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ABSTRACT

Equal Opportunity through Higher Education: Theory and Evidence on Privilege and Ability*

We model a higher education system that admits students according to their admission signal (e.g., matriculation GPA, SAT), which is, in turn, affected by their cognitive ability and socioeconomic background. We show that subsidizing education loans increases neither human capital stock nor aggregate consumption, but only yields income redistribution mainly among the upper class. We show that the policies aimed at compensating for poor socioeconomic background result in a higher aggregate consumption, as well as income redistribution from top to bottom. We test the model using a unique dataset that includes proxies of socioeconomic background and cognitive ability. Results show that the high school matriculation GPA is a weak predictor of academic achievements. We demonstrate that, while the high school matriculation GPA is explained by proxies of cognitive ability and socioeconomic background, academic GPA is solely explained by cognitive ability proxies. Finally, the lack of a matriculation certificate is associated with a poor socioeconomic background.

JEL Classification: C83, D31, D62, I22, I28, R23

Keywords: higher education, human capital formation, income inequality, socioeconomic background, subsidies

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1. Introduction

The growing importance of human capital in enhancing economic growth, as well as in generating personal income (Barro 1991; Benhabib and Spiegel 1994; Bils and Klenow 2000; Restuccia and Urrutia 2004; Thomas and Zhang 2005; Bound and Turner 2007; Rogers 2008; Acemoglu 2009; Manuelli and Seshadri 2014) and promoting social mobility (Becker and Tomes 1979), has led many governments, especially in the second half of the twentieth century, to adopt policies aimed at expanding their higher education systems (Barr and Crawford 1998; Greenaway and Haynes 2003; Checchi 2006).

Higher education is costly and, therefore, demands for public subsidies are constantly raised (Cellini 2009). From an economic point of view, subsidization is justified, since the positive externalities generated by an investment in higher education are ignored by the individual deciding whether to invest in higher education and to what extent (Bevia and Iturbe-Ormaetxe 2002; Moretti 2004a; Moretti 2004b; Blankenau 2005; Acemoglu and Angrist 1999). However, the public financing of higher education might also have regressive effects, since most students enrolling in higher education belong to upper classes (Fernandez and Rogerson 1995).

Since human capital cannot easily serve as collateral to loans, banks are reluctant to finance investment in higher education. Therefore, potential students from poor backgrounds may face binding credit constraints, resulting in underinvestment in higher education and, therefore, overall lower national income (Galor and Zeira 1993; Carneiro and Heckman 2002; Dynarski 2003; Nielsen, Sørensen, and Taber 2010). One possible solution to the credit constraints is the use of an income-contingent loan program (ICLP) operated by the government.[1] Eckwert and Zilcha (2012) showed that a properly designed ICLP can remedy inefficiencies in the human capital investment process caused by capital market failures. Eckwert and Zilcha (2014) compared uniform and proportional income contingent subsidization of higher education and showed that both yield higher investment in higher education and higher consumption, and produce a more equal income distribution. The Eckwert–Zilcha (EZ) models are based on an implicit assumption of open admission to higher

[1] The use of income-contingent payoffs to rectify some of the credit market failure that prevent investment in higher education is due to Friedman (2009). Today ICLPs for higher education exist in Australia, Sweden, the UK, Chile and other countries (see Chapman 1997; Lleras and Barr 2007; Chapman 2006).

education, namely, each individual acquires higher education if he/she expects a net of tuition fee positive return to the investment in higher education. Nevertheless, most higher education institutions around the world, especially the most prestigious (e.g., US Ivy League universities), are highly selective (Hoxby 2009; Avery and Levin 2010). This selectivity might advantage individuals with high socioeconomic background, who received better secondary schooling (Card and Krueger 1992; Benabou 1996; Cameron and Heckman 2001; Hastings, Justine and Weinstein, 2008).

From a social perspective, the primary purpose of education is to provide equal opportunities. Restrictions on admissions to higher education impede this equal opportunity when the criteria for admission do not adequately account for socioeconomic background. There is often privilege through admission criteria that advantages students from families with high socioeconomic status. In this paper, we use the background of higher education in Israel to show that admission criteria provide returns to privilege rather than students' abilities to succeed in their studies.

