification of the Model

Object	Description	Procedure/Target
$F(I)$	Marginal distribution of of parental income	Directly taken from NSLY97
(θ, I)	Joint and conditional distribution of innate abilities	Directly taken from NSLY97
w	Individual wage	Calibration from income as in Saez (2001)
$G^H(w\|\theta)$	Conditional Wage Distribution High-school	Estimated from regressions
$G^C(w\|\theta)$	Conditional Wage Distribution College	Estimated from regressions
$tr^H(I)$	Conditional Transfer Distribution High-school	Estimated from regressions
$tr^C(I)$	Conditional Transfer Distribution College	Estimated from regressions
$K(\theta, I, \kappa)$	Joint distributions with psychic costs	Maximum Likelihood
	Utility Function: $\frac{\left(C-\frac{l^{1+\varepsilon}}{1+\varepsilon}\right)^{1-\gamma}}{1-\gamma}$	
ε=0.5	Labor Supply Elasticity	Chetty, Guren, Manoli, and Weber (2011)
γ =1.85	Curvature of Utility	Enrollment Elasticitites
	Current Policies	
$\bar{s}$	Stafford Loan Maximum	Value in year 2000
$T(y)$	Current Tax Function	Gouveia-Strauss (Guner et al. 2013)
$\mathcal{G}(\theta, \mathcal{I})$	Need- and Merit Based Grants	Estimated from regressions

4.2 Data & Procedure

We use two data sets to bring our model to the data: the National Longitudinal Survey of Youth 79 and 97 (henceforth NLSY79 and the NLSY97). A big advantage of these data sets, which has been exploited in many previous papers, is that they contain the *Armed Forced Qualification Test Score* (AFQT-score) for most individuals, which is a cognitive ability score for high school students that is conducted by the US army. The test score is a good signal of ability. Cunha, Karahan, and Soares (2011), e.g., show that it is the most precise signal of innate ability among comparable scores in other data sets.

The NLSY97 is the baseline for our analysis. To quantify the joint distribution of parental income and ability, we take the cross sectional joint distribution in our sample. We then estimate how these variable map into the other variables (parental transfers, wages, grants, psychic costs) of the model. Since individuals in the NLSY97 set are born between 1980 and 1984, not enough information about their earnings is available to quantify the conditional wage distributions. To obtain these conditional wage distributions, we therefore use the NLSY79 data as this data set contains more information about labor market outcomes – individuals are born between 1957 and 1964. Combining both data sets in such a way has proven to be a fruitful way in the literature to overcome the limitations of each individual data set, see Johnson (2013) and Abbott, Gallipoli, Meghir, and Violante (2016). The underlying assumption is that the relation between AFQT and wages has not changed over that time period. We use the method

[12] Micro-evidence suggests that the compensated elasticity is probably lower, around .33 (Chetty, Guren, Manoli, and Weber 2011), Given that our elasticity reflects the labor supply responsiveness over the life cycle, we take a larger value of .5.

[13] See `http://nces.ed.gov/fastfacts/display.asp?id=569`.

of Altonji, Bharadwaj, and Lange (2011) to make the AFQT-scores comparable between the two samples and different age groups.

Finally, we define an individual as a college graduate if she has completed at least a bachelor's degree. Otherwise she counts as a high school graduate. Since individuals in the NLSY97 turn 18 years old between 1998 and 2002, we express all US-dollar amounts in year 2000 dollars. To quantify our model, we proceed as follows:

1. We calibrate and preset a few parameters and policies, decribed in Section 4.2.1.
2. We estimate $G^H(w|\theta)$, $G^C(w|\theta)$ in 4.2.2.
3. Transfer function $tr^C(I)$, $tr^H(I)$ and grant receipt are estimated $\mathcal{G}(\theta, \mathcal{I})$ by regressions. So we estimate empirically the need-based and merit-based component of current financial aid. For brevity, details of our procedure for transfers and grants are relegated to the appendix. Economically, the most important results for parental transfers is the strong dependence on education choice by the child. This contingency of parental transfers acts as a price subsidy for college. On top, we recover the well-know positive correlation between parental income and transfers. For grants, we find a strong negative effects of parental transfers on financial aid receipt at the extensive and intensive margin. Additionally, we can capture merit based grants by the conditional correlation of AFQT scores with grant receipt.
4. Based on that, we calculate $V^C(I, \theta, \kappa; \mathcal{G}(.), T(.))$ and $V^H(I, \theta; T(.))$ for each individual and estimate the distribution of psychic costs with maximum likelihood in Section 4.2.3.

4.2.1 Current Policies

To capture current tax policies, we use an approximation of Guner, Kaygusuz, and Ventura (2013) for effective marginal tax rates in the year 2000.[14] We use the year 2000 because individuals in the NLSY97 are 18 in the year 2000 on average. Marginal tax rates concavely increase and converge to roughly 32%. We set the lump sum element of the tax code $T(0)$ to minus \$1,800 a year. For average incomes this fits the deduction in the US-tax code quite well.[15] For low incomes this reflects that individuals might receive transfers such as food stamps.[16] We set the value of exogenous government spending to 11.2% of the GDP, which is the value that leads to a balanced government budget. This value is a bit low, but this should not be too surprising as we do not take into account corporate taxes or capital income taxes.

For tuition costs, we take average values for the year 2000 from Snyder and Hoffman (2001) for the regions Northeast, North Central, South and West, as they are defined in the NLSY. For all these regions we also take into account the amount of money coming from the taxpayer

[14] We use the "Gouveia-Strauss"-specification including local sales taxes and take the average over all individuals. The parameters can be found in Table 12 of Guner, Kaygusuz, and Ventura (2013).

[15] Guner, Kaygusuz, and Ventura (2013) report a standard deduction of \$7,350 for couples that file jointly. For an average tax rate of 25% this deduction could be interpreted as a lump sum transfer of slightly more than \$1,800.

[16] The average amount of food stamps per eligible person was \$72 per month in the year 2000. Assuming a two person household gives roughly \$1,800 per year. Source: http://www.fns.usda.gov/sites/default/files/pd/SNAPsummary.pdf

that is spent per student, which has to be taken into account for the fiscal externality. Both procedures are described in detail in Appendix A.2.1. The average values are \$7,434 for annual tuition and \$4,157 for the annual subsidy (public appropriations) per student. Besides these implicit subsidies, student receive explicit subsidies in the form of grants and tuition waivers. We estimate how this grant receipt varies with parental income and ability in Section A.2.4 using information provided in the NLSY. Finally, we make the assumption that individuals can only borrow through the public loan system. In the year 2000, the maximum amount for Stafford loans per student was \$23,000. The latter assumption does not seem innocuous. For our results about the desirability of increasing college subsidies, it is rather harmless because we show how our results can be understood in terms of sufficient-statistics and our quantified model predicts values for these sufficient statistics that are in line with empirical evidence.

4.2.2 Estimation of Wage Functions

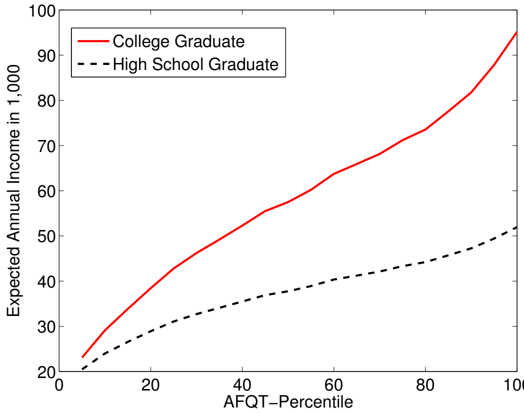
In our model, y refers to an average income over the lifetime as we only have one labor market period. Therefore, we took annuitized income as the data counterpart.

