Arts vs Engineering: Choosing Consumption of and Investment in Education[1]

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Abstract

In this paper we develop a model in which students choose their college coursework based on both investment and consumption incentives. We show that these education decisions are socially inefficient. This result is driven by the fact that students do not consider an externality in the working environment of acquiring education for investment purposes. We show when and how it is possible to design tuition fees in such a way that students acquire the socially optimal level of education.

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1. Introduction

In the literature on the economics of education, the theory of human capital assumes that investments in education increase a worker's productivity (Becker, 1993). The classic theory of human capital does not consider that consumption incentives may also influence educational choices. Substantial evidence supports the hypothesis that consumption incentives are important in understanding higher education. For example, some coursework and related fields of study offer little prospect for increasing future income yet continues to attract students. Before reviewing this evidence, we summarize the model and some implications of it.

In our model, students vary in endowed ability and income, and they acquire education both with consumption and investment features. Educational *investment* increases a student's future earnings and has a positive effect on the general productivity of the working environment (Benabou, 1996). Thus, investment in education is associated with a positive externality. Other educational expenditure has only a consumption value. When a student chooses its levels of consumption and investment education, the investment externality is not taken into account. As a consequence, in the private equilibrium, a student acquires too little educational investment compared to the social optimum.

The paper considers next possible government interventions to engender the social optimum, specifically (i) regulated tuition fees and (ii) regulated levels of education. We show that with enough information it is possible to either manipulate tuition fees or set minimal levels of education to induce students to acquire the socially optimal levels of education. In the case with regulated tuition fees, this result emerges if tuition fees for education consumption are kept at the marginal production cost of providing education, whereas the tuition fees for education investment are set below marginal production cost. Assuming student ability is private information, we show when these schemes are incentive compatible.

While privately and socially optimal educational investment varies with ability in our model, it is independent of initial income. On the other hand, education consumption (privately chosen and socially efficient) increases with income since it is a normal good. These imply: (i) educational expenditure that does not increase future earnings arises; (ii) richer households of given ability will spend more on education; and (iii) richer households of given ability will choose a mix of courses with relatively less investment payoff. These predictions are consistent with some empirical evidence.

College curricula vary widely in the job prospects after graduation. Students are often observed choosing majors and courses with weak job opportunities. This is not for lack of information. A

student has a multitude of information about job opportunities in each field of study. For example, it is widely acknowledged that the job opportunities associated with pursuing an engineering degree are more favorable compared to those from an art degree. Interpreting education as a consumption good can help explain attendance at college courses that have weaker job prospects. A student may, for example, find taking an art course more enjoyable than taking an engineering course.

There is a relationship between income and the education acquired by an individual. This relationship refers both to the amount of education acquired and to the choice of curricula. In both cases, interpreting education as a consumption good may help to explain this relationship. First, educational attainment increases with income (Becker, 1967, 1993, McMahon, 1976, 1984, and 1991, Acemoglu and Pischke, 2001, Blanden and Machin, 2004, Vona, 2011, inter alia). The economic literature offers three explanations for this: financial constraints; pre-existing ability differences correlated with parental income (e.g., due to non-cognitive skills acquired from the environment in which a student is raised); and differences in risk aversion (Ellwood and Kane 2000, Cameron and Heckman 2001, Carneiro and Heckman 2002). The empirical evidence is also consistent with the alternative interpretation that some education may be considered as a normal consumption good rather than a pure investment good.[4] As noted, our analysis shows that higher income students of given ability will do more coursework because they are engaging in more educational consumption.

Second, there is a relationship between the choice of coursework and the student's household income. In our model, again for given ability, students from lower-income households will choose *relatively* more investment-type courses. There is some evidence supporting this statement. Baird (1967), in a study based on a comparative socioeconomic analysis of 18,378 prospective college students, found that students from higher income homes were relatively more concerned with developing their intellect, while students from less affluent households were more concerned with vocational and professional training. The Baird (1967)'s results are confirmed by Dealney (1998), who provides evidence that lower income students are more concerned about how college will prepare them for a career. Trusty *et al.* (2000), using the NELS:88 data set, examined choice of major field of study at postsecondary institution when students were 2 years beyond high school. They found that, at the highest level of socio-economic status, increases in academic performance resulted in a decrease in the choice of enterprising-related majors. Leppel *et al.* (2001) examine the data from the 1990 survey of Beginning Postsecondary Students (BPS) that follows a group of students who began their postsecondary educational careers during the academic year 1989-90.

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[4] Caneiro and Heckman (2002) note that consumption incentives are relevant in understanding educational expenditure. "In addition, there is, undoubtedly, a consumption component to education. Families with higher incomes may buy more of the good for their children and buy higher quality education as well (p. 992)."

They show that an increase in socio-economic status of the families of college students would be good news for humanities and social science departments, but bad news for education, science and engineering departments.[5] Leppel *et al.* (2005) exploit the National Longitudinal Survey of Youth in order to examine processes by which students enter lucrative fields of study, selective colleges, and lucrative fields within selective colleges. They show that students from families with high socio-economic status have a much greater probability of selecting lower income fields of study. To be clear, our model does not predict absolutely less educational investment by higher income students, but relatively less as a proportion of their educational expenditure. The evidence on income and major choice is consistent with our model only if richer students are still *investing* as are poorer students of given ability.

Third, evidence on lower marginal return to educational attainment of higher income households is consistent with consumption incentives (Brenner and Rubinstein, 2012). For given ability, higher educational attainment of richer households measured by years of schooling or educational expenditure is due to more educational consumption in our model, implying a lower average and likely marginal return to richer households.