We first present a theoretical model of investment in higher education, in which individuals are differentiated by their unobservable innate ability and socioeconomic background. Each individual receives a publicly observable signal (e.g., SAT or matriculation test score) correlated with his/her ability, but also with the socioeconomic background. We show that there is a case for affirmative action, in the form of a lower admission threshold for individuals from a lower socioeconomic background (see also Howell 2010). We also evaluate the effect of a subsidized income-contingent loan for higher education and show that it yields neither higher human capital stock nor higher aggregate consumption. The only effect is income redistribution, mainly among the upper class. We also show that, under restricted admission to higher education, policies aimed at improving the signals (i.e., SAT or matriculation test scores) of lower background individuals yield higher human capital stock and aggregate consumption, and also result in the redistribution of income from the top to the bottom of the income distribution. Along this line, Cameron and Heckman (2001) pointed out that policies aimed at improving family and environmental factors are more likely to be successful in eliminating college attendance differentials than short-term tuitions reduction and family income supplement policies aimed at families with college age children. Fryer and Katz (2013) showed that investment in schooling quality may reduce the persistence of economic and educational inequalities. In addition, Kling, Liebman, and Katz (2007) and Chetty, Hendren, and Katz (2016) showed that neighborhood improvements help reduce physical and mental health inequalities as well as college attendance. In addition, vast literature showed that neighborhood (or nurture) affect cognitive and noncognitive skills, which jointly determine lifetime achievements (Heckman and Rubinstein 2001; Cunha et al. 2006; Cunha and Heckman 2007 ; Heckman 2007; Cunha, Heckman, and Schennach 2010; Heckman and Mosso 2014; Corbin and Heckman 2016).

In the second part of the paper, we empirically test the model. We collected data on academic and high school achievements, as well as a series of proxies for cognitive ability (like the level of Mathematics and English, usage of private tutoring, number of courses per semester etc., as well as the score in a CRT) and socioeconomic background characteristics (the education level of the parents, rooms per capita during high school, socioeconomic ranking of the settlement she / he lived in during high school, etc.). The sample consists of two groups of B.A. students who completed at least half of their academic curricula. The treatment group consists of students from The Open University of Israel (OU), some of whom have full matriculation certificates and some do not. The control group consists of standard university students with a full matriculation certificate. Unlike standard Israeli universities, which screen candidates based on high school matriculation GPA and psychometric test scores, the OU implements an open admission policy, while maintaining high academic standards. Therefore, the OU provides the setting of a unique natural experiment, in which students from relatively low socioeconomic backgrounds (compared with standard university students) not admitted to standard universities due to insufficient matriculation GPA or even lack of a matriculation certificate, face equal academic requirements to their fellow students in standard universities.

By applying a treatment-effect model, we provide statistical evidence supporting the matching between the academic level of the OU and that of standard universities. We show that the high school matriculation GPA is a weak predictor of academic achievements. Consequently, the signals provided by candidates towards academic studies tend to overstate the true gaps in academic achievements. Moreover, the difference across OU students with and without a full matriculation certificate is statistically insignificant. Our results indicate that, while high school matriculation

GPA is consistently explained by cognitive ability and socioeconomic background, academic GPA is solely explained by cognitive ability proxies. A lower probability of obtaining a full matriculation certificate is associated with lower socioeconomic background characteristics. Our econometric analysis provides support for the model's main policy implication of benefits arising from augmenting the resources dedicated to primary and secondary education, particularly in places with lower socioeconomic ranking. The paper proceeds as follows. Section 2 presents the theoretical model. Section 3 provides a brief background on the Israeli higher education system. Section 4 presents the empirical analysis. Section 5 summarizes and concludes the paper.

2. The Model

We consider a two-period model with a continuum of individuals on the interval $[0,1]$ and a single commodity (capital good). In the latter part of the first period, following compulsory education, an individual may contract a loan and make a capital investment in higher education in order to acquire additional skills. Therefore, the capital investment increases the agent's human capital in the second period, when the agent enters the labor market and earns labor income. Labor income depends on the agent's skills or human capital, which is assumed to be observable. In the second period, each individual consumes his net wealth, which is calculated as the difference between his labor income and the loan repayment obligation.

Diversity within the population, denoted by G, is generated by random innate ability a, which affects an agent’s productivity level, and by random background quality b. Abilities are assigned to individuals by nature at birth, i.e., at the outset of the first period. At this time, individual ability is not observable, and is not even known to the agent himself/herself. Therefore, the investment decision in the first period is made under uncertainty. The background is also assigned to individuals by nature, and is known to the individual prior to the investment decision.

