

"Allocation of Public Funding Within the Higher Education System"

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Abstract

There is an ongoing debate related to the issues of quality and efficiency of higher education colleges, and the public funding for these institutions. Our goal is to examine the theoretical justification for the establishment of colleges, subsidized or nonsubsidized, by the government, and their contribution to the economic development. We study an economy in which young heterogeneous young individuals, following the basic education stage, optionally invest in higher education to achieve skills. Initially there are universities subsidized by public funds and with excess-demand. Our analysis explores the impact of adding lower-quality colleges to the higher education system on economic growth, concentrating on two issues. Given that the quality, or productivity, of colleges is lower than that of universities, (a) Should the government establish colleges? (b) Should the government divide the higher education budget between colleges and universities? We obtain positive answers to both questions, and also claim that the subsidies should be merit-based rather than uniform. Our model accounts for several stylized facts that characterize developed countries, including (1) The expansion of colleges: the decline in college admission standards over time and the corresponding increase in the number of students; (2) the decline in government subsidies to higher education and the corresponding increase in the net student out-of-pocket payments to higher education.

Allocation of Public Funding Within the Higher Education System

Introduction

This article examines the recent criticism on the allocation of public resources to higher education, and specifically to colleges. This criticism is more pronounced in Western countries where governments plan to cut their contributions to higher education (see, e.g., UK, USA, the Netherlands and Israel). The claim is that with scarce resources and budgetary pressures, it is difficult to justify massive funding for institutions that in many cases are costly

To study these issues we use an OLG open economy model in which at the outset the higher education system relies mainly on Universities characterized by highly productive educational system (say, due to better curriculum and faculty), which face excess demand. Subsequently, we consider the introduction of less productive higher education institutions, to be called Colleges, that usually accept students with lower ability that have been rejected by the Universities, in order to meet the demand for higher education.

We address two issues that are often raised: (1) is it worthwhile to establish colleges, or what is the justification for the observed expansion of the higher education through the introduction of colleges? (2) Should the government enhance colleges by allocating the higher education resources between universities and colleges or divert the resources to universities only?

Our analysis suggests that the role played by colleges in generating 'skilled' human capital enhances the economic growth. This occurs under the two regimes we consider: the case in which college students are subsidized by the public funding and the case where all higher education public funds are diverted to the universities.

Our study is carried out in an overlapping-generations open economy, where intergenerational transfers (from parents to their children) take place, because parents are altruistic. Young individuals, born with heterogeneous 'initial endowment' (which is defined by random innate ability and family background), obtain basic compulsory education, and later consider investing in optional higher education to achieve additional skills. The heterogeneity in initial endowments gives rise to heterogeneity in the returns to higher education.

Given the initial endowment and the cost of higher education, individuals can attain supplementary skills by enrolling to a university or a college and becoming a 'skilled worker', or remain with 'low skills' acquired by the basic education. We assume that students who attend universities are partly subsidized by the government, while students attending the 'less productive' educational institutions, the colleges, may or may not obtain government funding. The subsidies may endogenously determine the share of the population going to the higher education institutions..

In this framework, we characterize non-stationary dynamic competitive equilibria and analyze: (i) the effects of establishing colleges on the stock of human capital. (ii) the effects of public subsidies to colleges, taken from the higher education budget, on the stock of human capital. Note that subsidizing colleges on top of universities reduces the subsidies to university students, and thereby increases their

tuition fees. In many developed countries this feature corresponds to the recent shift in the structure of higher education funding: Reducing the share of public funding (through various forms of subsidies), while increasing the share of private funding, while making the student loans more attractive.

Using a general process of hierarchical education and comparing dynamic equilibrium paths period by period, we obtain the following results: (a) establishing colleges reduces the stock of human capital in the economy in the period where colleges are established, but increases the stock of human capital in all subsequent periods;

(b) providing college students with the same government subsidies as university students affects economic growth as in case (a).

(c) if colleges are sufficiently productive, uniform subsidies are more desirable than merit-based subsidies, which are allocated only to students with high initial endowments. Merit-based subsidies may draw university students into colleges, and thus damage the economic growth.

The impact of the "College expansion" on the economic growth is caused by the expansion of the set of skilled workers (students with higher education), and the decline of college admission standards over time. Establishing colleges, subsidized or unsubsidized, has two effects. On the one hand, it leads initially to a loss in the stock of human capital. The reason is the forgone earnings of young individuals who acquire college education instead of working as low-skilled workers. On the other hand, their additional skills as college graduates improve the stock of human capital in the following periods, compensating for the loss of their earnings as low-skilled

workers.

Note that providing college education to low-skilled workers relates with another common criticism. Low-skilled workers contribute to the higher education budget (their labor income is taxed to finance higher education), though they do not directly benefit from their investments in higher education (see Garrat and Marshall, 1994; Fernandez and Rogerson, 1995; Gradstein and Justman, 1995; Taber, C., 2001; Bevia and Iturbe-Ormaetxe, 2002). Because of this concern, it has been argued that investing in other programs, like improving the basic schooling, may generate a higher social value than investing in higher education (Johnson, 1984).

This concern may be alleviated when we establish colleges and share the higher education resources between colleges and universities. A government policy that allocates certain subsidies to all individuals who attend colleges, similar to that in universities, provides individuals who otherwise would become low-skilled workers the opportunity to enjoy directly from their investments in higher education by gaining a college degree. Therefore, establishing colleges and subsidizing them at the expense of universities is an 'efficient' education policy regarding the welfare of the future generations.

Some features of our model have been analyzed before in a different hierarchical education frameworks. Particularly, Driskill and Horowitz (2002) find that the optimal investment in hierarchical human capital exhibits a non-monotonicity in human capital stocks. Su (2004) examines the efficiency and income inequality in a hierarchical education system, and the effects of introducing subsidies to higher education on growth. Blankenau (2005) finds a critical level of expenditure above

which higher education should be subsidized since its impact on growth is positive. Arcalean and Schiopu (2010) study the interaction between public and private spending in a two-stage education system. They observe that increased enrolment in tertiary education does not always enhance economic growth. Kaganovich and Su (2016) analyze the diverging selectivity of colleges, and examine its implications on student outcomes in the labor market.

The Economic Framework

The following model illustrates the implications of establishing colleges and granting subsidies to their students on the stock of human capital, or aggregate earning potential, in the economy. Our research strategy specifies lifetime preferences of individuals and derives their optimal behaviour. Optimal decision variables are then aggregated to obtain variables at the economy level, like the economy's human capital and the government balance sheet. Subsequently, the competitive equilibrium is fully characterized.

Preferences Under Hierarchical Education

To formulate the model, consider an overlapping generation economy with a continuum of individuals in each generation. Each individual is characterized by a family name $\omega \in [0,1]$ where $\Omega = [0,1]$ denotes the set of all families in each generation and μ the Lebesgue measure on Ω . Each individual lives for three periods: a study period, a working period and a retirement period.

During the early stage each child is engaged in education/training, but

takes no economic decision like schooling, consumption or saving. Youth is followed by adulthood which is split in two periods: individuals are economically active during the working period and later enter the retirement period.

Individuals give birth to one offspring at the beginning of their working period. Therefore, the population growth is zero and three generations with the same family name co-exist at any date t : (1) the child, born at the outset of date t , who gets his education/skills during period t ; (2) the parent, born at date $t-1$, who takes economic decisions at the outset of date t ; (3) the grandparent, born at date $t-2$, who has been active at date $t-1$ and consumes his savings at date t .

The analysis focuses on the optimal behavior of each parent at any date t whose decisions matter for their child's human capital, or economic potential, at date $t+1$, and therefore for the aggregate economy at date $t+1$.