Our approach to estimate the relationship between innate ability, education and labor market outcomes relates to Abbott, Gallipoli, Meghir, and Violante (2016) and Johnson (2013). We run regressions of log annuitized income on AFQT for both education levels. This gives us conditional log-normal distributions of labor inocme. See Appendix A.2.2 for details

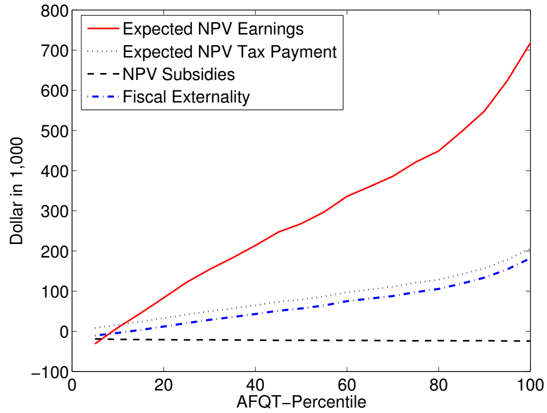
Top incomes are underrepresented in the NLSY as in most survey data sets. Following common practice in the optimal tax literature (Piketty and Saez 2013), we therefore append Pareto tails to each income distribution, starting at incomes of \$350,000. We set the shape parameter a of the Pareto distribution to 2 for all income distributions.[17] Figure 1(a) shows the expected annual before tax income as a function of the AFQT (in percentiles) for both education levels and clearly demonstrates the complementarity between innate ability and education, which has also been highlighted in previous papers (Carneiro and Heckman 2005). The red bold line in Figure 1(b) shows how this translates into an expected NPV difference in lifetime earnings. As was argued in the theoretical section, the returns to education play an important role for the fiscal effects of an increase in college enrollment. The additional tax payment (again in NPV) is clearly increasing in AFQT (black dotted line). To get the overall impact on the government budget, subsidies have to be subtracted, which are given by the black dashed-line. Subsidies are increasing in ability which reflects the fact individuals with higher ability currently obtain higher scholarships (merit-based financial aid), which we elaborate in Section A.2.4. The net impact on public funds is given by the blue dashed-dotted line.

The last step consists of calibrating the respective skill/wage distribution from the income distributions by exploiting the first-order condition of individuals as pioneered by Saez (2001).

[17] Diamond and Saez (2011) find that starting from $\approx \$350,000$ the Pareto parameter is constant and 1.5. Since their data are for 2005 and our data are also for earlier periods, we choose a Pareto parameter of 2 because top incomes were less concentrated earlier. The rationale for having the Pareto parameter independent of education and innate ability is that we did not find any systematic relationship between the Pareto parameter and either θ or education in the NLSY.



(a) Expected Annual Income



(b) NPV Income and Fiscal Externality

4.2.3 Estimation of Psychic Costs

Based on the estimated reduced form relationships, we can calculate the two value functions for each individual in the data. In line with the empirical literature, we assume that the decision to go to college is also influenced by heterogeneity in preferences for college. We assume that these psychic costs are determined by parental education and by innate ability – see Cunha, Heckman, and Navarro (2005), among others.[18] These assumptions give us a binary choice model

$$P(co_i = 1) = Prob(Y_i^* > 0)$$

where

$$Y_i^* = V_{co}^i - V_{hs}^i + \beta_1^{pc} + \beta_2^{pc} AFQT_i + \beta_3^{pc} S_i^{father} + \beta_4^{pc} S_i^{mother} + \varepsilon_i^{pc}$$

and where $\varepsilon_i^{pc} \sim N(0, \sigma)$. We restrict the coefficient on the difference in the value function to be one, as utility is our unit of measurement. For the power of the estimation, however, this is no restriction as we have one degree of freedom in parameter choice. As expected, all the variables have a positive and significant impact on the college choice, see Table 4 in the appendix.

Based on these estimations, we calculate the estimated psychic cost for each individual:

$$\hat{\kappa}_i = -\hat{\beta}_1^{pc} - \hat{\beta}_2^{pc} AFQT_i - \hat{\beta}_3^{pc} S_i^{father} - \hat{\beta}_4^{pc} S_i^{mother} - \hat{\varepsilon}_i^{pc}.$$

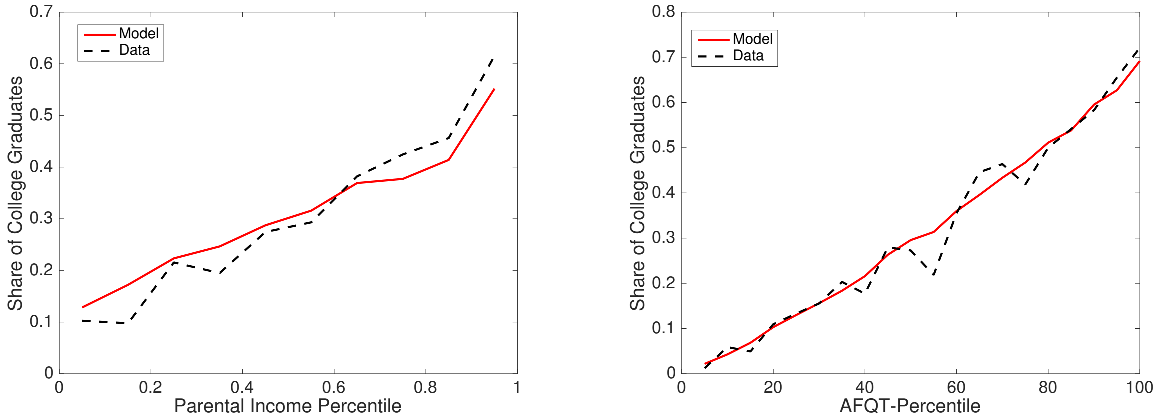
where $\hat{\varepsilon_i^{pc}} \sim N(0, \hat{\sigma})$. We draw 1,000 values for each ε_i and then fit a normal distribution of κ conditional on innate ability and parental income. Finally, we are then equipped with the joint distribution of parental income, innate ability and psychic costs.

4.3 Model Performance and Relation to Empirical Evidence

In order to assess the suitability of the model for policy analysis, we look at how well it replicates well known findings from the empirical literature and especially quasi-experimental studies.

[18]The literature also suggests that individuals that grew up in urban areas are more likely to go college. The coefficient did not turn out as significant in our estimation and we therefore do not include it in our analysis. The inclusion of the variable does not affect any of our results.

Graduation Shares. Figure 1 illustrates graduation rates as a function of parental income and AFQT in percentiles respectively. The bold lines indicate results from the model and the dashed lines are from the data. We slightly underestimate the parental income gradient. The correlation between AFQT and college graduation, however, is fitted well. The overall number of individuals with a bachelor degree is 30.56% in our sample and 30.85% in our model. Data from the United States Census Bureau are very similar: the share of individuals aged 25-29 in the year 2009 holding a bachelor degree is 30.6% – this comes very close to our data, where we look at cohorts born between 1980 and 1984.



(a) Graduation Rates and Parental Income

(b) Graduation Rates and AFQT

Figure 1: Removing Borrowing Constraints

Responsiveness of Graduation to Grant Increases. Many paper have analyzed the impact of increases in grants or decreases in tuition on college enrollment. Kane (2006) and Deming and Dynarski (2009) survey the literature. The estimated impacts of a $1,000 increase in yearly grants (or a respective reduction in tuition) on enrollment ranges from 1-6 percentage points, depending on the policy reform and research design. Numbers differ since some of the evaluated programs were targeted towards low income groups and others were not, and sometimes the higher amount of grants was associated with a lot of paperwork, which might create selection. The majority of studies arrive at numbers between 3 and 5 percentage points, however. As our model is a model of college graduation instead of college enrollment, the numbers are not directly comparable for two reasons: (i) not all of the newly enrolled students will indeed graduate with a bachelor's degree, (ii) some of the newly enrolled students enroll in community colleges and (iii) students that have enrolled also for lower grants are less likely to drop out of college. Relatively little is known about (iii). Concerning (i), we know that in the year 2000 roughly 66% of newly enrolled students enroll in 4-year institutions (Table 234 of Snyder and Dillow (2013)). Of those 66%, only slightly more than half should be expected to graduate with a bachelors degree. In Section A.3.2, we estimate that the dropout probability of the marginal students in our model is 45%. However, of those initially enrolled at two year colleges, also 10% graduate with a bachelors degree (Shapiro et al. (2012), Figure 6). Thus, translating the 3-5 percentage points increase in enrollment into numbers for graduation rates, we get 1.2-2 percentage points when taking into account (i) and (ii). Taking into account (iii)

would yield slightly higher numbers, however, there is no strong empirical evidence about this effect that would guide us about the quantitative importance. We chose the parameter $\gamma = 1.85$ of the utility function such that we are exactly in the middle of this range, i.e. at 1.6.

A more recent study by Castleman and Long (2015) looks at the impact of grants targeted to low income children. Applying a regression-discontinuity design for need-based financial aid in Florida (Florida Student Access Grant), they find that a $1,000 increase in yearly grants for children with parental income around $30,000 increases enrollment by 2.5 percentage points. Interestingly, they find an even larger increase in the share of individuals that obtain a bachelor degree after 6 years by 3.5 percentage points. After 5 years the number is also quite high at 2.5 percentage points. These results show that grants can have substantial effects on student achievement conditional on enrollment.