Keane (2002) and Keane and Wolpin (2001) develop a model where agents obtain utility directly from schooling that can vary with income. Thus, consumption incentives play a role in their analyses in the choice of educational attainment. Our analysis differs in having education explicitly modeled as a consumption *or* investment good. The analysis can provide input to help design an efficient educational policy. A question that may arise is why university courses that are associated with weaker job prospects should be subsidized. Similarly, should tuition fees be the same for university courses that differentially affect a student's future earnings? The aim of this paper is to address such questions.

This paper offers theoretical support to policies stimulating STEM (science, technology. engineering and mathematics) education. An example of such a policy is the 2007 "America Competes Act" (P.L. 110-69), which responds to concerns that the United States may not be able to compete economically with other nations in the future due to insufficient investment today in workforce development. The policy is intended to increase the nation's investment in STEM education from kindergarten to graduate school and beyond to postdoctoral education. The act authorizes funding increases for the National Science Foundation (NSF), National Institute of Standards and Technology (NIST) laboratories, and the Department of Energy (DOE) Office of Science.

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[5] Both the NELS:88 and the BPS were conducted by the National Center for Education Statistics (NCES) of the U.S. Department of Education.

The remainder of the paper is organized as follows. Section 2 presents the model. Section 3 shows the difference between the private equilibrium and the social optimum. Section 4 considers possible government interventions, in particular either (i) the design of optimal tuition fees or (ii) the introduction of minimum (optimal) levels of education investment. Section 5 concludes. Proofs are provided in the appendix.

2. The model

Students differ continuously in ability θ and household income Y_0. The joint distribution on student type (θ, Y_0) is continuous and given by $F(\theta, Y_0)$, with joint density function $f(\theta, Y_0)$, assumed to be positive on its support $(0, \bar{\theta}] \times (0, \bar{Y_0}]$.

There are two periods. In period 0, students attend college. In period 1, they work and earn an income. When students attend college, they decide the amount and type of education they want to acquire. The unique feature of this model is that education can be acquired for two different reasons: (i) for investment, i.e., education can be acquired to increase future income; and (ii) for consumption. Regarding the latter, an individual may be interested in a specific topic, may want to become more knowledgeable for social interactions in trendy topics, and/or may want to acquire social status given by obtaining a college degree though such coursework will not increase future income.

In college, different courses of study present different proportions of these two elements of education. This is due to different labor demands for alternative expertise (engineers may be more in demand than art experts), and to alternative interest from a social point of view toward topics (e.g., being conversant about arts, cinema, philosophy, and literature may be considered more interesting than being able to do advanced mathematics). The relative consumption vs. investment value of topics may change over time. In the future, people may find more socially intriguing a mathematician than an artist, and the labor market may need more philosophers than engineers. Our analysis does not refer to specific courses. Instead, we denote the amount of education acquired for consumption as e_1, with per unit tuition fee $t_1 > 0$; and the amount of education acquired for investment as e_2, with per unit tuition fee $t_2 > 0$. We do not put constraints on the amount of education needed to acquire a degree. Even though a degree requires usually a specific amount of courses, a student may attend college only one year, or keep studying at a master's program, or attend a short term course, or a summer school.

Provision of higher education is perfectly competitive. Colleges set their tuition fees in such a way as to cover their marginal resource cost, $t_i = c_i$, where c_i is the constant marginal resource cost of providing teaching and other inputs for every course type $i \in \{1, 2\}$.

Students have a utility function over numeraire consumption in the present c_0, education consumption e_1, and future numeraire consumption y:

$$U = \alpha\, ln\left(\theta^\beta e_1^{1-\beta}\right) + \gamma\, ln\left(c_0\right) + k\, ln\left(y\right),\ \ \alpha, \gamma, k > 0; \tag{1}$$

where $ln\left(\theta^\beta e_1^{1-\beta}\right)$ denotes the benefit obtained by consuming education, assumed to increase with a student's ability.[6] Future consumption is given by:

$$y = \left(\theta e_2\right)^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}} + s\left(1+r\right),\ \ \sigma > 1; \tag{2}$$

where $\left(\theta e_2\right)^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}}$ is income; savings $s \in \Re$ (borrowing if negative), is determined in period 0; and r is the interest rate. E measures productivity of the workforce and is given by:[7]

$$E = \left(\iint \left(\theta e_2\right)^{\frac{\sigma-1}{\sigma}} f\left(\theta, Y_0\right) d\theta dY_0\right)^{\frac{\sigma}{\sigma-1}}. \tag{3}$$

The specification follows Benabou (1996).[8] Future earnings are Cobb-Douglas in own human capital (θe_2) and an index of all worker's human capital (E), with constant returns to scale. The index of all workers' human capital is increasing in any worker's human capital with a constant elasticity of substitution (σ) between any two worker's human capital. In this specification, $\sigma > 1$ is needed for human capital to have a positive marginal product. Our central results do not require these functional forms, but the specification is appealing and easy to work with. Note that we are assuming human capital is accurately measured by employers when individuals enter the labor market. In Section 4.3 alternatives to this assumption are discussed.

In equilibrium, students maximize their own utility by choosing their initial consumption, savings, educational consumption, and educational investment, subject to the budget constraint

$$Y_0 = c_0 + t_1 e_1 + t_2 e_2 + \psi_1\left(e_1\right) + \psi_2\left(e_2\right) + s,\ \ \psi_i', \psi_i'' > 0,\ i = 1,2; \tag{4}$$

where $\psi_i\left(e_i\right)$ is the time cost of education for each course type $i \in \{1,2\}$.