Consider generation t , denoted G_t , consisting of all children born at the outset of date t , and let $h_{t+1}(\omega)$ be the human capital of family name ω at the beginning of the working period. We assume that $h_{t+1}(\omega)$ is achieved by a hierarchical production process of human capital like in Restuccia and Urrutia (2004): it consists of **fundamental**, or basic, education (assumed to be compulsory) and **higher** education [Su (2004), Blankenau and Camera (2006)].

A child obtains his general skills from the basic education and may additionally acquire specialized skills from higher education. Individuals are born with innate abilities. The innate abilities, denoted by $\tilde{\theta}_t(\omega)$ for individual

ω , are assumed to be independent and identically distributed random variables across individuals in each generation and over time.

In addition to the innate abilities, the empirical literature has established that parental inputs together with school inputs are key factors affecting the human capital of individual ω while attending compulsory education. These inputs are included in our process of human capital formation.

The human capital of an individual $\omega \in G_t$ who does not enroll in higher education, is given by:

$$(1) \quad h_{t+1}^l(\omega) = \tilde{\theta}_t(\omega) h_t^\nu(\omega) X_t^\xi$$

where $h_t(\omega)$ stands for parental human capital and X_t represents public investment in early-life and compulsory schooling¹. We call this agent a **low-skilled worker** (denoted by l).

The above human capital formation process represents the complex interaction between innate ability, family dynamics and public intervention. It stresses the key role played by the individual home environment that is specific to each ω via the individual parental human capital, and the public resources invested in public education that are common to all.

The elasticities ν and ξ represent the effectiveness of parents' human

¹ Researchers in a number of fields have showed that investments in well-being and education early in life achieve high individual and social rates of returns, and are a crucial preparation for subsequent stages of education (see a review of the evidence in Cunha *et al.* (2006)). Blankenau (2005), Hatsor (2015), and Gilpin and Kaganovich (2012) model education as a sequence of stages, where the human capital achieved in lower stages acts as an input in the education technology at higher stages. Correspondingly, in a number of OECD countries (The Czech Republic, Germany, New Zealand and Poland) annual expenditures per student are higher on pre-primary education than on primary education.

capital in their efforts towards educating their child, and the efficiency of public education in generating human capital respectively: ν is affected by home education and family background while ξ is affected by the schooling system, teachers, size of classes, facilities, neighborhood, etc.

Define $Z_{t+1}(\omega) = \tilde{\theta}_t(\omega)h_t(\omega)^\nu$ and call it *the initial endowment* of ω . It is the product of both ability and parental human capital and describes the background a young individual inherits prior to any education. Empirically it has been demonstrated that both factors are essential parts in the formation of offspring's human capital. In our framework this 'initial endowment' is important, because it is the main tool by which the sets of skilled and low skilled workers are determined².

Acquiring higher education, by attending a university, augments each individual's basic skills by some factor $B > 1$. Then, his/her human capital accumulates to the level:

$$(2) \quad h_{t+1}^s(\omega) = Bh_{t+1}^l(\omega) = B\tilde{\theta}_t(\omega)h_t^\nu(\omega)X_t^\xi$$

He/she is then called a **skilled worker** (denoted by s). To simplify our analysis

²For a fixed $Z_{t+1}(\omega)$, there is a convex iso-endowment locus which connects all alternative combinations of $\tilde{\theta}_t(\omega)$ and $h_t(\omega)$ (with marginal rate of substitution $-\nu\tilde{\theta}_t(\omega)/h_t(\omega)$) and endows learning children with this given level of endowment. Thus, there is an iso-endowment map representing each level of $Z_{t+1}(\omega)$. In general, the distribution function of $Z_{t+1}(\omega)$ over the continuum of agents has a complex derivation from the underlying variables. However, under our assumptions, the random ability is a time-independent i.i.d. process and, given the human capital distribution of the older generation, it is possible to derive the distribution $Z_{t+1}(\omega)$. $Z_{t+1}(\omega) = \tilde{\theta}_t(\omega)h_t(\omega)^\nu$ is formed as the product of two distributions whose algebra is explained in Springer (1979). Very likely, $h_t(\omega)$ is log-normally distributed. Whether $\tilde{\theta}_t$ has a uniform distribution or a log-normal distribution, the product $\tilde{\theta}_t(\omega)h_t(\omega)$ is log-normal. However, the probability distribution function of $Z_{t+1}(\omega) = \tilde{\theta}_t(\omega)h_t(\omega)h_t(\omega)^{\nu-1}$ becomes unknown except for extreme values of ν . In all cases, it can be evaluated by implementing numerical algorithms as in Glen *et al.* (2004).

(without restricting the generality), we assume that B is time-independent.

Enrollment in higher education is costly and, in most countries, requires the payment of a tuition fee at each date t , denoted z_t^* . We assume that higher education institutions charge a tuition fee that equals the full cost to educate each student. The government may participate in the cost of higher education and finance these subsidies by taxing the labor incomes.

Denote by g_t the government (or public) subsidy allocated to each student in the higher education system. Thus, $z_t(\omega) = z_t = z_t^* - g_t$ is the net payment (or net tuition fee) that each individual pays at date t to the higher education institutions.³

The cost of higher education is thus the same for all students of the same generation. For simplicity, we assume that the tuition and public funding are denominated in dollars of the working period of the student (e.g., it can be financed by students loan) and, throughout our analysis, we take the education tax imposed on wage incomes to be constant at the rate τ .

The wage earnings of skilled workers and low-skilled workers are determined according to their human capital level. Instead of attending some higher education institution after his basic education is attained, low-skilled individuals work during a portion m ($0 \leq m < 1$) of their youth period using the

³Public funding provides only a share of investments in tertiary education. In 2006 the proportion of private funding of tertiary education ranged between 3.6% in Denmark and 83.9% in Chile (OECD, 2009, Table B3.2b). Different combinations of tuition fees and government subsidies in our model can reproduce the relative importance of private funding observed in the data.

basic skills given in Eq. (1). Since they work fully at period $t+1$ as well, the lifetime after-tax wage income earned by a low-skilled worker ω is:

$$(3a) \quad (1-\tau)h_{t+1}^l(\omega)[mw_t(1+r_{t+1})+w_{t+1}]$$

where $(1+r_{t+1})$ is the return to capital at date $t+1$; w_t and w_{t+1} are the wage rates per unit of effective labor at date t and $t+1$, respectively.

In contrast, a skilled worker's after-tax lifetime wage earnings are derived from performing work only during period $(t+1)$:

$$(3b) \quad (1-\tau)h_{t+1}^s(\omega)w_{t+1}$$

To simplify the presentation, define $w_{t+1}^l = mw_t(1+r_{t+1})+w_{t+1}$ (or $w_{t+1}^s = Bw_{t+1}$) as the returns to an effective unit of low-skilled (or skilled) human capital at date $t+1$. The following assumption guarantees that the returns to skilled human capital is strictly larger than the returns to low-skilled human capital at date $t+1$, $w_{t+1}^s > w_{t+1}^l$, and will be established later as essential for the existence of higher education.

Assumption 1: *Given the exogenous wages and interest rates, the economy's parameters m and B ,*

$$(4) \quad \frac{w_{t+1}}{1+r_{t+1}} > \frac{m}{B-1}w_t \quad \text{holds at all dates } t, t=0, 1, 2, \dots$$

To further understand how individuals become skilled or low-skilled workers, the lifetime preferences of each $\omega \in G_t$ are represented by the Cobb-Douglas utility function:

$$(A1) \quad U_t(\omega) = (c_t^a(\omega))^{\alpha_1} (c_t^r(\omega))^{\alpha_2} (y_{t+1}(\omega))^{\alpha_3}$$

Consumption when 'active' and 'retired' are denoted by $c_t^a(\omega)$ and $c_t^r(\omega)$ respectively; $y_{t+1}(\omega)$ is the offspring's lifetime income.