Importance of Parental Income. It is a well known empirical fact that individuals with higher parental income are more likely to receive a college degree, see also Figure 1(a). However, it is not obvious whether this is primarily driven by parental income itself or variables correlated with parental income and college graduation. Using income tax data and a research design exploiting parental layoffs, Hilger (2014) finds that a $1,000 increase in parental income leads to an increase in college enrollment of 0.43 percentage points. Using a similar back of the envelope calculation as in the previous paragraph – i.e. that a 1 percentage point enrollment increase leads to a 0.40 percentage points increase in graduation rates – this implies an increase in graduation rates of .17 percentage points. To test our model, we increased parental income for each individual by $1,000 and obtained increases in bachelors completion by 0.08 percentage points. In line with Hilger (2014), our model predicts a small effect of parental income, even a bit smaller but in line with Hilger (2014).

The College Wage Premium and Marginal Returns. The college-earnings premium in our model is 99%, i.e. the average income of a college graduate is twice as high as the average income of a high-school graduate. As our earnings data are for the 1990s and the 2000s, this is well in line with empirical evidence in Oreopoulos and Petronijevic (2013); see also Lee, Lee, and Shin (2014). Doing the counterfactual experiment and asking how much the college graduates would earn if they had gone to college, we find that the returns to college are 62.9%. This implies a return of 12.43% for one year of schooling, which is in the upper half of the range of values found in Mincer equations (Card 1999, Oreopoulos and Petronijevic 2013).[19]

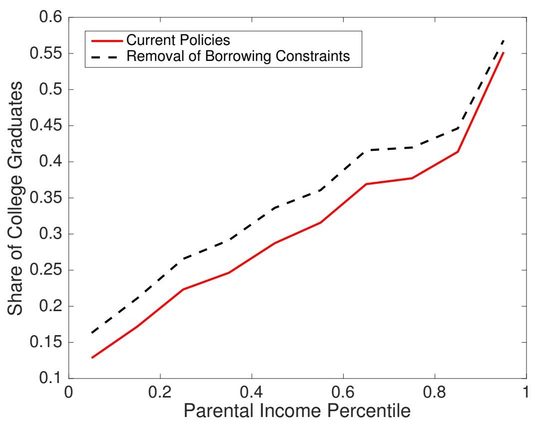
The more important number for our analysis is the return to college for *marginal students*. We find it to be slightly lower at 58.62%, which implies a return to one year of schooling of 11.53%. This reflects that marginal students are of lower ability on average than inframarginal students and also is in line with Oreopoulos and Petronijevic (2013). A clean way to infer returns for marginal students is found in Zimmerman (2014). In his study marginal refers to the *academically marginal* around a GPA admission cutoff. He finds returns of about 9.9% per

[19] The calculation is as follows. In a Mincer regression, the log of earnings is regressed on years of schooling. The difference in $log(1.64y)$ and $log(y)$ is equal to $log(1.64)$. Dividing by four years of schooling (for a bachelor degree) yields 12.20% per year of schooling.

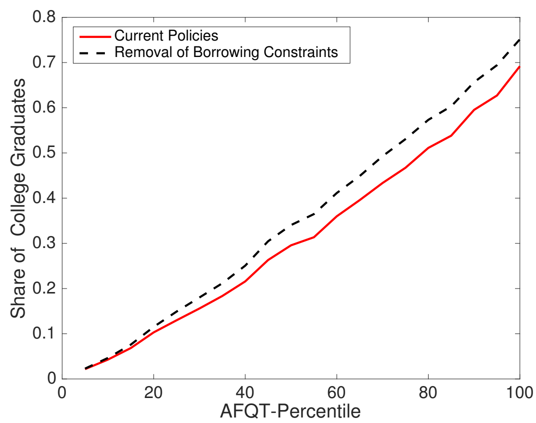
year.[20] However, his number refers to the *academically marginal* students (implying a GPA of 3), whereas in our thought experiment we refer to those students who are marginal w.r.t. to a small change in financial aid – these students are likely to be of higher ability than the academically marginal students. We explore this issue and make use of the fact that the NLSY also provides GPA data. In fact our model gives a return to college of 51.73% for students with a GPA in the neighborhood of 3, which implies a Mincer return of 10.42% for one year of schooling – which comes very close to the 9.9% from Zimmerman (2014).

Finally, we do not account for differing rates of unemployment and disability insurance rates. Both numbers are typically found to be only half as large for college graduates (See Oreopoulos and Petronijevic (2013) for unemployment and Laun and Wallenius (2013) for disability insurance). Further, the fiscal costs of Medicare are likely to be much lower for individuals with college degree. Lastly, we assume that all individuals work until 65 not taking into account that college graduates on average work longer (Laun and Wallenius 2013). These facts would strengthen the case for an increase in college subsidies.

The Role of Borrowing Constraints. To assess the importance of borrowing constraints, we completely remove them to ask by how much graduation increases. In this experiment enrollment increases by 3.94 percentage points from 30.85% to 34.79%. This value is in the realm of values the literature has found, see, e.g., Johnson (2013) and Navarro (2011). As Figure 2(a) reveals, the removal of borrowing constraints has larger effects for low income children. Figure 2(b) illustrates the importance of borrowing constraints for individuals with different innate abilities. Naturally, individuals with high ability have the strongest need for more borrowing because of high expected future earnings.



(a) Borrowing Constraints and Parental Income



(b) Borrowing Constraints and AFQT

Figure 2: Removing Borrowing Constraints

[20]He finds gains of 22% to obtain four-year college admission, which should be compared to the return of community colleges, which are the most frequent outside options for those students and take on average about 2 year less to complete. In addition, his findings are for earnings around 8 and 14 years after high school completion. Given that college students have a steeper earnings profile (see, e.g., Lee et al. 2014), these numbers are likely to underestimate the return to lifetime earnings.

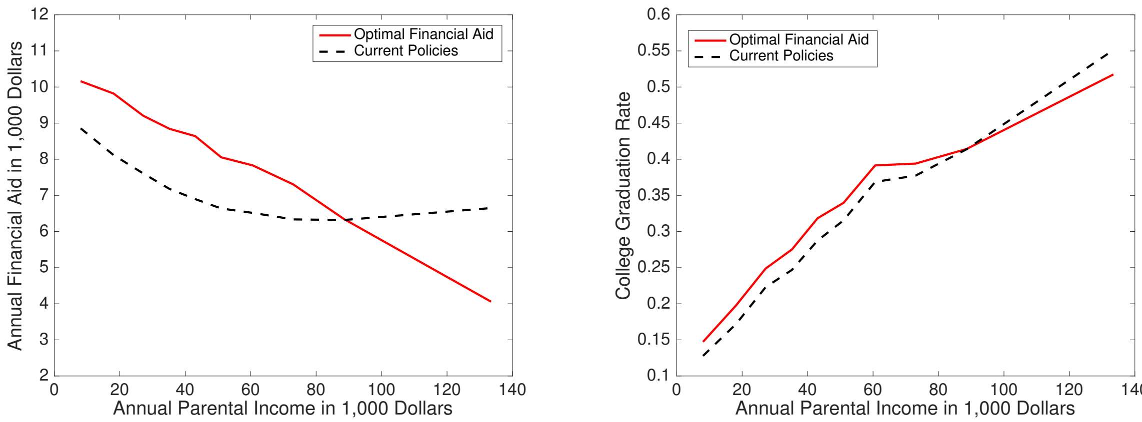
5 Results: Optimal Financial Aid

In this section we quantitatively present our main result of progressive financial aid policies. After presenting the benchmark in Section 5.1, we show that results are robust to the welfare function and also hold if the government only wants to maximize tax revenue in Section 5.2. One might think that results are driven by borrowing constraints. As we show in Section 5.3, even if a perfect credit market could be provided, the optimal financial aid schedule is strongly progressive. In Section 5.4, we also chose the need-based element optimal and find that this does not at all alter our result.

Finally, we show a larger degree of progressivity can be implemented in a Pareto improving way in Section 5.5.

5.1 Optimal (Need-Based) Financial Aid

For our first policy experiment, we ask which levels of financial aid for different parental income levels maximize welfare and thus solve (3). For this experiment, we do not change taxes or any other policy instrument but instead only vary the targeting of financial aid. At this stage, we leave the merit-based element of current financial aid policies unchanged, i.e. we do not change the gradient of financial aid in merit. In Section 5.4, we show that our main result also extends to the case where the merit-based elements are chosen optimally.