3. Private vs social optimum

In this section we develop the baseline results of the paper. We compare the private equilibrium with socially optimal allocations. For every student type $\left(\theta, Y_0\right)$, the private problem is:

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[6] Our main results do not depend on the assumption that higher ability students get more value from consuming education. We have in mind that brighter students generally learn more in their tertiary studies.

[7] All integration in what follows is over the support of household types.

[8] See equations (5) and (6) in Benabou (1996).

$$\underset{c_0,s,e_1,e_2,y}{Max} \; \alpha \, ln(\theta^\beta e_1^{1-\beta})+\gamma \, ln(c_0)+k \, ln(\, y \,)$$

$$s.t. \; (\, 2 \,) \; and \; (\, 4 \,); \tag{5}$$

taking as given E.[9] Solving the individual's problem (see the appendix), one obtains:

Proposition 1. *For every student* (θ, Y_0), *the individually optimal levels of education chosen in equilibrium are* e_1^P *satisfying:*

$$\frac{c_0}{\gamma} \frac{\alpha(1-\beta)}{e_1} = t_1 + \psi'_1(e_1), \tag{6}$$

and e_2^P *satisfying:*

$$\frac{\sigma-1}{\sigma} \frac{e_2^{-\frac{1}{\sigma}} \theta^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}}}{(1+r)} = t_2 + \psi'_2(e_2). \tag{7}$$

Condition (6) equates the marginal consumption benefit of e_1 (LHS) to the marginal cost (RHS), the latter consisting of the tuition and time costs. Condition (7) equates the discounted marginal increase in future income from educational investment (LHS) to the marginal cost (RHS). Straightforward manipulation of the first-order conditions to the individual's problem (see the appendix) shows that e_1^P is increasing in household income. This is, of course, because the utility specification implies that consumption goods are normal. Observe, however, that (7) implies educational investment is independent of income. Under our assumption of perfect capital markets (i.e., s is unconstrained), the educational investment decision reduces to maximization of the present value of lifetime income, the solution depending on ability but not endowed income. With perfect capital markets, the correlation between household income and educational expenditure is then explained by educational consumption.   Using $\psi_2'' > 0$ and $\sigma > 1$, one can confirm using (7) that e_2^P is increasing in own ability and the economy human capital index, these results reflecting complementarity in the workplace.

We turn now to the social problem and characterize first-best Pareto efficient allocations. Let $\omega(\theta, Y_0) > 0$ denote the weight on student (θ, Y_0)'s utility in the social welfare function, and let $T_0(\theta, Y_0)$ $[T(\theta, Y_0)]$ denote the planner's monetary transfer to household (θ, Y_0) in period 0 [1] and $\iint T_0(\theta, Y_0) f(\theta, Y_0) d\theta dY_0$ $[\iint T(\theta, Y_0) f(\theta, Y_0) d\theta dY]$ the corresponding total transfers. In the social welfare problem, the government budget must be balanced:

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[9] Consistent with the atomism of individuals in the economy, an individual's own choice of e_2 will not affect his own earnings by affecting E.

$$\iint c_1 e_1 f(\theta, Y_0) d\theta dY_0 + \iint c_2 e_2 f(\theta, Y_0) d\theta dY_0 + \iint T_0(\theta, Y_0) f(\theta, Y_0) d\theta dY_0 +$$

$$\frac{1}{1+r} \iint T(\theta, Y_0) f(\theta, Y_0) d\theta dY_0 = 0 \tag{8}$$

The social planner dictates period-0 consumption $c_0(\theta, Y_0)$, savings $s(\theta, Y_0)$, the levels of educational consumption and investment $e_1(\theta, Y_0)$ and $e_2(\theta, Y_0)$, and chooses balanced-budget transfers $T_0(\theta, Y_0)$ and $T(\theta, Y_0)$ so as to maximize the social welfare function:

$$W\left(c_0(\theta, Y_0), s(\theta, Y_0), e_1(\theta, Y_0), e_2(\theta, Y_0), T_0(\theta, Y_0), T(\theta, Y_0)\right) =$$

$$\iint \omega(\theta, Y_0) \left[\alpha \ln\left(\theta^\beta e_1(\theta, Y_0)^{1-\beta}\right) + \gamma \ln\left(c_0(\theta, Y_0)\right) + k \ln\left(y + T(\theta, Y_0)\right)\right] f(\theta, Y_0) d\theta dY_0; \tag{9}$$

where y is implied by the planner dictated savings and the production constraint. Suppressing the type dependence of choice variables, the social planner's problem is:

$$\begin{cases} \max_{c_0, e_1, e_2, s, y, T_0, T, E} & W(c_0, s, e_1, e_2, T_0, T) \\ \\ s.t. & y = (\theta e_2)^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}} + s(1+r) \quad \forall (\theta, Y_0) \\ \\ & E = \left(\iint (\theta e_2)^{\frac{\sigma-1}{\sigma}} f(\theta, Y_0) d\theta dY_0\right)^{\frac{\sigma}{\sigma-1}} \\ \\ & Y_0 = c_0 + \psi_1(e_1) + \psi_2(e_2) + s - T_0 \quad \forall (\theta, Y_0) \\ \\ & \iint c_1 e_1 f(\theta, Y_0) d\theta dY_0 + \iint c_2 e_2 f(\theta, Y_0) d\theta dY_0 + \\ \\ & \iint T_0 f(\theta, Y_0) d\theta dY_0 + \frac{1}{1+r} \iint T f(\theta, Y_0) d\theta dY_0 = 0 \end{cases} \tag{10}$$