Our framework assumes that parents are altruistic towards the well-being of their children. Specifically, parents care about the future of their offspring and derive utility directly from the lifetime income of their child⁴. The altruistic motives of parents are conveyed in three forms of intergenerational transfers (from parents to their children). The first two involve investment in education of the younger generation in order to increase its earning potential. First, parents pay taxes to finance the public education budget. Second, they pay the net tuition fee of higher education.

Lastly, parents transfer tangible assets, like *inter vivos* gifts and bequests, as well (see Viaene and Zilcha, 2002; Zilcha, 2003). Denote by $b_t(\omega)$ the transfer of physical capital by household $\omega \in G_t$ to his/her offspring. Given the return to capital and wages $\{r_t, w_t\}$, lifetime non-wage income of an offspring, whether skilled and low-skilled, is $(1 + r_{t+1})b_t(\omega)$. Thus, lifetime income of a **low-skilled** worker is:

$$(5) \quad y_{t+1}^l(\omega) = (1 - \tau)h_{t+1}^l(\omega)[mw_t(1 + r_{t+1}) + w_{t+1}] + (1 + r_{t+1})b_t^l(\omega)$$

In contrast, if he/she is a **skilled** worker then:

$$(6) \quad y_{t+1}^s(\omega) = (1 - \tau)h_{t+1}^s(\omega)w_{t+1} + (1 + r_{t+1})b_t^s(\omega)$$

Given the human capital of skilled and low-skilled workers, (1) and (2), it is straightforward to obtain variables at the economy level, the aggregate human

⁴ This is a more common and tractable representation of parents' altruism than a dynastic model where the utility of all future generations enter the utility of the current generation.

capital and the government balance sheet. First, the aggregate (or **mean** as well in our case) human capital, H_t , available to the economy at date t is given by

$$(7) \quad H_t = \int h_t(\omega) d\mu(\omega) + m \int_{\sim A_t} h_{t+1}^l(\omega) d\mu(\omega)$$

where A_t denotes the subset of children in G_t who attend higher education and $\sim A_t$ is the complement of A_t , the set of children not attending higher education.

The stock of human capital H_t that serves as a primary factor in production is the sum of two terms: the first is the aggregate human capital of all individuals in generation G_{t-1} (all are active at time t), while the second represents the human capital of children not attending higher education (the set $\sim A_t$).

The second variable to be defined is the government balance sheet. The government budget at date t is balanced if the following identity holds:

$$(8) \quad \tau w_t \left[\int h_t(\omega) d\mu(\omega) + m \int_{\sim A_t} h_{t+1}^l(\omega) d\mu(\omega) \right] = X_t + g_t \mu(A_t)$$

The left-hand side is simply $\tau w_t H_t$, a useful shorthand expression for government tax revenues, where H_t is defined in Eq. (7). On the other side of its balance sheet the government faces the total expenditure (on both stages of education). Denote by $\mu(A_t)$ the measure of skilled individuals who (all) receive some public funding for higher education.

To simplify the presentation, let γ_t , $0 \leq \gamma_t \leq 1$, be the **fraction** of government revenues at date t **allocated to compulsory schooling**. Then:

$$X_t = \gamma_t \tau w_t H_t$$

$$g_t \mu(A_t) = (1 - \gamma_t) \tau w_t H_t$$

With $\gamma_t = 1$, the government revenues are fully allocated to compulsory education, and tertiary education is privately financed, $g_t = 0$. With $g_t = z_t^*$, higher education is fully publicly financed.

We say that an **education policy** $\{(X_t, g_t)\}$ is **feasible** if at each date t : (a) given X_t and g_t , the set A_t of skilled descendants is determined by each individual's 'optimal choice' and (b) condition (8) holds in all periods t .

Expression (8) stresses the importance of including both sides of the government balance sheet when the effects of new policies are examined. This issue is also confirmed by studies dealing with the empirics of growth which show that the growth effects of public education spending are generally mixed except when the method of finance is properly accounted for in which case they are clearly positive (see, e.g., Bassanini and Scarpenta, 2001; Blankenau *et al.*, 2007b).

Production is carried out by competitive firms that produce a single commodity which is both consumed and used as production input. Physical capital K_t (assumed to fully depreciate) and effective human capital H_t (computed in (7)) are inputs of a neo-classical production function that exhibits constant returns to scale; it is strictly increasing and concave.

We consider a small open economy that, as of date $t=0$, is integrated into the rest of the world in two ways. First, the final good is freely traded which implies a single commodity price worldwide. Second, physical capital is assumed to be internationally mobile while labor is internationally immobile.

With the small economy assumption, $\{r_t\}$ must be equal to the foreign interest rate⁵.

With similar final goods prices and equal interest rates, the domestic wage must equal the pre-determined foreign wage as long as production technologies are similar⁶.

Given this framework, any education policy that leads to human capital accumulation is expected to temporarily increase the domestic marginal return to physical capital and, hence, bring about an inflow of foreign physical capital. The increase in both primary inputs must increase the domestic output.

Competitive Equilibrium

Given K_0, H_0 , education policy $\{(X_t, g_t)\}_{t=0}^{\infty}$, the international prices of capital and labor $\{r_t, w_t\}$, and the tax rate τ , each agent ω at time t with intergenerational transfers $b_{t-1}(\omega)$ chooses the level of savings $s_t(\omega)$ and bequest $b_t(\omega)$ together with the financial investment in higher education $z_t(\omega)$, so as to maximize:

$$(9) \quad \text{MAX}_{s_t, b_t, z_t} [U_t(\omega) = (c_t^a(\omega))^{\alpha_1} (c_t^r(\omega))^{\alpha_2} (y_{t+1}(\omega))^{\alpha_3}]$$

⁵ There are several reasons why these returns may not be equalized. Barriers to capital mobility like capital controls and corporate income tax differentials would create a difference in rates of return. To characterize such difference, let λ be the proportional difference in the rate of return to physical capital between the domestic economy and the rest of the world. With capital market integration the equality between rates of return implies $r_t = \lambda r_t^*$. A less than full capital mobility is represented by $\lambda \neq 1$ but this does not modify our results qualitatively as long as the wedge λ stays constant.

⁶ Particularly, wages are the solution to two iso-price equations of the model, one for each economy. With equal prices and interest rates, wages must be similar only when production technologies are the same in both economies. Different technologies would cause a cross-country difference in wages and trigger international migration. While physical capital is homogenous, human capital is not and this feature makes it difficult to determine the extent and the skill content of the labor flow.

subject to constraints:

$$(10) \quad z_t(\omega) = 0 \quad \text{or} \quad z_t(\omega) = z_t^* - g_t, \quad b_t(\omega) \geq 0$$

$$(11) \quad c_t^a(\omega) = y_t(\omega) - s_t(\omega) - b_t(\omega) - z_t(\omega) \geq 0$$

$$(12) \quad c_t^r(\omega) = (1 + r_{t+1})s_t(\omega) \geq 0$$

where $y_t(\omega)$ and $y_{t+1}(\omega)$ are the corresponding incomes given either by (5) or (6),

while $h_{t+1}^s(\omega)$ is defined by Eq. (2) for a skilled worker and $h_{t+1}^l(\omega)$ is defined by

Eq. (1) for a low-skilled worker.

Given K_0, H_0 , $\{(c_t^a(\omega), c_t^r(\omega), s_t(\omega), b_t(\omega), z_t(\omega)); w_t, r_t)\}_{t=0}^{\infty}$ is a **competitive equilibrium** if:

(i) For each date t , given factor prices (r_t, w_t) and the public education policy

$\{(X_t, g_t)\}_{t=0}^{\infty}$, the optimum under conditions (9)-(12) for household ω with bequest

$b_{t-1}(\omega)$ is $(c_t^a(\omega), c_t^r(\omega), s_t(\omega), b_t(\omega), z_t(\omega)) \geq 0$.