An agent may either invest one unit of capital in education or not invest at all. If an individual does not invest, he/she remains unskilled and attains a basic productivity level, $A>0$, in the first period. The basic productivity level A is independent of the agent’s ability but does depend on the level of the aggregate human capital H (i.e., $A=A(H)$, as specified below). If the agent invests, then he/she becomes a skilled worker. In this case, his human capital in the second period is $A(H)+\tilde{a}$, where ability $\tilde{a}$ represents additional productivity due to higher education. We assume that an individual's background does not affect his/her productivity. The random variable $\tilde{a}$ assumes values in the interval $A\in\left[a^1,a^2\right]\subset\mathbb{R}_{++}$. Therefore, the human capital h^i of agent $i\in G$ depends on his/her investment decision x^i and on his/her ability a^i according to:

$$h^i=\begin{cases}A(H)+a^i; & if\ x^i=1\\ A(H) \quad ; & if\ x^i=0\end{cases}. \tag{1}$$

As previously mentioned, in our model, the basic productivity level $A(H)$ is not entirely exogenous, but depends on the aggregate human capital $H:=\int_G h^i di$ in the economy.

Assumption 1: The basic productivity level of unskilled workers depends on the aggregate stock of human capital and satisfies $A'(H)\in(0,1)$ and $A''(H)\leq 0$.

This assumption introduces externality, through which the aggregate stock of human capital affects individual capital formation: unskilled workers are more productive if the economy is endowed with more human capital in the aggregate.

We denote by $\nu(a)$ the density of agents with ability a. From the perspective of an individual in the first period, ability is random, as it is the realization of a random variable with distribution $\nu(\cdot)$. However, there is no aggregate uncertainty in the economy (i.e., the ex-post distribution of abilities across the population is exactly ν).[2]

Each agent receives a publicly observable signal, $y\in Y:=\left[\underline{y},\bar{y}\right]\subset\mathbb{R}$, before he/she makes the investment decision. The signal might be interpreted as a noisy test result, and which is correlated with the agent's ability a^i and background b^i. The random variable $\tilde{b}$ takes two possible values: $b\in B:=\{b_1,\ b_2\}\subset\mathbb{R}$, where $b_2>b_1$

[2] See proposition 2 in Feldman and Gilles (1985) for a similar modeling technique.

with posterior probability function $p(\tilde{b})$. We assume that $\operatorname{cov}(\tilde{a},\tilde{b})=0$ and $\nu(\tilde{a}|b)=\nu(a)\ \forall\ b$, that is, the background affects the signal created by an individual, but does not affect innate ability. In reality, many higher education institutions screen their candidates by using high school grades, matriculation examinations, SAT tests, etc. Nevertheless, screening tools are noisy, that is, individuals with the same ability a receive different signals, which are, however, correlated with the agent's ability and background.

We denote by $\nu_{a,b_i}(y)$ the density according to which signals are distributed across agents with ability a and background b_i (i=1,2). The signals are distributed across the entire population with background b_i according to $\mu_{b_i}(y)=\int_A \nu_{a,b_i}(y)\ \nu(a)da$, where $\nu(a)$ is the density of agents with ability a. If $\nu_{y,b_i}(a)$ denotes the density of the conditional distribution of $\tilde{a}$ given signal y of individuals with background b_i, the average ability of all agents with background b_i who received signal y is $\bar{a}_{y,b_i} := \int_A a\nu_{y,b_i}(a)da$.

For convenience, we assume that the strict monotone likelihood ratio property (MLRP) holds as follows.

Assumption 2:

a) The signals are ordered in such a way that $y_b' > y_b$ implies that the posterior distribution of abilities conditional on background b, y_b', dominates the posterior distribution of abilities conditional on b, y_b, in the first-degree stochastic dominance. Formally, $\int_A \varphi(a)\ \nu_{y',b}(a)da > \int_A \varphi(a)\ \nu_{y,b}(a)da$ holds for any (integrable) strictly increasing function φ.

b) Signals are ordered in such a way that, given a certain ability level, the posterior distribution of signals among agents with background level b_2 stochastically dominates the posterior distribution of signals among agents with background level b_1 in the first-degree stochastic dominance.

Formally, $\int_Y \varphi(y)\ \nu_{a,b_2}(y)dy > \int_Y \varphi(y)\ \nu_{a,b_1}(y)dy$ holds any (integrable) strictly increasing function φ.[3]

We also assume the following.

Assumption 3: For any two signals $y > y'$,

$$(3a) \qquad \frac{(\tilde{a}|y)}{\bar{a}_y} \succ_{ssd} \frac{(\tilde{a}|y')}{\bar{a}_{y'}} \quad \forall b$$

and

$$(3b) \qquad \frac{(\tilde{b}|y)}{\bar{b}_y} \succ_{ssd} \frac{(\tilde{b}|y')}{\bar{b}_{y'}} \quad \forall a \quad .$$

In economic terms, condition (3a) means that the (normalized) abilities of agents with high signals are less dispersed in the sense of a mean preserving spread (MPS) then the abilities of agents with low signals, given a certain background, b. Assumption (3b) implies that the (normalized) background levels of agents with high signals are less dispersed in the sense of a mean preserving spread (MPS) then the backgrounds of agents with low signals.