The first two constraints in (10) are the technological constraints determining future incomes. The third constraint is the household balanced budget condition that individual "choices" must satisfy. The last constraint is, again, the planner's balanced budget condition. We have written the problem having the planner pay for the cost of education. Since the planner can do lump-sum income transfers, the latter is with no loss of generality.[10] A solution of the problem is Pareto efficient for any social welfare weights $\omega(\theta, Y_0)$. If a Pareto improvement were feasible relative to any solution, then the objective function would increase with the change, so that a contradiction would emerge. As the social weights vary, alternative Pareto efficient allocations are determined, since as one moves along the Paretian frontier the slope changes, which equal the social welfare weights corresponding to the particular Pareto efficient allocation. If the utility possibilities set is convex,

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[10] Allowing the planner to just do lump-sum income transfers in one of the periods does not restrict the solution since the planner can dictate savings. We write the problem allowing both, and then verify the latter (see the appendix). Similarly, the planner could have households pay for their dictated educational levels and then offset these with transfers. We had to choose one way to write the problem!

then all Pareto efficient allocations are a solution to the maximization problem for some set of weights.[11]

Solving the problem (see the appendix) we obtain:

Proposition 2. *For every* (θ, Y_0) *student, the socially optimal levels of education in equilibrium are* $e_1^W(\theta, Y_0)$ *such that:*

$$\frac{c_0}{\gamma} \frac{\alpha(1-\beta)}{e_1} = c_1 + \psi'_1(e_1), \qquad (11)$$

and $e_2^W(\theta, Y_0)$ *such that:*

$$\frac{e_2^{-\frac{1}{\sigma}} \theta^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}}}{(1+r)} = c_2 + \psi'_2(e_2). \qquad (12)$$

Comparing (6) and (11), using that $t_1 = c_1$ in competitive equilibrium, one sees that the private and social optimum coincide if the level of first-period consumption is the same in each solution.[12] No externality arises in private choice of educational consumption. In contrast, comparing the LHS of (12) to the LHS of (7) with $t_2 = c_2$, one sees the difference in the social marginal benefit and private marginal benefit equals $\dfrac{e_2^{-\frac{1}{\sigma}} \theta^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}}}{\sigma(1+r)} > 0,$ if the marginal benefits are evaluated at the same values of e_2 and E. Using that $\psi''_2 > 0$ and that E is increasing in the $e_2(\theta, Y_0)$ values, it is easy to show:

Proposition 3. *For educational consumption, the private and social optimum coincide. For educational investment, the private optimum has lower e_2 than in any social optimum.*

Underinvestment in education in the private equilibrium is due to the human capital externality in production. Individuals do not reap the full social benefit of their educational investment, while bearing the full cost. In the next section we examine intervention that would provide socially optimal incentives.

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[11] If the utilities possibilities set is not convex, then one can still find all Pareto efficient allocations as extrema of the planner's problem (Panzar and Willig, 1976).

[12] Because the economy will be more productive in the social welfare solution and the planner may have preference for redistribution, we would not expect c_0 to be the same in the two solutions. However, given the desired transfers and socially efficient choices of e_2, letting households choose e_1 would be efficient. This is shown below in Proposition 4.

Finally, notice that social-welfare weights on student types $\omega(\theta, Y_0)$ do not play any role in determining the socially optimal levels of e_2. Similarly to in the private solution, optimal levels of e_2 simply maximize lifetime income, but in the aggregate in the social solution.

4. Government intervention

4.1. The design of optimal tuition fees

In this section, the planner sets and collects tuition fees, while paying for actual cost of education, and individuals make their privately optimal choices. The main result is:

Proposition 4. *Regulated tuitions:*

$$m_1(\theta, Y_0) = c_1 \text{ and } m_2(\theta, Y_0) = c_2 - \frac{e_2^w(\theta, Y_0)\theta^{\frac{\sigma-1}{\sigma}}(E^w)^{\frac{1}{\sigma}}}{\sigma(1+r)}, \tag{13}$$

with appropriately adjusted lump-sum income transfers (see the appendix) induce private choices that replicate any Pareto Optimum.

Formal proof is in the appendix, but Proposition 4 is very intuitive. Tuition for educational investment is subsidized relative to marginal production cost by the amount of the marginal externality. The marginal externality equals the last term on the RHS of m_2 in (13). The optimal tuition subsidy must vary by type, in particular by ability. This issue is further discussed below.

4.2 Regulated levels of education

In this section, we assume that the government imposes regulated levels of education, without altering tuition fees from the competitive ones. In particular, we consider the case in which the government sets a minimum level of education investment that students need to acquire. That is, the planner requires $e_2 \geq e_2^M$, where the superscript M stands for "minimum". The main result here is:

Proposition 5. *A minimum required level of education investment $e_2^M = e_2^W(\theta, Y_0)$, combined with appropriately adjusted lump-sum income transfers (see the appendix) induces private choices that replicate any Pareto Optimum.*

4.3 Discussion

Several issues, mainly related to informational constraints, warrant discussion. A key finding of our analysis is that efficient educational investment varies with student ability. Thus the interventions examined above require that ability can be observed or discerned by the policy maker. If students

know their ability but it is private information, they would not generally have an incentive to reveal truthfully their ability when confronted with the above interventions. In the case of tuition subsidies, they would want to maximize the subsidy. In the case of a minimum educational investment, they would want the minimum to correspond to their preferred investment. Neither intervention is consistent with truthful reporting of ability. Suppose, though, that "good" tests exist that can be used to determine ability prior to pursuing higher education. *If a student takes the test seriously*, then their ability is well measured. More precisely, students can perform to the level of their ability if they try, cannot perform beyond their ability, but could underperform if they choose. The issue is then whether the above interventions are consistent with students not underperforming on college entry exams. To consider this, we assume that any transfers are independent of student ability (i.e., social welfare weights in the social objective function do not depend on ability). Then we have:

Proposition 6. *If pre-college tests exist that allow students to perform only up to their ability (or to underperform), then the regulated tuition scheme induces accurate ability signaling while the minimum educational investment scheme does not.*

The proof (see the appendix) follows this intuition. Confronted with an educational investment minimum that exceeds their preferred investment (Propositions 3 and 5) with truthful ability revelation, students prefer a lower minimum. Because the socially efficient minimum decreases with actual ability (see the Proof of Proposition 6), students prefer to underperform on an entry exam. In contrast, the socially efficient subsidy to educational investment increases with student ability (as shown in the Proof). Of course, students are better off the higher is the subsidy to educational investment, providing them with efficient incentive to perform on an entry. *It is notable that the incentive to perform as well as one can on an entry test under the tuition subsidy scheme applies as well if students are unsure about their ability.* That is, if the tuition subsidy scheme is based on measured ability with an accurate test (conditional on students doing their best), then the efficiency and incentive compatibility findings continue to apply if students do not know their own abilities. The results here obviously are supportive of using the tuition subsidy approach rather than investment minima.

Absent informational problems, the investment minimum approach requires coercion of students while the tuition subsidy scheme does not. How might an investment minimum be enforced in a socially acceptable way? Again, the tuition subsidy scheme is more appealing.

Our analysis has assumed human capital is observed in the labor market. Firms can and sometimes do test job applicants. College exit exams, which are becoming increasingly popular, provide a measure of human capital acquisition. A substitute for observation of human capital by employers is observation of ability and educational investment.[13] If, however, students could shirk and complete coursework without effectively developing their skills, then observing educational investment is more difficult. It is then important that colleges enforce standards. College reputation can also assist in this regard.[14]

Colleges generally have graduation requirements, including course diversity and major requirements in addition to total credit requirements. If employers can measure human capital accurately, then it is not clear what explains such requirements. Confronted with course completion requirements, a student could still quit college at the point of having privately optimized (consistent with social optimization if educational investment is subsidized), and be rewarded appropriately in the labor market. By the same argument, such requirements do not serve as a workable substitute for investment minima absent coercion. If such requirements are efficient, then the explanation must lie in failures in the labor market. We do not here pursue this problem, but, obviously, educational consumption should not be built into college requirements. Whether graduation requirements and variation in them across majors might be explained by labor market imperfections is an interesting topic for research.

5. Summary and concluding remarks

In this paper we have analyzed a simple model in which students choose their university coursework with both investment and consumption incentives. The intent of the analysis is to clarify how these incentives determine choices and how private choices compare to efficient allocations. Assuming education is priced at marginal cost, students would underinvest in education due to a human capital externality in the workplace. Subsidizing tuition for educational investment could correct the externality as could minimum educational investment requirements. Since the efficient tuition subsidy or investment minimum varies with student ability, these interventions are not simple and require the policy maker to observe or infer student ability. Tuition subsidies correct incentives to underperform on exams used to measure ability, while this incentive compatibility would fail with the use of educational investment minima. It is of interest to investigate higher education policies like graduation requirements in light of imperfect information.

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[13] Firms might measure student ability from exams like IQ exams.
[14] Macleod and Urquiola (2013) develop a model where colleges have more information about student ability than do employers and college reputation provides a signal about student human capital.

Although the paper's aim to investigate consumption versus investment incentives is somewhat limited in scope, we hope the results provide useful input to the design of higher education policies.

6. Appendix

Proof of Proposition 1: To solve the problem stated in (5), substitute (2) into the objective function and write the Lagrangian function:

$$L^P = \alpha \ln\left(\theta^\beta e_1^{1-\beta}\right) + \gamma \ln(c_0) + k \ln\left[\left(\theta e_2\right)^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}} + s(1+r)\right] +$$
$$\lambda_1\left[Y_0 - \left(c_0 + t_1 e_1 + t_2 e_2 + \psi_1(e_1) + \psi_2(e_2) + s\right)\right]. \tag{A.1}$$

The first-order conditions with respect to c_0, e_1, e_2, s and λ_1 are:

$$\frac{\partial L^P}{\partial c_0} = \frac{\gamma}{c_0} - \lambda_1 = 0, \tag{A.2}$$

$$\frac{\partial L^P}{\partial e_1} = \frac{\alpha(1-\beta)}{e_1} - \lambda_1\left(t_1 + \psi'_1(e_1)\right) = 0, \tag{A.3}$$

$$\frac{\partial L^P}{\partial e_2} = \frac{\sigma-1}{\sigma} \frac{k e_2^{-\frac{1}{\sigma}} \theta^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}}}{\left(\theta e_2\right)^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}} + s(1+r)} - \lambda_1\left(t_2 + \psi'_2(e_2)\right) = 0, \tag{A.4}$$

$$\frac{\partial L^P}{\partial s} = \frac{k(1+r)}{\left(\theta e_2\right)^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}} + s(1+r)} - \lambda_1 = 0, \tag{A.5}$$

$$\frac{\partial L^P}{\partial \lambda_1} = Y_0 - \left(c_0 + t_1 e_1 + t_2 e_2 + \psi_1(e_1) + \psi_2(e_2) + s\right) = 0. \tag{A.6}$$

Substitute (A.5) into (A.4):

$$\frac{\sigma-1}{\sigma} \frac{k e_2^{-\frac{1}{\sigma}} \theta^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}}}{\left(\theta e_2\right)^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}} + s(1+r)} - \frac{k(1+r)\left(t_2 + \psi'_2(e_2)\right)}{\left(\theta e_2\right)^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}} + s(1+r)} = 0 \; or, simplifying:$$

$$\frac{\sigma-1}{\sigma} \frac{e_2^{-\frac{1}{\sigma}} \theta^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}}}{(1+r)} = t_2 + \psi'_2(e_2); \tag{A.7}$$

confirming (7). Now substitute (A.2) into (A.3) giving:

$$\frac{c_0}{\gamma} \frac{\alpha(1-\beta)}{e_1} = t_1 + \psi'_1(e_1); \tag{A.8}$$

confirming (6) and completing the proof.