(ii) Given the aggregate production function, the wage rate of effective labor w_t is

determined by the marginal product of (effective) human capital.

(iii) The education policy $\{(X_t, g_t)\}_{t=0}^{\infty}$ is **feasible**, hence the government budget

constraint in (8) holds at each date t .

(iv)

After substituting all constraints, the first order conditions with respect to

$b_t(\omega)$ and $s_t(\omega)$, respectively, are (assuming interior solutions):

$$(13) \quad \frac{c_t^a(\omega)}{y_{t+1}(\omega)} = \frac{\alpha_1}{\alpha_3} \frac{1}{(1 + r_{t+1})}$$

$$(14) \quad \frac{c_t^a(\omega)}{c_t^r(\omega)} = \frac{\alpha_1}{\alpha_2} \frac{1}{(1 + r_{t+1})}$$

We assume that intergenerational transfers are unidirectional and therefore cannot take negative values along the equilibrium path.

From *Eq.* (12), (13) and (14) we obtain that:

$$(15) \quad s_t(\omega) = \frac{\alpha_2}{\alpha_3} \frac{1}{(1+r_{t+1})} y_{t+1}(\omega)$$

Using *Eq.* (15) and the definitions of income in (5) and (6), we obtain the expression for bequest if the offspring turns out to become low skilled:

$$(16) \quad b_t^l(\omega) = \frac{\alpha_3}{\alpha_2} s_t(\omega) - \frac{(1-\tau)[mw_t(1+r_{t+1}) + w_{t+1}]}{(1+r_{t+1})} h_{t+1}^l(\omega) \geq 0$$

Likewise for a skilled offspring:

$$(17) \quad b_t^s(\omega) = \frac{\alpha_3}{\alpha_2} s_t(\omega) - \frac{(1-\tau)w_{t+1}}{(1+r_{t+1})} h_{t+1}^s(\omega) \geq 0$$

Due to free capital mobility, both intergenerational transfers are affected by international market conditions. The reason is that when altruistic rational parents make forward-looking decisions regarding direct financial transfers and/or investment in attaining skills, they consider the return to physical capital. Thus, in such considerations they take into account the future interest rate and the future wage rate respectively.

Substituting *Eq.* (16) and (17) in *Eq.* (5) and (6) respectively, and making use of first order conditions *Eq.* (13) and (14) we obtain the reduced-form income of agent ω who is either a low-skilled or a skilled offspring:

$$y_{t+1}^l(\omega) = \left(\frac{\alpha_3}{\alpha_1 + \alpha_2 + \alpha_3} \right) (1+r_{t+1}) \left\{ \frac{(1-\tau)(w_{t+1} + mw_t(1+r_{t+1}))}{(1+r_{t+1})} Z_{t+1}(\omega) X_t^\xi + y_t(\omega) \right\}$$

$$y_{t+1}^s(\omega) = \left(\frac{\alpha_3}{\alpha_1 + \alpha_2 + \alpha_3} \right) (1+r_{t+1}) \left\{ \frac{(1-\tau)w_{t+1}}{(1+r_{t+1})} B Z_{t+1}(\omega) X_t^\xi - (z^* - g_t) + y_t(\omega) \right\}$$

The two expressions for $y_{t+1}(\omega)$ exhibit an intergenerational persistence of incomes, which is similar for all households ω :

$$\frac{\partial y_{t+1}^l(\omega)}{\partial y_t(\omega)} = \frac{\partial y_{t+1}^s(\omega)}{\partial y_t(\omega)} = \left(\frac{\alpha_3}{\alpha_1 + \alpha_2 + \alpha_3} \right) (1 + r_{t+1})$$

It is increasing in the altruism parameter α_3 and in the interest rate at the future date.

Note that we can solve fully for the competitive equilibrium path. Given the parameters at date t (including $Z_{t+1}(\omega)$), $y_{t+1}(\omega)$ can be calculated at date t . Thus, we can solve for the optimal $(c_t^a(\omega), c_t^r(\omega), s_t(\omega))$ using Eq. (13), (14) and (15). In the next sections, both expressions of income will be crucial in partitioning the work force between skilled and low-skilled workers.

Skilled and Low-Skilled Workers

To determine the sets of skilled and low-skilled workers explicitly we derive the reduced-form utility function. Inserting $c_t^a(\omega) = (\alpha_1 / \alpha_2) y_{t+1}(\omega) / (1 + r_{t+1})$ and $c_t^r = (\alpha_2 / \alpha_3) y_{t+1}(\omega)$, obtained from the first order conditions (13) and (14), into the utility function (Eq. (9)) yields the following reduced-form utility function (for both skilled and low-skilled offspring):

$$(18) \quad U_t(\omega) = \Phi \left(\frac{1}{1 + r_{t+1}} \right)^{\alpha_1} [y_{t+1}(\omega)]^{\alpha_1 + \alpha_2 + \alpha_3}$$

where parameter Φ is a constant independent of time and independent of ω .

The reduced-form utility of parents is proportional to the lifetime income of their offspring. In other words, by maximizing their offspring's future income parents

augment their own utility at the same time. Therefore, parents decide whether to invest in higher education by comparing the future lifetime earnings of their child as a skilled worker or low-skilled worker. This way, parents generate the education demand, and affect the sets of skilled and low-skilled workers in the economy in the following period. Note that, in this framework, a utilitarian social planner, who is interested in the current aggregate of individual utilities, is equally concerned with the next generation's aggregate income.

Education Demand and Supply

The next step is to define the demand and supply for universities using the reduced-form utility (18). It sheds some light into the observed cross-country variations in the skill composition of work forces in both developed and developing countries.

For example, Table 1 shows the skill composition of work forces for a subset of OECD countries and for OECD's partner countries in the year 2007. The share of skilled workers in the labor force is approximated by the share of age group 25-64 with at least upper secondary education.

Table 1: Cross-Country Variation of the Skilled Labor Force^{a,b}

<i>OECD Countries</i>	<i>Age Group 25-64 with at least Upper Secondary Education</i>	<i>Partner Countries</i>	<i>Age Group 25-64 with at least Upper Secondary Education</i>
<i>Italy</i>	52	<i>Brazil</i>	37
<i>Korea</i>	78	<i>Chile</i>	50
<i>Mexico</i>	33	<i>Estonia</i>	89
<i>Netherlands</i>	73	<i>Israel</i>	80
<i>Portugal</i>	27	<i>Russian Fed</i>	88
<i>Turkey</i>	29	<i>Slovenia</i>	82

Notes: (a) The share of skilled workers in the labor force is approximated by the percentage of the population of age group 25-64 with at least upper secondary education; (b) In percentage, in 2007. *Source:* OECD (2009, Table A1.2A, column 1)

The share of skilled workers in the labor force varies largely among countries, between 27 percent in Portugal and 89 percent in Estonia.

Given assumption 1, and given the distribution of $Z_{t+1}(\omega)$ (the background, or initial endowment, of each individual), the next proposition defines the demand for universities at date t , A_t^U , as a function of both the relative returns to higher education and the relative cost.

Proposition 1: *Let A_t^U denote the demand for universities. Then, (a) condition (4) is a necessary condition for A_t^U to be nonempty.*

(b) Define:

$$\Lambda_t = \left(\frac{1}{1-\tau} \right) \left[\frac{1}{(B-1) \frac{w_{t+1}}{1+r_{t+1}} - mw_t} \right] \left(\frac{z^* - g_t}{X_t^\xi} \right). \quad \text{Then:}$$

$$(19) \quad A_t^U = \{ \omega \mid Z_{t+1}(\omega) \geq \Lambda_t \}$$

That is, all individuals $\omega \in G_t$ with initial endowments above Λ_t generate the demand for universities.