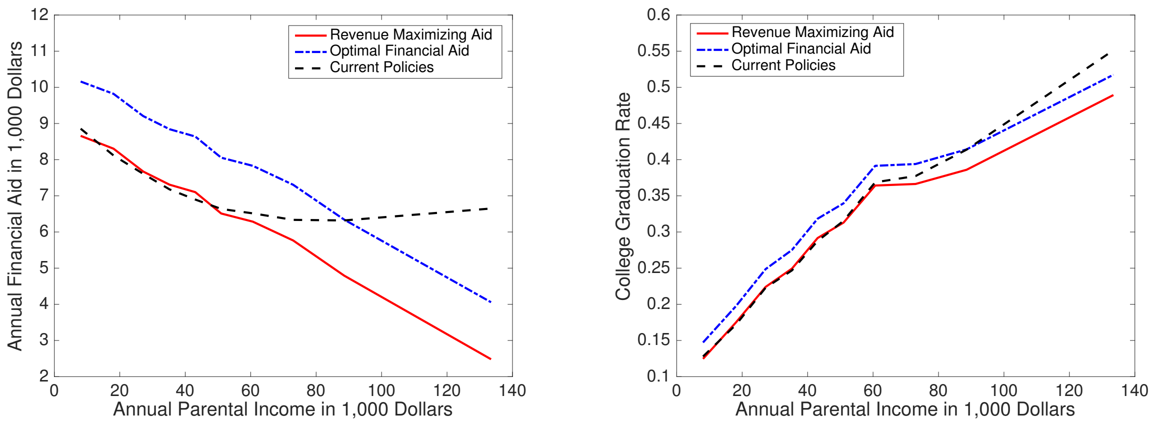
(a) Financial Aid (b) Graduation Rates

Figure 3: Optimal versus Current Financial Aid

Figure 3(a) illustrates our main result for the benchmark case. Optimal financial aid is strictly decreasing in parental income. Compared to current policies, financial aid is higher for students with parental income below $90,000. This is partly financed by a reduction of financial aid for richer students and partly by the fact that the increase is more than self-financing for the poorest students as we further elaborate in Section 5.5. This change in financial aid policies is mirrored in the change of college graduation as shown in Figure 3(b). Overall graduation even increases by 1.6 percentage points to 32.44%. This number highlights the efficient character of this reform. As we now show, even in the absence of redistributive purposes does this result survive.

5.2 Tax-Revenue Maximizing Financial Aid

One might be suspicious that the progressivity is driven by a desire for redistribution from rich to poor students. If this were the case, the question would naturally arise whether the financial aid system is the best means of doing so. However, we now show that the result even holds in the absence of redistributive purposes. We ask the following question: how should a government that is only interested in maximizing the budget set financial aid policies? Figure 4(a) provides the answer: revenue maximizing financial aid also in this case is very progressive. Whereas the overall level is naturally lower if the consumption utility of students is not valued, the declining pattern is basically unaffected. For lower parental income levels, revenue maximizing aid is even above the current one which implies that an increase must be more than self-financing. We study this in more detail in Section 5.5. The implied graduation patterns are illustrated in Figure 4(b).



(a) Financial Aid

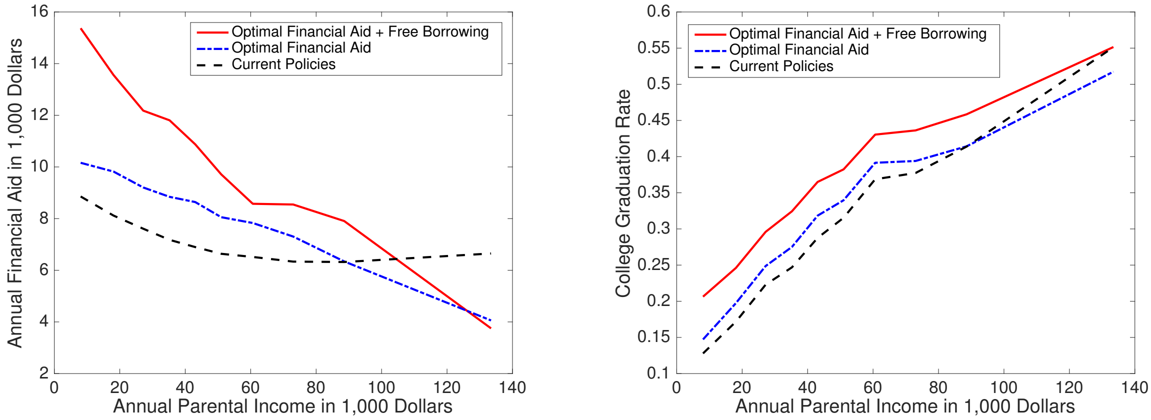
(b) Graduation Rates

Figure 4: Tax Revenue Maximizing Financial Aid Policies

5.3 The Role of Borrowing Constraints

We have shown that the optimal progressivity is not primarily driven by redistributive tastes but rather by efficiency considerations. Given that our analysis assumes that students cannot borrow more than the Stafford Loan limit, the question arises these efficiency considerations are driven by borrowing limits that should be particularly binding for low parental income children.

To elaborate upon this question, we ask how normative prescriptions for financial aid policies change if students can suddenly borrow as much as they want. As illustrated in Figure 5(a), optimal financial aid policies become even more progressive. The abolishment of borrowing constraints implies a boost in college education which implies a large increase in tax revenue that can now be used to increase financial aid. The increase is mainly targeted at the low parental income children. First because of their higher welfare weight. Second because also in the absence of borrowing constraint, the general force survives that subsidizing low parental income children is relatively cost-effective because of the much lower share of inframarginal students as can be seend in Figure 5(b).

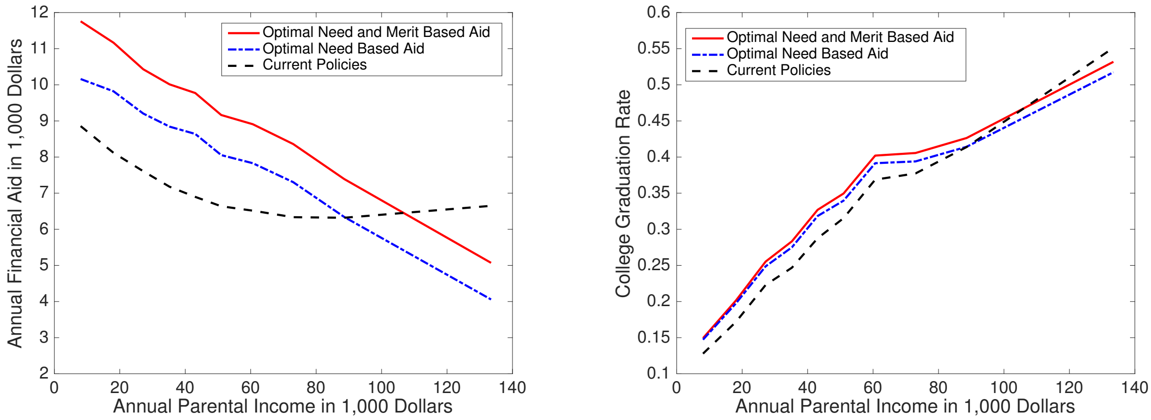


(a) Financial Aid (b) Graduation Rates

Figure 5: Financial Aid and Graduation with Free Borrowing

5.4 Merit Based Financial Aid

Up to now, we have assumed that the merit-based element of financial aid policies stays unaffected. We now allow the government to optimally choose the gradient in merit and parental income. Figure 6(a) shows that – if optimally targeted also in terms of merit – financial aid policies can be more generous. The progressive nature however is even slightly reinforced.



(a) Financial Aid (b) Financial Aid: Above Median Ability

Figure 6: Optimal Need and Merit Based Financial Aid

Figure 7 shows how optimal financial aid is increasing is increasing in AFQT. The slope is almost independent of parental income.

5.5 Pareto Improving Reforms

As anticipated in Section 5.2, an increase in financial aid can be self-financing if properly targeted.

Figure 8(a) illustrates the fiscal return if financial aid is increased for individuals with income lower or equal to X. An increase in financial aid targeted to children with parental income below

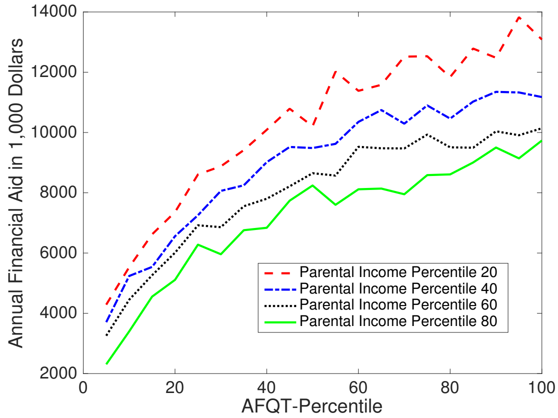
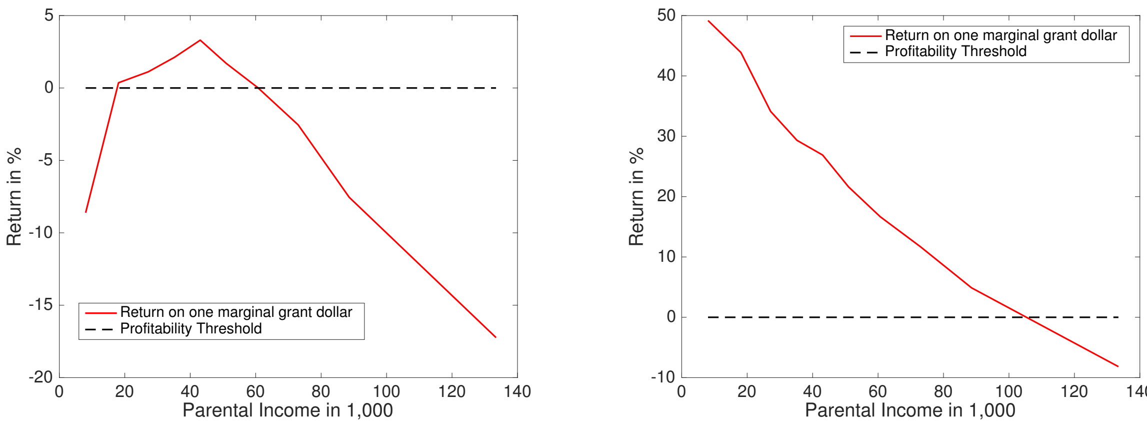