Proof that e_1^P is Increasing in Y_0: Eliminate λ_1 from (A.2) and (A.5) yielding:

$$c_0 k(1+r) = \gamma s(1+r) + \gamma(\theta e_2)^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}}.$$

From (A.7) one can see that e_2 is independent of Y_0. Differentiating the latter equation with respect to Y_0 then gives:

$$k(1+r)\frac{dc_0}{dY_0} = \gamma(1+r)\frac{ds}{dY_0}. \tag{A.9}$$

Now differentiate the budget constraint (A.6), again using that e_2 is independent of Y_0:

$$1 = \frac{dc_0}{dY_0} + t_1\frac{de_1}{dY_0} + \psi_1'\frac{de_1}{dY_0} + \frac{ds}{dY_0}.$$

Substitute (A.9) into the latter:

$$1 = (1+\frac{k}{\gamma})\frac{dc_0}{dY_0} + (t_1 + \psi_1')\frac{de_1}{dY_0}. \tag{A.10}$$

Differentiate (A.8) with respect to Y_0:

$$\frac{\alpha(1-\beta)}{\gamma}\frac{dc_0}{dY_0} = (t_1 + \psi_1'' e_1)\frac{de_1}{dY_0}.$$

Combining the last two equations yields:

$$\frac{de_1}{dY_0} = [t_1 + \psi_1' + (1+\frac{k}{\gamma})\frac{\alpha(1-\beta)}{\gamma}\frac{1}{t_1 + e_1\psi_1''}]^{-1};$$

which is seen to be positive by inspection.

Proof of Proposition 2: The Lagrangian function for the problem in (10) is:

$$L^W = \iint \omega(\theta,Y_0)\left[\alpha\ln(\theta^\beta e_1^{1-\beta}) + \gamma\ln(c_0)\right]f(\theta,Y_0)d\theta dY_0 +$$

$$\iint \omega(\theta,Y_0)\left[k\ln\left((\theta e_2)^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}} + s(1+r) + T\right)\right]f(\theta,Y_0)d\theta dY_0 +$$

$$\lambda_1\left[Y_0 - (c_0 + \psi_1(e_1) + \psi_2(e_2) + s + T_0)\right] +$$

$$\lambda_2\left[\iint c_1 e_1 f(\theta,Y_0)d\theta dY_0 + \iint c_2 e_2 f(\theta,Y_0)d\theta dY_0 + \right. \tag{A.11}$$

$$\left.\iint T_0 f(\theta,Y_0)d\theta dY_0 + \frac{1}{1+r}\iint Tf(\theta,Y_0)d\theta dY_0\right] +$$

$$\lambda_3\left[E - \left(\iint(\theta e_2)^{\frac{\sigma-1}{\sigma}} f(\theta,Y_0)d\theta dY_0\right)^{\frac{\sigma}{\sigma-1}}\right].$$

We first find the first-order conditions with respect to the type-dependent variables and multipliers $c_0(\theta,Y_0), e_1(\theta,Y_0), e_2(\theta,Y_0), s(\theta,Y_0), T(\theta,Y_0), T_0(\theta,Y_0)$, and $\lambda_1(\theta,Y_0)$. It is more convenient to compute the first variations of the Langrangian with respect to the density weighted values; e.g., with respect to $c_0(\theta,Y_0)f(\theta,Y_0)$ rather than $c_0(\theta,Y_0)$. With some abuse of notation, we write these variations as $\dfrac{\partial L}{\partial x}$. We have:

$$\frac{\partial L^W}{\partial(c_0 f)} = \frac{\omega(\theta,Y_0)\gamma}{c_0} - \frac{\lambda_1}{f} = 0, \tag{A.12}$$

$$\frac{\partial L^W}{\partial(e_1 f)} = \frac{\omega(\theta,Y_0)\alpha(1-\beta)}{e_1} - \frac{\lambda_1}{f}\psi'_1(e_1) + \lambda_2 c_1 = 0, \tag{A.13}$$

$$\frac{\partial L^W}{\partial(e_2 f)} =$$

$$\omega(\theta,Y_0)\frac{\sigma-1}{\sigma}\frac{ke_2^{-\frac{1}{\sigma}}\theta^{\frac{\sigma-1}{\sigma}}E^{\frac{1}{\sigma}}}{(\theta e_2)^{\frac{\sigma-1}{\sigma}}E^{\frac{1}{\sigma}} + s(1+r) + T(\theta,Y_0)} - \frac{\lambda_1}{f}\psi'_2(e_2) + \lambda_2 c_2 - \lambda_3 E^{\frac{1}{\sigma}}e_2^{-\frac{1}{\sigma}}\theta^{\frac{\sigma-1}{\sigma}} = 0, \tag{A.14}$$

$$\frac{\partial L^W}{\partial(s f)} = \frac{\omega(\theta,Y_0)k(1+r)}{(\theta e_2)^{\frac{\sigma-1}{\sigma}}E^{\frac{1}{\sigma}} + s(1+r) + T(\theta,Y_0)} - \frac{\lambda_1}{f} = 0, \tag{A.15}$$

$$\frac{\partial L^W}{\partial(T f)} = \frac{\omega(\theta,Y_0)k}{(\theta e_2)^{\frac{\sigma-1}{\sigma}}E^{\frac{1}{\sigma}} + s(1+r) + T(\theta,Y_0)} + \frac{\lambda_2}{(1+r)} = 0, \tag{A.16}$$

$$\frac{\partial L^W}{\partial(T_0 f)} = \frac{\lambda_1}{f} + \lambda_2 = 0, \tag{A.17}$$

and

$$\frac{\partial L^W}{\partial \lambda_1} = Y_0 - (c_0 + \psi_1(e_1) + \psi_2(e_2) + s + T_0(\theta,Y_0)) = 0. \tag{A.18}$$