We relegate the proofs to the Appendix. While all individuals with a sufficiently large initial endowment (above Λ_t) generate the demand for universities, all other individuals will not invest and become low-skilled workers⁷.

The demand for universities, the set A_t^U , depends on the relative returns and the relative cost of higher education. Condition (4) guarantees that the returns to skilled human capital is strictly larger than the returns to low-skilled human

⁷ Eicher (1996) also model a partition of the labor force between skilled and low-skilled workers but it is individuals who make their own occupation choice based on the respective career paths as skilled or low-skilled.

capital, $w_{t+1}^s > w_{t+1}^l$ (which means that the denominator of the threshold Λ_t is positive); In other words, attaining a university sufficiently augments each individual's basic skills, or the parameter B is relatively large.

Universities exist as long as condition (4) holds. Otherwise, if the costly higher education does not achieve excess returns, or $w_{t+1}^s = w_{t+1}^l$, all individuals become low-skilled workers (the threshold $\Lambda_t \rightarrow \infty$, and the set A_t^U is empty).

Besides the relative returns, the demand for universities depends on the relative cost of higher education, the centre of current policy debates in the USA. If the private investment in higher education, $z^* - g_t$, is high relative to the public investment in compulsory schooling, X_t , then the demand for universities is small (the threshold Λ_t is large).

On the other extreme, when higher education is fully funded by the government, $g_t = z_t^*$, the demand for universities consists of all individuals. From these examples, it is clear that the relative returns and relative cost of higher education play an important role in the formation of types of workers.

After describing the demand for universities, the next assumption defines the supply side. Typically, the demand for universities is larger than supply. Universities have binding capacity constraints. As a result, they impose access restrictions on students; only students with sufficiently large initial endowments are accepted to universities.

Assumption 2: *The set of individuals who invest in higher education at date t , or the skilled work force, denoted by A_t , is given by:*

$$(19b) \quad A_t = \{\omega \mid Z_{t+1}(\omega) \geq \lambda_t\},$$

where $\lambda_t > \Lambda_t$ is the access restriction of the universities.

Because of the excess demand for universities, the supply actually determines the set of students who attend universities. All individuals with initial endowments above λ_t become skilled workers, while all individuals below λ_t become low skilled workers. The excess demand for universities is generated by individuals with initial endowments within $\{\Lambda_t, \lambda_t\}$, who demand higher education but do not meet the university requirements.

Introduction of Colleges

The excess demand for universities has caused the emergence of colleges in many countries. Typically, colleges alleviate the access restrictions of universities. For simplicity, we assume that colleges accept all applicants and that their tuition fee is identical to universities. As a result, individuals with initial endowments $\{\Lambda_t, \lambda_t\}$, who are not accepted to the universities, can now attend colleges.

Nevertheless, the demand for colleges is lower than the demand for universities because of two reasons: colleges' quality and colleges' cost. First, colleges' quality is lower than universities'. That is, while universities augment each individual's basic skills by some quality factor $B > 1$, it is likely that colleges have a lower quality factor, generated by lower investments in teaching quality and facilities, $B > B_C > 1$. Thus, if agent ω attends college, then his/her human capital accumulates to the level:

$$(20) \quad h_{t+1}^c(\omega) = B_c h_{t+1} = B_c \tilde{\theta}_t(\omega) h_t^v(\omega) X_t^\xi$$

The second reason for the lower demand for colleges is that, typically, the government allocates smaller funds to colleges. For simplicity, we assume for now that the government does not participate in the cost of colleges, and therefore students of colleges pay the whole tuition fee.

Formally, denote by g_{ct} the government (or public) allocation to each student wishing to attain additional skills via a college. Thus, $z_{ct}(\omega) = z_{ct} = z_t^* - g_{ct}$ is the net payment that each individual pays at date t to access a college and $g_{ct} = 0$ ⁸. Because of their lower quality and larger cost, colleges are less attractive than universities.

Education Decision

Making use of the utility (18), the next result defines the demand for colleges. As all applicants are accepted to colleges, the demand for colleges actually determines the proportion of the population that attends college.

Proposition 2: *Let C_t denote the set of individuals who choose to invest in college at date t . Then: (a) a necessary condition for C_t to be nonempty is:*

⁸ Public funding provides only a share of investments in tertiary education. In 2006 the proportion of private funding of tertiary education ranged between 3.6% in Denmark and 83.9% in Chile (OECD, 2009, Table B3.2b). Different combinations of tuition fees and government subsidies in our model can reproduce the relative importance of private funding observed in the data.

$$(21) \quad \frac{w_{t+1}}{1+r_{t+1}} > \frac{m}{B_c-1} w_t$$

(b) Assume that condition (19) holds. Define:

$$\Lambda_{ct} = \left(\frac{1}{1-\tau} \right) \left[\frac{1}{(B_c-1) \frac{w_{t+1}}{1+r_{t+1}} - m w_t} \right] \left(\frac{z^* - g_{ct}}{X_t^\xi} \right). \quad \text{Then:}$$

$$(22) \quad C_t = \{ \omega \mid \lambda_t \geq Z_{t+1}(\omega) \geq \Lambda_{ct} \}$$

Namely, all individuals $\omega \in G_t$ with initial endowments above Λ_{ct} become skilled workers.

After introducing colleges, all individuals with sufficiently low endowment (below Λ_{ct}) become low-skilled workers, whereas all other individuals invest in higher education and become skilled workers. There are two types of skilled workers: Individuals with initial endowments above λ_t attend universities (also called university students), and individuals with initial endowments $\{\Lambda_{ct}, \lambda_t\}$ attend colleges (also called college students).

Similarly to the demand for universities, the demand for colleges depends on their relative returns and cost. Specifically, colleges must be sufficiently cost-effective in order to exist. To simplify the presentation, define $w_{t+1}^c = B_c w_{t+1}$ as the returns to an effective unit of 'college' human capital, or the human capital attained by college graduates, at date $t+1$.

Then, assumption (21) guarantees that the returns to college human capital is strictly larger than the returns to low-skilled human capital at date $t+1$, $w_{t+1}^c > w_{t+1}^l$. In other words, graduating from college sufficiently augments each individual's basic skills, or the parameter B_c is relatively large. Otherwise, if colleges

do not achieve excess returns relative to basic education, all individuals become low-skilled workers.

Besides the relative returns, the demand for colleges depends on the relative cost of higher education in the same way as the demand for universities. Therefore, cost-efficiency is necessary for colleges to survive.

Economy's Human Capital

After defining how individuals are divided between the three levels of education, universities, colleges, and basic education, important questions arise regarding the role of colleges in the human capital formation.

The emergence of colleges alleviates the excess demand for universities by offering another alternative of higher education. As a result, the set of skilled workers, A_t , expands. Not only individuals with initial endowments above λ_t attend universities, but also individuals with lower initial endowments $\{\Lambda_{ct}, \lambda_t\}$ attend colleges.

There are two attendant questions: (a) is it worthwhile to establish colleges; or specifically, does the resulting expansion of the set of skilled workers leads to higher aggregate stock of human capital that is available for production activities? (b) is it justified to subsidize colleges, which may further extend the demand for them?

The next proposition answers the first question and to fix ideas let us make the following assumption:

Assumption 3: $B_c > 1+m$ holds.

Recall that m measures the time a low-skilled worker's human capital is used in production. $(B_c - 1)$ measures the increased qualification this worker gets if he/she attend a college instead. Hence, $B_c - 1 - m > 0$ guarantees that the individual's human capital made available for productive activities is higher if he decides to attend a college rather than to remain a low skilled worker.⁹ Note that our assumption that $B > B_c$ implies that attending a university would obtain even higher human capital than colleges. We also assume that the university access restriction, λ_t , does not change over time, $\lambda_t = \lambda_{t+1} = \lambda$.