Figure 7: Illustration of Optimal Merit Based Element

\$60,000 is slightly above the margin of being self-financing. This is a striking result: increasing subsidies for this group is a free lunch.

Figure 8(b) illustrates the same, however for the case where subsidies are only increased for those AFQT scores above the 50th percentile. Here policy implications become more stark. An increase in subsidies targeted to the poorest students can have a huge fiscal returns of up to 50% as defined in equation (4). Thus, for each marginal dollar invested in grants the government obtains \$1.50 in discounted future tax revenue.



(a) Financial Aid

(b) Graduation Rates

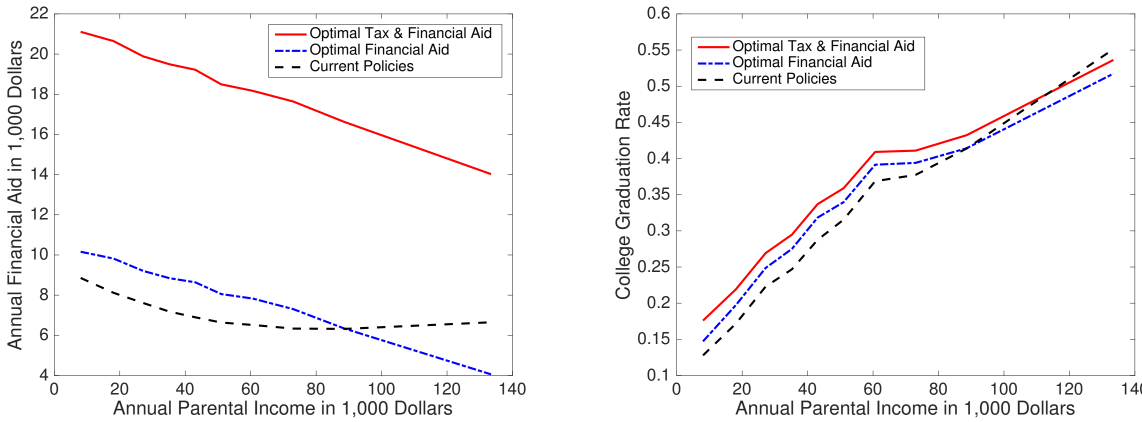
Figure 8: Fiscal Returns on Increase in Financial Aid

6 Results: Jointly Optimal Financial Aid and Income Taxation

The previous section has shown that optimal financial aid policies are very progressive. In particular, we have emphasized the efficiency role of progressive policies. Nevertheless, one might wonder how robust this result is with respect to the tax system. Given that the optimal Utilitarian tax schedule is likely to be more progressive than the current tax schedule, how do

our results for optimal financial aid change if the tax system is chosen optimally? In particular, is there a trade-off between ex-ante redistribution (through progressive financial aid policies) and ex-post redistribution (through progressive income taxation)?

In Section 3, we have show how to theoretically tackle the issue of optimal income in the spirit of Mirrlees. Thus, we allow the tax function to be arbitrarily nonlinear. We assume that agents are borrowing constraint and the government only (besides the tax schedule) maximizes the need-based element of the financial aid schedule. Results are barely changed if borrowing constraints are relaxed and/or the merit-based element is chosen optimally as well.



(a) Financial Aid

(b) Graduation Rates

Figure 9: Financial Aid and Graduation with Optimal Redistribution

Figure 9(a) illustrates optimal financial aid in the presence of the optimal tax schedule. Financial aid is at a much higher level and its progressive nature is preserved. The higher level in general is due to two facts and these can be best understood when comparing the optimal income tax schedule to the current one. Both are illustrated in Figure 10.The optimal tax schedule implies much higher tax rates than the current one. This implies that generally more tax revenue is potentially available to cover financial aid. More importantly, our results reflects the 'Siamese Twins' logic of Bovenberg and Jacobs (2005). Higher income tax rates increase the fiscal externality, which increases the optimal level of the college subsidy (i.e. financial aid).

7 Further Aspects

In this section we argue that the result about the progressive nature of optimal student financial aid is not altered if college dropout and general equilibrium effects on wages are taken into account.

7.1 Dropout

In our analysis we assumed that anybody who goes to college indeed graduates. Shapiro et al. (2012, Table 6) document that for the cohort which was first enrolled in a four year college in the fall of 2006, 62% graduated 6 years later. Thus, at most 38% never received a bachelor

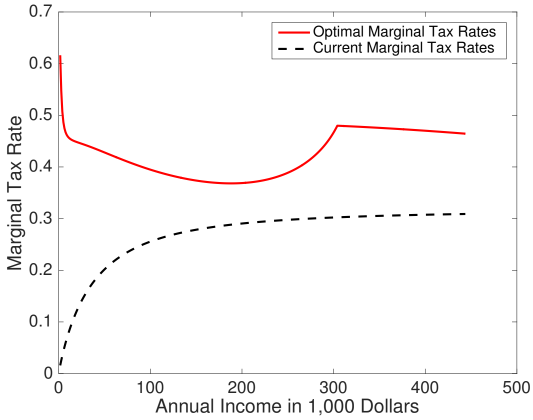


Figure 10: Optimal versus Current Marginal Tax Rates

degree. So one might wonder to what extent our results are robust to the incorporation of dropout. If one things about the optimality condition 3, what is changed? (i) The marginal costs of the reform are increased because the increase in subsidies now must also be paid for students that are inframarginal but do not graduate. If, for example, 38% are dropouts and the stay on average in college for two years, the marginal cost term – abstracting from discounting – is increased by $\frac{0.38}{0.62}\frac{2}{4.5}$ by 50%. (ii) An increase in college subsidies does not only imply marginal students that graduate but also marginal students that dropout. Note that for our quantitative part we were not making the mistake of assuming that every additionally enrolled student graduates. Instead we were only taking into account the share of those that actually graduate, see also our discussion in Section 4.3. Taking into account that higher subsidies in addition induce marginal students that dropout might make a an increase of grants more or less desirable depending on whether the college dropouts contribute more to public funds over their lifecycle than they would have in the absence of any college education. According to Lee, Lee, and Shin (2014) the earnings premium for 'some college' was between 25% and 40% between 1980 and 2005. In an earlier version of that paper (Findeisen and Sachs 2015a) we extended our marginal reform approach to incorporate these two aspects of dropout. We found that overall the desirability to increase grants is muted by dropout but did not find that it significantly changed the result that increasing grants for students with low parental income yields higher fiscal returns than for the average.

However, there is a third effect that we did not take into account and which should reinforce the progressive nature of optimal financial aid. College grants increase persistence, in particular for students with weak parental background (Angrist, Autor, Hudson, and Pallais 2015, Bettinger 2004, Castleman and Long 2015). This effect would reinforce our normative implications about the progressivity of financial aid.

7.2 General Equilibrium Effects on Wages

Our analysis abstracted from general equilibrium effects. A rising share of college graduates is likely to decrease the returns to college. What does this imply for our findings? A first educated guess might be that it generally weakens the case for an increase in subsidies. If returns to college decline, wages decline not only for the marginal but also for inframarginal

students. But there is a counteracting force: the increase in college labor increases wages for high school graduates and therefore their contribution to public funds. In the earlier version of this paper (Findeisen and Sachs 2015a), we quantitatively elaborated the effect with a standard production function with high skill labor supply (college) and low skill labor supply (non college) in accordance with Goldin and Katz (2009). We found that the second effect even dominates the first one: general equilibrium effects seem to strengthen the argument for increasing subsidies rather than weakening it. The reason is that are approximately twice as many high-school than college graduates. Whereas these arguments where about the general desirability of increasing college financial aid, there is no reason to assume that the progressivity result is altered by general equilibrium effects on wages.