The first-order conditions for the non-type dependent variable and multipliers are:

$$\frac{\partial L^W}{\partial E} = \iint \omega(\theta,Y_0) \left[\frac{k(e_2\theta)^{\frac{\sigma-1}{\sigma}} E^{\frac{1-\sigma}{\sigma}}}{\sigma\left((\theta e_2)^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}} + s(1+r) + T(\theta,Y_0)\right)} \right] f(\theta,Y_0) d\theta dY_0 + \lambda_3 = 0, \qquad (A.19)$$

$$\frac{\partial L^W}{\partial \lambda_2} = \iint c_1 e_1 f(\theta,Y_0) d\theta dY_0 + \iint c_2 e_2 f(\theta,Y_0) d\theta dY_0 +$$

$$\iint T_0(\theta,Y_0) f(\theta,Y_0) d\theta dY_0 + \frac{1}{1+r} \iint T(\theta,Y_0) f(\theta,Y_0) d\theta dY_0 = 0, \qquad (A.20)$$

and

$$\frac{\partial L^W}{\partial \lambda_3} = E - \left(\iint (\theta e_2)^{\frac{\sigma-1}{\sigma}} f(\theta,Y_0) d\theta dY_0 \right)^{\frac{\sigma}{\sigma-1}} = 0. \qquad (A.21)$$

Begin by noting that (A.12) implies:

$$\lambda_1 = \frac{\omega(\theta,Y_0)\gamma}{c_0}; \qquad (A.22)$$

(A.17) gives:

$$\frac{\lambda_1}{f} = -\lambda_2; \qquad (A.23)$$

and, finally, (A.16) implies:

$$-\frac{\lambda_2}{(1+r)} = \frac{\omega(\theta,Y_0)k}{(\theta e_2)^{\frac{\sigma-1}{\sigma}} E^{\frac{1}{\sigma}} + s(1+r) + T(\theta,Y_0)}. \qquad (A.24)$$

Substitute (A.24) into (A.19), yielding:

$$\iint -\frac{\lambda_2}{(1+r)} \frac{(e_2\theta)^{\frac{\sigma-1}{\sigma}} E^{\frac{1-\sigma}{\sigma}}}{\sigma} f(\theta,Y_0) d\theta dY_0 + \lambda_3 = 0. \qquad (A.25)$$

Using $E = \left(\iint (\theta e_2)^{\frac{\sigma-1}{\sigma}} f(\theta,Y_0) d\theta dY_0 \right)^{\frac{\sigma}{\sigma-1}}$ from (A.21), rewrite (A.25) as:

$$-\frac{\lambda_2}{(1+r)} \frac{E^{\frac{\sigma-1}{\sigma}} E^{\frac{1-\sigma}{\sigma}}}{\sigma} + \lambda_3 = 0,$$

$$\Rightarrow \frac{\lambda_3}{\lambda_2} = \frac{1}{\sigma(1+r)}. \qquad (A.26)$$

Consider now (A.14). Substituting (A.24) into (A.14) gives:

$$-\frac{\lambda_2}{(1+r)}\frac{\sigma-1}{\sigma}e_2^{-\frac{1}{\sigma}}\theta^{\frac{\sigma-1}{\sigma}}E^{\frac{1}{\sigma}}-\frac{\lambda_1}{f}\psi'_2(e_2)+\lambda_2 c_2-\lambda_3 e_2^{-\frac{1}{\sigma}}\theta^{\frac{\sigma-1}{\sigma}}E^{\frac{1}{\sigma}}=0. \tag{A.27}$$

Substituting (A.23) into (A.27), divide through by λ_2, and use (A.26) to get:

$$\frac{\sigma-1}{\sigma}\frac{e_2^{-\frac{1}{\sigma}}\theta^{\frac{\sigma-1}{\sigma}}E^{\frac{1}{\sigma}}}{(1+r)}-\psi'_2(e_2)-c_2+\frac{e_2^{-\frac{1}{\sigma}}\theta^{\frac{\sigma-1}{\sigma}}E^{\frac{1}{\sigma}}}{\sigma(1+r)}=0$$

$$\Rightarrow \frac{e_2^{-\frac{1}{\sigma}}\theta^{\frac{\sigma-1}{\sigma}}E^{\frac{1}{\sigma}}}{(1+r)}=c_2+\psi'_2(e_2). \tag{A.28}$$

Thus, we have confirmed (12). Consider now (A.13). Substituting (A.23) into (A.13) yields:

$$\frac{\omega(\theta,Y_0)\alpha(1-\beta)}{e_1\lambda_1/f}=\psi'_1(e_1)+c_1. \tag{A.29}$$

Plugging (A.12) into (A.29) to get:

$$\frac{c_0}{\gamma}\frac{\alpha(1-\beta)}{e_1}=c_1+\psi'_1(e_1). \tag{A.30}$$

This confirms (11) and completes the proof.