Under these assumptions, and given that typically universities have been established earlier than colleges, proposition 2 compares a regime with only universities to a regime where both universities and colleges co-exist. This way, we assess how the emergence of colleges affects the stock of human capital in the economy.

Proposition 3: *Under assumption 3, the emergence of colleges causes a decline in output at the current date t but an increase in output in **all** subsequent periods $t + k$, $k \geq 1$.*

After colleges are established, some youths study in college instead of being low-skilled workers expanding the set of skilled workers, A_t . Their lower labor market participation during their college studies reduces the stock of human capital

⁹Alternatively parameters B and B_c represent also the education wage gap between a skilled worker with a university or a college degree, respectively, relative to that of a low-skilled worker with high school and less. Using information on m , a testable hypothesis is to verify whether the education wage gap of any country exceeds the country-specific lower bound $(1+m)$. See Hotchkiss and Shiferaw (2011) and the references therein for measurement and estimation methodologies of the education wage gap.

available for production in period t , H_t , which further causes an outflow of physical capital. As a result, the economy also faces a decline in output at the current date t .

However, in the following periods, as low-skilled workers join college, the stock of human capital increases. Therefore, fewer individuals induce their children to be low-skilled workers, and the set of college students keeps increasing at the expense of the set of low-skilled workers. Thus, except for the initial period, establishing colleges leads to a higher stock of human capital. This result emphasizes another essential feature of the emergence of colleges. Because colleges accept all applicants, their admission standards, or the lower threshold of college students, Λ_{ct} , keep declining over time along with the increasing demand for colleges and the increasing stock of human capital.

Corollary 1: Under Assumption 3, college admission standards decline over time, or $\Lambda_{ct} > \Lambda_{ct+1} > \Lambda_{ct+2}$ and so on.

The positive effect of colleges on the stock of human capital leads to the second question. Is it justified to subsidize colleges, which may further expand the demand for them? Or more specifically, is it justified to split the higher education budget between colleges and universities? To answer this question, we assume that universities and colleges co-exist, and compare two cases: a regime with **unsubsidized colleges** vs. a regime with fully **subsidized colleges**.

The first case is the one we have discussed so far, where the educational budget is allocated only to university students as a subsidy $g_t > 0$, whereas the government allocation to each college student, g_{ct} , is zero.

In the second case, the higher education budget is allocated not only to universities, but also to colleges. That is, an equal subsidy is provided to each student who attends higher education, whether he or she enrolls to a college or to a university, $g_{ct} = g_{ut} > 0$, respectively.

Note that the subsidy per student is the key variable that changes in the shift from unsubsidized colleges to subsidized colleges. All other parameters of the educational budget remain fixed, including the education tax rate, τ , the fraction of compulsory schooling from the budget, γ_t , and the access restriction of universities, λ , which determines the proportion of university students. This way, we focus the discussion on the necessity of allocating a share of the existing higher education budget to college students.

Given these fixed parameters, subsidizing colleges on top of universities reduces the subsidy for university students in the initial period, $g_t > g_{ct} = g_{ut}$ (to maintain a balanced budget). In other words, the net tuition fee of each university student rises. This feature corresponds to the recent shift in many Western countries from public higher education funding (through various forms of subsidies) to private funding (based on student loans). In this framework, we assess how subsidizing college students affects the stock of human capital in the economy.

Proposition 4: *Under Assumption 3, introducing subsidized colleges at date t causes a decline in output at the current date t but an increase in output in **all** subsequent periods $t+k$, $k \geq 1$.*

The effect of subsidizing colleges is quite similar to the effect of the emergence of colleges. When each individual attending college becomes subsidized

by the government, more youths enrol to college instead of remaining low-skilled. On the one hand, their forgone earnings as low-skilled workers reduce the stock of human capital and the aggregate output at date t .

On the other hand, their augmented human capital as college-educated workers increases the stock of human capital in the following periods. As a result, fewer individuals induce their children to be low-skilled workers, and the set of college students keeps increasing at the expense of the set of low-skilled workers. Accordingly, college admission standards decline over time (Corollary 1 holds also when colleges become subsidized), and the stock of human capital keeps increasing over time.

Differential subsidies and universities' dominance

In our framework, the emergence and expansion of colleges (see Kaganovich and Su, 2016) and even subsidizing colleges provides incentives for low-skilled workers to become college-educated, and at the same time the universities do not shrink. That is, university students are not encouraged to become college students. Universities remain more popular than colleges, because their graduates enjoy higher returns relative to the cost.

First, universities are more productive than colleges, they augment the basic skills by a larger quality factor, $B > B_c > 1$ (say, due to better curriculum and faculty). As a result, university graduates enjoy higher earnings than college graduates. Second, the cost of higher education is similar among college students and university students (the subsidies are uniform and allocated equally among the higher

education students, $g_{ct} = g_{ut} > 0$). In this framework, with similar cost and higher returns, universities are clearly more cost-effective than colleges. Being more cost-effective, universities are the dominant (or the first choice) institutions in the market of higher education; students always prefer universities as their first choice, and may attend colleges only if they fail to pass the university access restrictions, λ_t . The dominancy, or hegemony, of universities among students appears not only when colleges are not subsidized, but also remains when the higher education budget is shared equally among university students and college students.

Because subsidizing colleges does not harm universities while providing incentives for low-skilled workers to become college-educated, the stock of human capital rises in future periods. This result, that subsidizing the less productive institutions enhances the economic growth, contradicts the common-knowledge that more productive institutions should be subsidized at the expense of less productive ones¹⁰. This result emerges in our framework as the outcome of specific circumstances, the hegemony of the more productive institutions in the market. Investing subsidies that basically attract more ‘consumers’ to these institutions, who already enjoy excess demand and cannot serve these additional consumers, is an inefficient policy

As long as universities are more cost-effective than colleges (for all students) their hegemony in the market for higher education remains. This begs two questions. Given that universities are more productive than colleges, and subsidies in colleges

¹⁰ Hatsor (2014) suggests that allocating more funds to a less productive education system may be the optimal choice of the majority of voters, and may even explain the 'budget puzzle', or why educational expenditures seem to be unrelated to educational achievements according to the empirical evidence.

and universities are provided according to the same policy, (a) is it possible under certain circumstances that some students choose to attend colleges although they are accepted to universities? (b) What are the consequences of colleges becoming the first choice of these students, breaking the university hegemony in the market?

One example where colleges may become the first choice of students is the case of differential subsidies. In reality, much of the higher education subsidies is directed to particular subsets of the population (the more able or the less wealthy, for example; see Blankenau et al., 2007a). Specifically, merit-based subsidies are quite popular and are typically argued to be a growth-enhancing policy. Suppose that instead of uniform subsidies, subsidies are merit-based. That is, universities and colleges subsidize only a certain proportion of their students, those with the highest earning potential (based on their initial background, $Z_{t+1}(\omega)$).

Accordingly, in contrast to uniform subsidies, by definition the least favourable, or the least successful, university candidates (based on their initial background) are not subsidized by the universities. At the same time, these candidates are the most favourable college candidates and as such are being offered college subsidies. Therefore, being subsidized by colleges but not by universities, their net tuition fee as college students is lower than as university students.

Considering their alternatives, their parents may face a trade-off between universities (more productive) and colleges (less costly). Consequently, they may pursue college education as a first choice if the college subsidy is sufficiently high to compensate for the lower college quality. In other words, the shift from uniform subsidies to merit-based subsidies may encourage certain university students to attend

colleges, although they are accepted to universities, breaking the university hegemony in the market. Formally,

Proposition 5: *Assume that subsidies are merit-based. Let C'_t denote the set of individuals who choose colleges at date t , although they are accepted to universities. Then:*

(a) *A necessary condition for C'_t to be nonempty is:*

Students in the set C'_t are subsidized by colleges, i.e., $g_{ct} > 0$, but not by universities, i.e., $g_t = 0$.