Another issue with general equilibrium is of course that individual college decisions might change in the presence of general-equilibrium effects. This is an important long-run question that is discussed in Abbott, Gallipoli, Meghir, and Violante (2016). Whereas these effects can alter the desirability of increasing financial aid in general, they should have no effects on the progressive nature of optimal financial aid.

8 Conclusion

To be written.

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A Appendix

A.1 Derivation of Optimal Tax Formula

To be added.

A.2 Appendix for Section 4

A.2.1 Tuition Fees and Public Costs of Colleges

First, we categorize the following 4 regions:

- Northeast: CT, ME, MA, NH, NJ, NY, PA, RI, VT
- North Central: IL, IN, IA, KS, MI, MN, MO, NE, OH, ND, SD, WI
- South: AL, AR, DE, DC, FL, GA, KY, LA, MD, MS, NC, OK, SC, TN , TX, VA, WV
- West: AK, AZ, CA, CO, HI, ID, MT, NV, NM, OR, UT, WA, WY

We base the following calculations on numbers presented by Snyder and Hoffman (2001). Table 313 of this report contains average tuition fees for four-year public and private universities. According to Table 173, 65% of all four-year college students went to public institutions, whereas 35% went to private institutions. For each state we can therefore calculate the average (weighted by the enrollment shares) tuition fee for a four-year college. We then use these numbers to calculate the average for each of the four regions, where we weigh the different states by their population size. We then arrive at numbers for yearly tuition & fees of \$9,435 (Northeast), \$7,646 (North Central), \$6,414 (South) and \$7,073 (West). For all individuals in the data with missing information about their state of residence, we chose a country wide population size weighted average of \$7,434.

Tuition revenue of colleges typically only covers a certain share of their expenditure. Figures 18 and 19 in Snyder and Hoffman (2001) illustrate by which sources public and private colleges finance cover their costs. Unfortunately no distinction between two and four-year colleges is

available. From Figures 18 and 19 we then infer how many dollars of public appropriations are spent for each dollar of tuition. Many of these public appropriations are also used to finance graduate students. It is unlikely that the marginal public appropriation for a bachelor student therefore equals the average public appropriation at a college given that costs for graduate students are higher. To solve this issue, we focus on institutions "that primarily focus on undergraduate education" as defined in Table 345. Lastly, to avoid double counting of grants and fee waivers, we exclude them from the calculation as we directly use the detailed individual data about financial aid receipt from the NLSY (see Section A.2.4). Based on these calculations we arrive at marginal public appropriations of \$5,485 (Northeast), \$4,514 (North Central), \$3,558 (South), \$3,604 (West) and \$4,157 (No information about region).

A.2.2 Details on Income Regressions

We first quickly explain the construction of the annuitized income variable. Assume that for a high school graduate i, one observes y_t^i for $t = 1, ..., 48$ – i.e. from 18 to 65. The discounted present value of earnings (at age 18) is then given by $\sum_{t=0}^{48} \frac{y_t^i}{(1+r)^{t-1}}$. Simply taking the average over y_t to obtain the relevant income for our model would be misleading since discounting is not taken into account. Thus, we use annuitized income $\tilde{y}_i$ which is given by:

$$\tilde{y}_i = \frac{\sum_{t=1}^{48} \frac{y_t^i}{(1+r)^{t-1}}}{\sum_{t=1}^{48} \frac{1}{(1+r)^{t-1}}}.$$

Everyone with less than 16 years of schooling is defined as a high school graduate.[21] Everyone with 16 or more years of schooling is defined as a college graduate.

We run separate regressions, one for high school graduates and one for college graduates, of the form:

$$\ln \tilde{y}_i = \alpha_{ce} + \beta_e^{IN} ln(AFQT_i) + \varepsilon_{ei}^{inc}, \tag{5}$$

for $e = hs, co$. α_{ce} is a cohort-education fixed effect. We find that a one percent increase in AFQT-test scores leads to a 1.88% increase in income for college graduates and 1.28% increase in income for high school graduates, which reflects a complementarity between skills and education.This procedure gives us the mean of log incomes as a function of an individual's AFQT-score and education level. Based on that, we then calculate the respective average annual income over the life cycle for each AFQT-score and education level. We assume errors are normally distributed, so income is distributed log-normally. To determine the second moment of this log-normal distribution across education and innate ability levels, we use the sample variances of the error terms from (5) for each education level.

For most individuals, we do not have information in every year. First of all, we never have information after age 53. Second, since 1994 the survey is conducted biannually. Third, we often have to deal with missing values. To resolve the first issue, we assume that incomes are flat afterwards, which is roughly what one finds in data sets with information on earnings over the whole life cycle. See, e.g., Figures 13 and 14 in Lee, Lee, and Shin (2014). Concerning the second issue, we take the average of the income in the year before and after. Concerning

[21] Note that this definition also includes high school dropouts and individuals with community college degrees. We also worked with different specifications but our main results were not significantly affected.

Table 2: Transfer Equation

	Parental Income	College	Dependent Children
Coefficient	.3136***	.5829***	-.0667**
Standard Error	(.0449)	(.0563)	(.0329)

N=3,238. Robust standard errors. * p $\leq$ 0.10, ** p $\leq$ 0.05, *** p $\leq$ 0.01.

the third issue, we proceed similarly but also take values that are two and three years away if information for the year before and after is missing as well. All other years that are still missing are then just not taken into account for calculating $\tilde{y}_i$. Assume, e.g., that only income at age 19, 33 and 46 were observable. Then we would calculate

$$\tilde{y}_i = \frac{\frac{y_{i19}}{(1+r)} + \frac{y_{i33}}{(1+r)^{14}} + \frac{y_{i46}}{(1+r)^{27}}}{\frac{1}{(1+r)} + \frac{1}{(1+r)^{14}} + \frac{1}{(1+r)^{27}}}.$$

All for all other monetary variables, incomes are measured in 2000 dollars.

Our estimates for the slopes are. $\hat{\beta}^{IN}_{co} = 1.88$ (0.186) and $\hat{\beta}^{IN}_{hs} = 1.28$ (0.074). As described in the main text, the second-moments of the log-normal parts are education dependent, so that until 350k, $\ln y$ is normal with standard deviation σ^e. We directly take the estimates for σ^e from the distribution of residuals from (5). The values are 0.6548 for college and 0.6631 for high-school.

A.2.3 Parental Transfers

In the NLSY97 we can observe the amount of transfers an individual obtained from its parents as well as family income. We take the constructed variable for parental transfers from Johnson (2013), who also takes into account the value of living at home as part of the parental transfer, for those individuals who cohabitate with their parents. We take yearly averages of those transfers for the ages 19-23. The sample average is \$6,703. We estimate the following equation:[22]

$$log(tr_i) = \alpha^{tr} + \beta^{tr}_1 log(\mathcal{I}_i) + \beta^{tr}_2 co_i + \beta^{tr}_3 depkids_i + \varepsilon^{tr}_i, \tag{6}$$

where *depkids* is the number of dependent kids living in the household of the parents. The coefficients are provided in Table 2. A 1% increase in parental income increases parental transfers by 0.31% and college graduates receive transfers that are 79% ($exp(.5829) - 1$) higher than for high school graduates. Note that this implies that the absolute increase of parental transfers because of going to college is higher for high income kids. Johnson (2013) and Winter (2014) have argued that it is crucial to take this effect into account to explain the large impact of parental income on college enrollment and completion.

Besides transfers that individuals receive during that time, they can also have some assets when they decide to study. In the NLSY97, information is provided on individual net worth at age 20. Certainly, this is not the best number for our purposes since it is highly influenced by choices at ages 18 and 19. We nevertheless take this noisy measure into account because

[22]We also estimated models with an interaction term between log parental income and college graduation. The coefficient on the interaction term is statistically insignificant.

it gives our quantitative model a better fit concerning the importance of parental income. To measure how net wealth varies with parental income, we estimate the following regression:

$$w_i = \alpha^w + \beta^w \mathcal{I}_i + \varepsilon_i^w. \tag{7}$$

We find a gradient for parental income of .127 (0.02) and an intercept of $7,950 (1164). To obtain the parental transfer for the model, we take the implied parental transfer from equation (6) and adjust it by the implied level of wealth from equation (7) and thereby recalculate the wealth into an annual transfer.

A.2.4 Estimation of Grant Receipt

In practice, grants and tuition subsidies are provided by a variety of different institutions. Pell grants, for example, are provided by the federal government. In addition, there exist various state and university programs. To make progress, similar to Johnson (2013) and others, we go on to estimate grant receipt directly from the data.