<u>Degree of Freedom in Choice of $T(\theta,Y_0)$ and $T_0(\theta,Y_0)$</u>: We noted in footnote 6 that the planner needs not do lump-sum transfers in both periods 0 and 1 to optimize. To see this from the solution to the optimization problem, note that the condition on the transfer in period 0 is (A.17). Note further that (A.17) is implied by conditions (A.15) and (A.16), i.e., the conditions on saving and the future transfer. This means that (A.17) can be satisfied for any period-0 transfer, including 0 transfer, so long as saving and the period-1 transfer are adjusted to satisfy (A.15) and (A.16). Similarly, one can argue that transfers could be 0 in period 1 while maintaining the optimum.

<u>Proof of Proposition 4</u>: We must show that the private solution with regulated tuitions as in (13) and appropriately adjusted lump-sum income transfers replicates any solution to the social problem. Let $T(\theta,Y_0)$ and $T_0(\theta,Y_0)$ denote the transfers in the social solution that will be replicated. (These transfers depend on the social welfare weights, which are suppressed.) Adjust the transfers in the regulated-tuition problem to be:

$$T_0^*(\theta,Y_0)=T_0(\theta,Y_0)+m_1 e_1^w(\theta,Y_0)+m_2(\theta,Y_0)e_2^w(\theta,Y_0)$$
$$T^*(\theta,Y_0)=T(\theta,Y_0); \tag{A.31}$$

where, recall, the w-superscript indicates the optimal educational values in the social solution. We suppress the type-arguments in the discussion that follows.

Replace t_2 with m_2 in the condition of the private problem for choice of e_2 [(6) or (A.7)], implying immediately that $e_2 = e_2^w$ is implied by the social optimal condition [(12) or (A.28)]. Comparing (6) and (11) [or (A.8) and (A.30)], using that $m_1 = c_1 = t_1$, we see the private choice of e_1 is the same as the socially efficient choice provided c_0 in the solution to the regulated-tuition problem is the same as in the social problem's solution. Using that future income in the regulated-tuition (private) problem now adds $T^* = T$ to future income, (A.2) and (A.5) imply:

$$\frac{\gamma}{c_0} = \frac{k(1+r)}{(\theta e_2)^{\frac{\sigma-1}{\sigma}} E + s(1+r) + T}. \tag{A.32}$$

Using (A.12) and (A.15) from the solution to the social problem, one obtains the same condition. Similarly, using the period-0 transfer in the regulated-tuition problem in (A.31), it is implied that the individual budget constraints (see (A.18)) are the same in both problems. Thus, the conditions determining the vector (c_0, s, e_1) are the same in each problem implying the same values.

Last, note that the government budget is balanced in the regulated-tuition problem, since, using (A.31) and that the government collects m_1 and m_2 for education choices from individuals, condition (A.20) is replicated. This completes the proof.

Proof of Proposition 5: Keeping in mind that the solution to the social problem had the planner pay directly for education costs, while the problem with minimum investment has individuals pay the competitive costs, the lump-sum transfers (indicated with superscript **) are adjusted to maintain the incomes of households:

$$T_0^{**}(\theta, Y_0) = T_0(\theta, Y_0) + c_1 e_1^w(\theta, Y_0) + c_2 e_2^w(\theta, Y_0)$$
$$T^{**}(\theta, Y_0) = T(\theta, Y_0).$$

The government budget remains balanced since the planner no longer pays for education. Given individuals will in fact choose the minimum investment, along the lines of the Proof of Proposition 4 all other private choices replicate the social optimum. Since the marginal time cost of investing in education is increasing, the investment choice will in fact be at the minimum.

Proof of Proposition 6: First we reject the investment minimum scheme as inducing accurate ability signaling. We have shown that $e_2^w > e_2^P$ for all types, so a student's incentive is to reduce their required education investment relative to e_2^w. Differentiating (12) one obtains:

$$\frac{\partial e_2^w}{\partial \theta} = \frac{\dfrac{\sigma - 1}{\sigma} e_2^{-\frac{1}{\sigma}} \theta^{-\frac{1}{\sigma}} E^{\frac{1}{\sigma}} / (1 + r)}{\psi_2'' + \dfrac{1}{\sigma} e_2^{-\frac{1+\sigma}{\sigma}} \theta^{\frac{\sigma - 1}{\sigma}} E^{\frac{1}{\sigma}} / (1 + r)} > 0, \tag{A.33}$$

where the inequality uses that $\sigma > 1$. Thus, any student would prefer to signal lower than their actual ability to reduce their required educational investment.

Now consider the scheme with tuition regulation. A student is better off facing a lower regulated tuition. From (13), the regulated tuition declines with ability if and only if $(e_2^w)^{-\frac{1}{\sigma}} \theta^{\frac{\sigma - 1}{\sigma}}$ is increasing in θ. Using (A.33) and differentiating, one obtains after straightforward manipulation:

$$\frac{\partial ((e_2^w)^{-\frac{1}{\sigma}} \theta^{\frac{\sigma - 1}{\sigma}})}{\partial \theta} = \frac{\sigma - 1}{\sigma} (e_2)^{-\frac{1}{\sigma}} \theta^{-\frac{1}{\sigma}} \cdot \left[1 - \frac{\dfrac{1}{\sigma} \theta^{\frac{\sigma - 1}{\sigma}} e_2^{-\frac{1+\sigma}{\sigma}} E^{\frac{1}{\sigma}} / (1 + r)}{\psi_2'' + \dfrac{1}{\sigma} \theta^{\frac{\sigma - 1}{\sigma}} e_2^{-\frac{1+\sigma}{\sigma}} E^{\frac{1}{\sigma}} / (1 + r)} \right] > 0; \tag{A.34}$$

the inequality using that the ratio in the bracketed term is less than 1. Thus, signaling as high an ability as feasible (i.e.,, actual ability) is the student's preferred strategy.

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