(b) *Assume that condition (a) holds. Define:*

$$\Lambda_{c't} = \left(\frac{1}{1-\tau} \right) \left[\frac{1}{(B-B_c) \frac{w_{t+1}}{1+r_{t+1}}} \right] \left(\frac{g_{ct}}{X_t^\xi} \right). \quad \text{Then:}$$

$$(23) \quad C'_t = \{ \omega \mid \lambda_t < Z_{t+1}(\omega) \leq \Lambda_{c't} \}$$

Namely, all individuals with initial endowments above $\Lambda_{c't}$ choose colleges at date t although they are accepted to universities.

Similarly to the case of uniform subsidies, while all individuals with sufficiently low endowments (below $\Lambda_{c't}$) become low-skilled workers, all other individuals invest in higher education and become skilled workers (recall proposition 2). However, compared to the case of uniform subsidies, the set C'_t of college students expands at the expense of universities. It includes individuals with initial endowments $\{\Lambda_{c't}, \Lambda_{c't}\}$, whereas individuals with initial endowments above $\Lambda_{c't}$ attend universities. Accordingly, the access restriction of universities, λ_t , is no longer effective, and there is no longer excess demand for universities.

The additional set of college students, C'_t , consists of individuals with initial endowments $\{\lambda_t, \Lambda_{c't}\}$. They pursue college education, although they are accepted to universities, considering the relative returns and the relative cost of higher education. Specifically, according to condition (23), parents prefer colleges over universities if the subsidies are sufficiently high (relative to the public investment in compulsory schooling, X_t) to compensate for the lower college quality.

In order to attract university students, besides the high subsidies, colleges must be sufficiently productive compared to universities, namely, $B - B_c$ must be sufficiently small (which also means that the gap between the returns to university human capital and the returns to college human capital, $w_{t+1}^s - w_{t+1}^c$, is sufficiently small). Moreover, the more productive colleges are, the lower the gap $B - B_c$ is, and the larger the set C'_t (that prefers colleges over universities) becomes. Therefore, by implementing a policy of merit-based subsidies instead of uniform subsidies, cost-effective colleges may draw university students and impair the university hegemony in the market of higher education.

Another implication of applying a merit-based subsidy policy is that the least favorable (or lowest-background) college students are not offered a subsidy. Consequently, instead of attending college they decide not to pursue higher education and become low-skilled workers (compared to the case of uniform subsidies the threshold $\Lambda_{c't}$ rises). I

These possible shifts of students to lower quality education (from universities to colleges and from colleges to basic education), caused by applying a merit-based subsidy policy, reduce the productivity of these students in the labor market. As a result, in contrast to the common- knowledge that merit-based subsidies are growth-enhancing, the stock of human capital in the economy and the output decline in all periods¹¹.

Proposition 6: *In the presence of universities and colleges, a shift from uniform subsidies to merit-based subsidies causes a decline in output in **all** periods.*

The proof of proposition 6 is straight-forward from the shifts of students to lower quality education and is available by request¹². Note that by the same reason, subsidies allocated to the students with the lowest earning potential are growth-enhancing compared to uniform subsidies, because they encourage low-skilled individuals to become college students¹³.

Summary and Conclusions

We study the effect of expanding the higher education system by including "Colleges" as an alternative to universities on the aggregate human capital (and growth).

¹¹ This result holds in a more general framework with various qualities of universities and colleges. The results may change if the competition between universities and colleges may affect their behaviour.

¹² Merit-based subsidies is one way to draw university students to college. Non-financial incentives that are out of the model may also increase the relative satisfaction from colleges. These include a friendlier approach and better availability of the staff towards students, a flexible schedule, a convenient location, a more attractive or updated curriculum, or a curriculum more suitable to specific students (see Kaganovich and Su, 2016; Eisenkopf and Wohlschlegel, 2012), and compromises in the requirements.

¹³ However, this type of subsidies may alter the individual incentives to invest effort in their basic education. While not in the model, some individuals may underinvest in their basic education in order to be qualified for college subsidies, while others may overinvest in order to obtain university subsidies.

For that purpose, we use a model featured by 'compulsory schooling', fully financed by public funding, and higher education, partially funded. At the outset, higher education is composed of 'universities' only, where students are partially subsidized by the government. Then, we expand the higher education system to include colleges as well, and compare the dynamic equilibrium paths period by period.

Our findings demonstrate that the emergence of colleges without subsidies as well as the case with subsidization reduce the stock human capital and the aggregate output in the period where the change takes place, but results in augmenting both of them in all subsequent periods.

The impact of the "College expansion" on economic growth is caused by the expansion of the set of skilled workers (students with higher education), and the decline of college admission standards over time. Introducing colleges, subsidized or unsubsidized, has two effects: initially it results in a loss in the stock of human capital due to the forgone labor of young individuals who acquire college education instead of working as low-skilled workers. Also, the additional skills of college graduates improve the stock of human capital in the subsequent periods, compensating for the loss of their earnings as low-skilled workers.

A certain conclusion emanates from our results about the optimal allocation of resources between universities and colleges. The results suggest that subsidizing colleges at the expense of universities is a growth-enhancing policy as long as the excess demand for universities remains. This condition always holds if uniform

subsidies are divided equally among college students and university students, because in this case colleges are less cost-effective than universities.

Moreover, in the presence of excess demand for universities, even allocating *the whole* budget to college students may be growth-enhancing, as long as the hegemony of universities in the market is preserved.

However, if colleges are sufficiently productive (specifically, condition (23) holds), then allocating the whole budget to college students, or even allocating merit-based subsidies equally among college and university students, may pull university students into colleges, and thus harm the dominance of universities and damage the economic growth.

Appendix

Proof of Proposition 1: Patents decide that their child will attend higher education if

$$y_{t+1}^s(\omega) > y_{t+1}^l(\omega) \Leftrightarrow U_t^s(\omega) > U_t^l(\omega)$$

which implies:

$$(1-\tau)B\tilde{\theta}_t(\omega)h_t(\omega)^v X_t^\xi w_{t+1} - (1+r_{t+1})z_t > (1-\tau)\tilde{\theta}_t(\omega)h_t(\omega)^v X_t^\xi [w_{t+1} + (1+r_{t+1})mw_t]$$

Note that this inequality holds only if condition (4) holds. Moreover it is easy to verify that when (4) holds the set of skilled individuals is given by (20). ■

Proof of Proposition 2: Patents decide that their child will attend a college (if not accepted to a university) if

$$y_{t+1}^c(\omega) > y_{t+1}^l(\omega) \Leftrightarrow U_t^c(\omega) > U_t^l(\omega)$$

which implies:

$$(1-\tau)B_c\tilde{\theta}_t(\omega)h_t(\omega)^v X_t^\xi w_{t+1} - (1+r_{t+1})z_t > (1-\tau)\tilde{\theta}_t(\omega)h_t(\omega)^v X_t^\xi [w_{t+1} + (1+r_{t+1})mw_t]$$

Note that this inequality holds only if condition (21) holds. Moreover it is easy to verify that when (21) holds the set of skilled individuals is given by (22). ■

Proof of Proposition 3: Denote the stock of human capital at date t in the presence of universities only:

$$H_t^U = \int h_t(\omega) d\mu(\omega) + m \int_{\sim A_t} h_{t+1}^l(\omega) d\mu(\omega)$$