Next, we estimate the amount of grants conditional on receiving grants:

$$gr_i = \alpha^{gr} + \beta_1^{gr} \mathcal{I}_i + \beta_2^{gr} \mathcal{I}_i + \beta_3^{gr} black_i + \beta_4^{gr} AFQT_i + \beta_5^{gr} depkids_i + \varepsilon_i^{gr}. \tag{8}$$

Besides grant generosity being need-based (convexly decreasing) and in favor of blacks, generosity is also merit-based as $\hat{\beta}_4^{gr} > 0$ and increases with the number of other dependent children (besides the considered student) in the family.

Table 3: OLS for Grants

	Parental Income	Parental Income^2	Black	AFQT	Dependent Children
Coefficient	-.0915***	6.00e-07 ***	649.06**	23.90***	224.69**
Standard Error	(0.0192)	(1.83e-07)	(296.03)	(4.57)	(99.11)

N=968. * p ≤ 0.10, ** p ≤ 0.05, *** p ≤ 0.01.

A.2.5 Probit Estimates

Table 4: Probit Estimation of College Graduation

	AFQT	Father's Education	Mother's Education
Coefficient	.0140***	0.0832***	0.0504***
Standard Error	(.0011)	(.0097)	(.0105)

N=3,897. * p ≤ 0.10, ** p ≤ 0.05, *** p ≤ 0.01.

A.3 Appendix for Section 5.5

A.3.1 Need-Based Grant Reforms and Parental Incentives

Assume that parents have preferences of the form:

$$u(c, K, \mathcal{I}),$$

where K is total resources available for their kids. For the child's resources, we have $K = tr_{co} + \mathcal{G}(\theta, \mathcal{I})$. Parents choose their transfer tr_{hs}. The budget constraint of the parents is $c = \mathcal{I} - T(\mathcal{I}) - tr_{co}$. Their problem then reads as:

$$\max_{tr_{co},\mathcal{I}} u\left(y - T(\mathcal{I}) - tr_{co}, tr_{co} + \mathcal{G}(\theta, \mathcal{I}), \mathcal{I}\right)).$$

The first-order conditions are

$$u_K = u_c$$

and

$$u_c \cdot [1 - T'(\mathcal{I})] + u_K \cdot \left[\frac{\partial \mathcal{G}(\theta, \mathcal{I})}{\partial \mathcal{I}}\right] = -u_{\mathcal{I}}$$

Combining the first-order conditions yields:

$$u_c \cdot \left[1 - T'(\mathcal{I}) + \frac{\partial \mathcal{G}(\theta, \mathcal{I})}{\partial \mathcal{I}}\right] = -u_{\mathcal{I}}$$

which implies that the parents will react to an decrease in $\frac{\partial \mathcal{G}(\theta,\mathcal{I})}{\partial \mathcal{I}}$ in the same way as to an increase in $\mathcal{T}'(\mathcal{I})$. Denote by $\varepsilon_{\mathcal{I}^*,1-T'+\frac{\partial \mathcal{G}(\theta,\mathcal{I})}{\partial \mathcal{I}}}$ the elasticity of income with respect to an increase of the effective marginal tax rate.

The reform we are considering is to increase grants for children with parental income below a certain threshold $\mathcal{I}^*$ by $d\mathcal{G}$. This implies an increase of $\frac{\partial \mathcal{G}(\theta,\mathcal{I})}{\partial \mathcal{I}}$ within a small interval $[\mathcal{I}^*, \mathcal{I}^* + \Delta\mathcal{I}]$ by

$$\Delta\left(\frac{\partial \mathcal{G}(\theta, \mathcal{I})}{\partial \mathcal{I}}\right) = \frac{d\mathcal{G}}{\Delta\mathcal{I}}$$

.

The impact of the change in parents behavior on public funds is then given by:

$$\left(\mathcal{T}' - \frac{\partial \mathcal{G}(\theta, \mathcal{I})}{\partial \mathcal{I}}\right) \varepsilon_{\mathcal{I}^*,1-T'+\frac{\partial \mathcal{G}(\theta,\mathcal{I})}{\partial \mathcal{I}}} \frac{\mathcal{I}^*}{1 - \mathcal{T}' + \frac{\partial \mathcal{G}(\theta,\mathcal{I})}{\partial \mathcal{I}}} \frac{d\mathcal{G}}{\Delta\mathcal{I}}.$$

The mass of affected parents is $h^{co}_{\mathcal{I}^*}\Delta\mathcal{I}$,where $h^{co}_{\mathcal{I}^*}$ is the density of parents with income $\mathcal{I}^*$ and children that go to college. The overall effect is therefore

$$\left(\mathcal{T}' - \frac{\partial \mathcal{G}(\theta, \mathcal{I})}{\partial \mathcal{I}}\right) \varepsilon_{\mathcal{I}^*,1-T'+\frac{\partial \mathcal{G}(\theta,\mathcal{I})}{\partial \mathcal{I}}} \frac{\mathcal{I}^*}{1 - \mathcal{T}' + \frac{\partial \mathcal{G}(\theta,\mathcal{I})}{\partial \mathcal{I}}} d\mathcal{G}.$$

We set $\epsilon^p_{\mathcal{I}^*,1-T',\frac{\partial \mathcal{G}}{\partial \mathcal{I}}} = 0.33$. Since the relevant period where the parents could adjust their labor supply is only 4 periods, we choose a lower number than for the children, for whom we consider a lifetime labor supply decision.

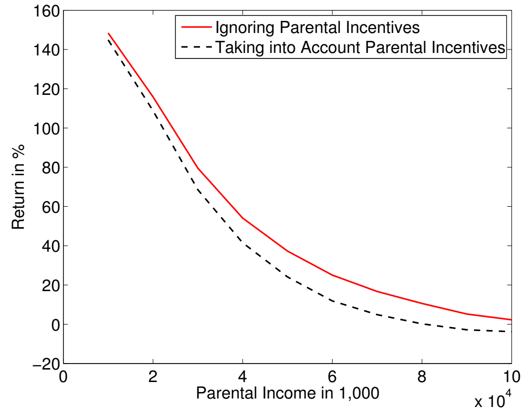


Figure 11: Need-based subsidy increase

Figure 11 illustrates the return on one dollar invested in grants for children with parental income below a certain threshold, taking into account parental incentives. The red bold line reflects the benchmark case (i.e. formula (**??**)) where parental incentives where not taken into account and the black dashed line reflects the case that they are taken into account. Returns are lowered, however, this effect is rather small. In particular, when the threshold is set at low parental income levels taking into account that parents might change their taxable income hardly affects the conclusions from the baseline case.

A.3.2 Robustness Check I: Dropout

In this subsection, we elaborate how our results change if college dropout is taken into account as well. We base our calculations on empirical evidence on dropout behavior as well as own estimates. Dropout changes the basic considerations from the previous subsections for two reasons: (i) subsidies are not only paid to those students who will graduate but also to those who drop out although for a shorter period of time. (ii) higher subsidies will not only induce individuals to study that will graduate but also some that will fail to graduate – whether this makes a subsidy increase fiscally more appealing depends on how large returns to 'some college' are.

We first look at effect (i) in isolation. Shapiro et al. (2012, Table 6) find that for the cohort which was first enrolled in a four year college in the fall of 2006, 62% graduated 6 years later. Thus, at most 38% never received a bachelor degree. Let's first assume that all marginal students indeed graduate. How does a first back of the envelope calculation change our result? The adjusted formula looks as follows

$$\gamma_D^{\mathcal{G}} = \frac{\Delta \bar{e} \times \Delta \bar{\mathcal{T}}}{G^{co}(\overline{\omega})\left(1 + \frac{1}{t_D}\frac{D_{infra}}{1-D_{infra}}\right)} - 1 = -.38, \tag{9}$$

where $\frac{1}{t_d}$ adjust for the fact that dropouts do not receive subsidies over 4.5 years, but less. We assume that dropouts spend two years in college, which is the average number dropouts spent in college in the NLSY97. This analysis reveals that taking into account dropout is not unimportant. We did not take into account fact (ii) in this first calculation, i.e. the impact of marginal students that drop out on the government budget. It is not obvious what value

Table 5: Dropout Probit

	$\mathcal{I}$	Father's Education	AFQT
Coefficient	-1.98e-06 ***	-.0622153 .***	-.0094686 ***
Standard Error	(6.47e-07)	(.0116132)	(.0013619)

N=1,921. * p ≤ 0.10, ** p ≤ 0.05, *** p ≤ 0.01.

to take for the dropout probability of marginal students. In addition, marginal students also partly benefit from college. To tackle the first issue, we estimated the dropout probability in the NLSY97 as function of parental income, father's education and AFQT. The results are displayed in Table 5.

As expected, all these variables have a negative impact on dropping out of college.[23] Predicting the dropout probability of marginal and inframarginal students for our model yields a dropout probability of 36% for individuals with characteristics of our infa-marginal students and 45% for individuals that have characteristics of our marginal students. Thus the formula should now look like

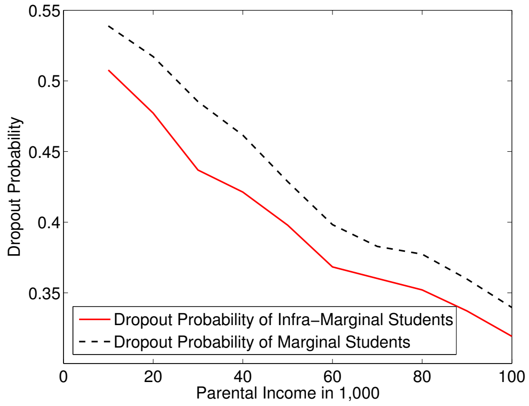
$$\gamma_D^{\mathcal{G}} = \frac{\Delta\bar{e} \times \Delta\bar{\mathcal{T}}\left(\Delta\bar{\mathcal{T}} + \frac{D_{marg}}{1-D_{marg}}\Delta\bar{\mathcal{T}}^D\right)}{G^{co}(\overline{\omega})\left(1 + \frac{1}{t_D}\frac{D_{infra}}{1-D_{infra}}\right)} - 1 = -.30 \tag{10}$$

A question that remains is how to quantify $\Delta\bar{\mathcal{T}}^{dropout}$. According to Lee, Lee, and Shin (2014) the earnings premium for 'some college' was between 25% and 40% between 1980 and 2005. Based on that, we assume that the earnings increase from some college (i.e. 2 years in college before dropout) is 30% of that from graduating.[24] For this case, we obtain $\gamma^{\mathcal{G}} = -.30$ – thus even when taking dropout into account, the government gets back \$0.70 for each dollar invested.

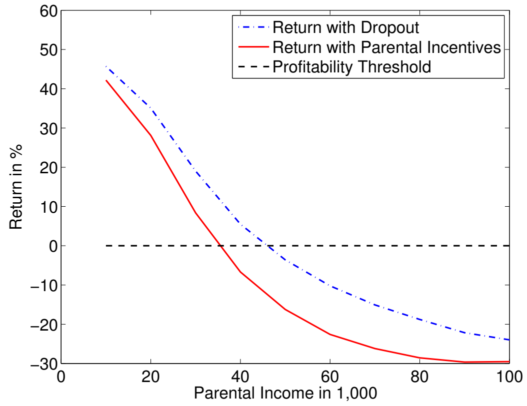
Need-Based Grants We also investigate how our results for need-based grants change when taking into account college dropout. In particular, the results from Table 5 might raise doubt about the robustness of our result for the efficiency of need-based grants as low income children are more likely to drop out. We address this question and calculate the return on increasing subsidies for children with parental income below certain income levels again and take into account how the dropout probabilities of marginal and inframarginal students vary with income. Figure 12(a) shows how the dropout probability varies with parental income for marginal and inframarginal students of our model. The dropout probability clearly decreases with parental income. As Figure 12(b) (which is the dropout-equivalent to Figure 11) shows, this has indeed an effect on how the profitability of grant increases varies with parental income (See blue dash-dotted line). However, the effect is not too large and does not change much with respect to

[23] This is in line with reported statistics. Individuals with lower academic ability are more likely to dropout, see e.g. Chatterjee and Ionescu (2012). It has also been documented that parental characteristics play an important role, see e.g. Stinebrickner and Stinebrickner (2003).

[24] The numbers cited from Lee, Lee, and Shin (2014) do not take into account different ability of those who graduate and those who dropout. The number that we take (i.e. 30%) is conditional on ability. Given that those who dropout are typically of lower ability, we consider our choice of 30% as a lower bound.



(a) Dropout Probability



(b) Fiscal Return

Figure 12: Revenue Gains as a Function of Annual Income

the main conclusion. We even look at a 'worst-case scenario' and take parental incentives into account as well. As the red bold line reveals even in this scenario increasing subsidies for children with parental income below \$35,000 is a free lunch; this corresponds to those children in the lowest parental income tercile.

A.3.3 Robustness Check II: General Equilibrium

Our analysis so far abstracted from general equilibrium effects. A rising share of college graduates is likely to decrease the returns to college. What does this imply for our findings? A first educated guess might be that it weakens the case for an increase in subsidies. If returns to college decline, wages decline not only for the marginal but also for inframarginal students. It turns out, however, that for the reforms we consider, general equilibrium effects seem to strengthen the argument for increasing subsidies rather than weakening it. The reason is that the increase in college labor increases wages for high school graduates and therefore their contribution to public funds. There are approximately twice as many high-school than college graduates. As a consequence, the second effect (i.e. increases high-school wages) dominates and general equilibrium effects strengthen the case for an increase in subsidies.

Following common practice, we assume a CES production function of the following form:

$$F(H,L) = ((A_l L)^\rho + (A_h H)^\rho)^{\frac{1}{\rho}}$$

where $\rho \in (-\infty, 1]$ and $\sigma = \frac{1}{1-\rho}$ is the elasticity of substation between college and non-college labor supply. For our model, we have

$$L = \int_\Theta \int_{\mathbb{R}_+} \int_\Omega y_{hs}(\omega) dG_\theta^{hs}(\omega) H_{\theta,\mathcal{I}}(\tilde{\kappa}(\theta,\mathcal{I})) dK_\theta(\mathcal{I}) dF(\theta)$$

and

$$H = \int_\Theta \int_{\mathbb{R}_+} \int_\Omega y_{co}(\omega) dG_\theta^{co}(\omega) \left(1 - H_{\theta,\mathcal{I}}(\tilde{\kappa}(\theta,\mathcal{I}))\right) dK_\theta(\mathcal{I}) dF(\theta).$$

It is simple to show that wages per efficiency unit of high school and college labor are given by

$$w_{hs} = A_l^\rho \left(A_l^\rho + A_h^\rho \left(\frac{H}{L} \right)^\rho \right)^{\frac{1-\rho}{\rho}}$$

and

$$w_{co} = A_h^\rho \left(A_h^\rho + A_l^\rho \left(\frac{H}{L} \right)^{-\rho} \right)^{\frac{1-\rho}{\rho}} .$$

Without loss of generality, we set $w_{hs} = w_{co} = 1$ for our calibrated economy – it is w.l.o.g. since one cannot jointly identify the level of ω for workers and the wages for an efficiency unit of labor supply. We now repeat our analysis from above and ask what the revenue consequences are from marginally increasing grants for all (potential) college students. But now we assume that wages will change as a consequence of the increase in college labor supply. The consequence is that also tax payments of all individuals that do not change their college decision will change. The tax payments of college graduates will decrease as their wage decreases whereas the opposite is true for the high school graduates – for this simple exercise we assume that labor supply will be constant; as we argue below, endogenous labor supply would strengthen our results.

To compute how the number for $\gamma^{\mathcal{G}}$ changes, we therefore have to compute how the tax payments of those who do not change their behavior changes. Our adjusted formula thus reads as

$$\gamma_R^{\mathcal{G}} = \frac{\Delta\bar{e}\Delta\bar{\mathcal{T}} + G^{co}(\overline{\omega})\Delta\bar{\mathcal{T}}_{GE}^{co} + G^{hs}(\overline{\omega})\Delta\bar{\mathcal{T}}_{GE}^{hs}}{G^{co}(\overline{\omega})} - 1, \tag{11}$$

where $\Delta\bar{\mathcal{T}}_{GE}^{hs}$ and $\Delta\bar{\mathcal{T}}_{GE}^{co}$ reflect the average increase in the contribution to public funds due to general equilibrium effects on wages. We make the assumption that $\rho = .39$ which implies $\sigma = 1.64$ in accordance with Goldin and Katz (2009). We find that $\gamma^{\mathcal{G}} = -0.10$ for this case. Thus, general equilibrium effects increase this number by .03. Whereas tax payments from college graduates decrease, the opposite is true for high school graduates. As the share of high school graduates is larger than that of college graduates, it outweighs this effect even though high school wages increase less than college wages decrease and even though high school graduates face lower marginal tax rates given the progressivity of the tax code. Finally note that taking into account endogenous labor supply should strengthen our results: high school graduates would work more and college graduates would work less. Given that the wage increase effect of high school graduates dominated the wage decrease effect, it is unlikely that the opposite is true for labor supply responses. To conclude, taking into account that relative wages may change because of an increase of college educated labor supply does not affect the fiscal externality argument strongly and is likely to strengthen it. Another important question that we leave for future research is how decisions of future generations to go to college will be affected by the implied decline in the college wage premium and what this implies for policies.