In the emergence of colleges, the set of skilled workers, A_t , increases, because individuals with initial endowments $\{\Lambda_{ct}, \lambda_t\}$ enrol to college. Therefore, while the first term in this expression remains unchanged, the second decreases and H_t drops. Specifically, the stock of human capital at date t that corresponds to the co-existence of universities and colleges, denoted by H_t^{U+C} , equals

$$H_t^{U+C} = H_t^U - m \int_{\Lambda_{ct}}^{h_{t+1}^l(\omega)} d\mu(\omega)$$

Consider now later periods:

$$H_{t+1}^U = \int h_{t+1}(\omega) d\mu(\omega) + m \int_{\sim A_{t+1}} h_{t+2}^l(\omega) d\mu(\omega)$$

The emergence of colleges has two effects. First, low-skilled workers join the skilled work force by enrolling to college: A_t increases but $\sim A_t$ decreases by the same number. Since we transfer low-skilled workers to the skilled labor force we obtain that $\int h_{t+1}(\omega) d\mu(\omega)$ increases. Second, fewer individuals induce their children to be low-skilled workers: $\sim A_{t+1}$ decreases (hence A_{t+1} expands, and therefore $\int h_{t+2}^l(\omega) d\mu(\omega)$ increases). Specifically, the stock of human capital at date $t+1$ that corresponds to the co-existence of universities and colleges, denoted by H_{t+1}^{U+C} , equals

$$\begin{aligned} H_{t+1}^{U+C} &= H_{t+1}^U + \int_{\Lambda_{ct}}^{h_{t+1}^c(\omega)} (h_{t+1}^c(\omega) - h_{t+1}^l(\omega)) d\mu(\omega) - m \int_{\Lambda_{ct+1}}^{h_{t+2}^l(\omega)} d\mu(\omega) \\ &> H_{t+1}^U + (B_c - 1 - m) \int_{\Lambda_{ct}}^{h_{t+1}^l(\omega)} d\mu(\omega) \end{aligned}$$

The last inequality is obtained using Eq. (20) and the fact that the set of college students keeps increasing at the expense of the set of low-skilled workers, which

means that the lower threshold of college students keeps declining, thereby

$$\int_{\Lambda_{ct}}^{\lambda_t} h_{t+1}^l(\omega) d\mu(\omega) > \int_{\Lambda_{ct+1}}^{\lambda_{t+1}} h_{t+2}^l(\omega) d\mu(\omega).$$

This implies that $H_{t+1}^{U+C} - H_{t+1}^U > (B_c - 1 - m) \int_{\Lambda_{ct}}^{\lambda_t} h_{t+1}^l(\omega) d\mu(\omega)$, which is strictly positive by assumption 3. This process can be continued for all coming dates since we obtained that A_{t+1} also expands. Thus our claim is proved. ■

Proof of Proposition 4: Denote the stock of human capital at date t in the presence of universities and unsubsidized colleges, $g_{ct} = 0$:

$$H_t^{U+C} = \int h_t(\omega) d\mu(\omega) + m \int_{\sim A_t} h_{t+1}^l(\omega) d\mu(\omega)$$

Recall the demand for college education, defined by Eq. (22)

$$\Lambda_{ct} = \left(\frac{1}{1-\tau} \right) \left[\frac{1}{(B_c - 1) \frac{w_{t+1}}{1+r_{t+1}} - mw_t} \right] \left(\frac{z^* - g_{ct}}{X_t^\xi} \right)$$

$$C_t = \{ \omega \mid \lambda_t \geq Z_{t+1}(\omega) \geq \Lambda_{ct} \}$$

With unsubsidized colleges, $g_{ct} = 0$, all individuals with initial endowments above Λ_{ct} become skilled workers. When the government starts subsidizing colleges at date t , $g_{ct} = g_t > 0$, the private cost of each college student declines, and consequently more individuals enrol to college, $\Lambda_{ct}^{SB} < \Lambda_{ct}$ (SB denotes ‘subsidized’) and A_t increases. Therefore, while the first term in the stock of human capital remains unchanged, the second decreases and H_t drops. Specifically, the stock of human capital at date t that corresponds to the co-existence of universities and colleges, with subsidized colleges, denoted by $H_t^{U+C,SB}$, equals

$$H_t^{U+C,SB} = H_t^{U+C} - m \int_{\Lambda_{ct}^{SB}}^{\Lambda_{ct}} h_{t+1}^l(\omega) d\mu(\omega)$$

Consider now later periods:

$$H_{t+1}^{U+C} = \int h_{t+1}(\omega) d\mu(\omega) + m \int_{\sim A_{t+1}} h_{t+2}^l(\omega) d\mu(\omega)$$

Subsidizing colleges has two effects. First, low-skilled workers join the skilled work force by enrolling to college: A_t increases but $\sim A_t$ decreases by the same number. Since we transfer low-skilled workers to the skilled labor force we obtain that $\int h_{t+1}(\omega) d\mu(\omega)$ increases. Second, fewer individuals induce their children to be low-skilled workers: $\sim A_{t+1}$ decreases (hence A_{t+1} expands, and therefore $\int h_{t+2}(\omega) d\mu(\omega)$ increases). Specifically, the stock of human capital at date $t+1$ that corresponds to the co-existence of universities and colleges, denoted by H_{t+1}^{U+C} , equals

$$\begin{aligned} H_{t+1}^{U+C,SB} &= H_{t+1}^{U+C} + \int_{\Lambda_{ct}^{SB}}^{\Lambda_{ct}} (h_{t+1}^c(\omega) - h_{t+1}^l(\omega)) d\mu(\omega) - m \int_{\Lambda_{ct+1}^{SB}}^{\Lambda_{ct+1}} h_{t+2}^l(\omega) d\mu(\omega) \\ &> H_{t+1}^{U+C} + (B_c - 1 - m) \int_{\Lambda_{ct}^{SB}}^{\Lambda_{ct}} h_{t+1}^l(\omega) d\mu(\omega) \end{aligned}$$

The last inequality is obtained using Eq. (20) and the fact that when colleges are subsidized the set of their students keeps increasing relative to the case of unsubsidized colleges. As a result, the stock of human capital of college-educated

workers keeps declining, or $\int_{\Lambda_{ct}^{SB}}^{\Lambda_{ct}} h_{t+1}^l(\omega) d\mu(\omega) > \int_{\Lambda_{ct+1}^{SB}}^{\Lambda_{ct+1}} h_{t+2}^l(\omega) d\mu(\omega)$.

This implies that $H_{t+1}^{U+C,SB} - H_{t+1}^{U+C} > (B_c - 1 - m) \int_{\Lambda_{ct}^{SB}}^{\Lambda_{ct}} h_{t+1}^l(\omega) d\mu(\omega)$, which is strictly positive

by assumption 3. This process can be continued for all coming dates since we obtained that A_{t+1} also expands. Thus our claim is proved. ■

Proof of Proposition 5: Assume that subsidies are merit-based. Therefore, some students who are accepted to universities, $Z_{t+1}(\omega) > \lambda_t$, are eligible for subsidies as college students, $g_{ct} > 0$, but not as university students, $g_t = 0$. Their parents decide that they will attend a college if

$$y_{t+1}^c(\omega) > y_{t+1}^u(\omega) \Leftrightarrow U_t^c(\omega) > U_t^u(\omega)$$

which implies:

$$(1-\tau)B_c\tilde{\theta}_t(\omega)h_t(\omega)^{\nu}X_t^{\xi}w_{t+1}-(1+r_{t+1})(z^*-g_{ct}) > (1-\tau)B\tilde{\theta}_t(\omega)h_t(\omega)^{\nu}X_t^{\xi}w_{t+1}-(1+r_{t+1})z^*$$

Note that this inequality holds only if condition (a) holds. Moreover it is easy to verify that when (a) holds the set of skilled individuals is given by (23). ■

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