All agents are risk-averse expected utility maximizes with a vNM-utility function $u(\cdot)$. However, our results are largely independent of individual preferences. At this stage, therefore, there is no need to specify the vNM-utility functions beyond assuming that marginal utility is strictly positive and non-increasing.

Production is carried out by competitive firms in the second period according to a constant returns to scale production technology, which uses physical capital K and human capital H as factors of production. Each individual i inelastically supplies l units of labor in this period, making his effective labor supply lh^i and his labor income wlh^i, where w denotes the wage rate (price of one efficiency unit of labor). For simplicity, we adopt the normalization $l = 1$.

[3] For further details, see Milgrom (1981).

Assumption 4: The aggregate production function $F(K,H)$ is concave, homogeneous of degree 1, and satisfies $F_K > 0$, $F_H > 0$, $F_{KK} < 0$, $F_{HH} < 0$.

Our economy represents a small country in a world where physical capital is internationally mobile, while human capital is immobile. This specification is in line with the empirical observation that the globalization process has promoted the international mobility of physical capital far more than that of labor. International capital mobility in combination with a small country assumption implies that the interest rate r is exogenously given. We assume that physical capital fully depreciates in the production process. Hence, marginal productivity of aggregate physical capital equals $R = 1 + r$. Given the aggregate stock of human capital H, the stock of physical capital K adjusts such that

$$F_K(K,H) = R \tag{2}$$

is satisfied. Equation (2), in combination with Assumption 4, implies that K/H is determined by the gross international rate of interest R. The wage rate, which equals the marginal product of effective labor, $w = F_L(K/H, 1)$, is also determined given R.

2.1. The Social Optimum

Before turning to the agents' decision problems, we characterize the social optimum attained by a central planner in the analyzed economy. We consider a case where the background becomes public knowledge. Following Eckwert and Zilcha (2012), when investment decisions are made, agents differ by their signals and backgrounds. We refer to the set of all agents coming from background b_i with the same signal y as "signal group y_i." At the social optimum, the aggregate consumption C is maximized:

$$\begin{aligned} C_{\max} &= \max_{y_1', y_2'} C(y_1', y_2'), \\ C(y_1', y_2') &:= A(H)w + \int_{y_1'}^{\bar{y}} \left((\bar{a}_{y,b_1})w - R\right)\mu_1(y)\,dy + \int_{y_2'}^{\bar{y}} \left((\bar{a}_{y,b_2})w - R\right)\mu_2(y)\,dy. \end{aligned} \tag{3}$$

Note that, since the central planner knows the average ability of an individual with signal y and background b, following assumption 3, the central planner sets two threshold signals, one for each background level. Investment takes place in background group b_i for all signals $y \geq y_i'$. The return to investment in signal group y_i is $\bar{a}_{y,b_i} w - R$, which is strictly increasing in y by MLRP. Therefore, if signal group y_i invests in higher education at the social optimum, then any signal group $\tilde{y}_i > y_i$ also invests. This means that the set of all signals in background level b_i, for which investment occurs in the corresponding signal groups, is of the type $[y_i', \bar{y}]$. This observation justifies the representation in (3).

The aggregate human capital is

$$H = A(H) + \int_{y_1'}^{\bar{y}} \bar{a}_{y,b_1} d\mu_1(y) + \int_{y_2'}^{\bar{y}} \bar{a}_{y,b_2} d\mu_2(y), \tag{4}$$

and

$$\frac{\partial H}{\partial y_1'} = \frac{-\bar{a}_{y_1',b_1}}{1 - A'(H)} < 0, \tag{5}$$

$$\frac{\partial H}{\partial y_2'} = \frac{-\bar{a}_{y_2',b_2}}{1 - A'(H)} < 0 \tag{6}$$

The first best socially optimal cutoff levels, y_1^*, y_2^*, satisfy the necessary and sufficient first-order-conditions for the problem in (3). By deriving equation (3) with respect to y_1' and y_2', and using equations (5) and (6), we obtain the sufficient first-order-conditions for the problem in (3) as:

$$-\bar{a}_{y_1^*,b_1} w \left[\frac{A'(H)}{1 - A'(H)} \right] + R = 0, \tag{7}$$

$$-\bar{a}_{y_2^*,b_2} w \left[\frac{A'(H)}{1 - A'(H)} \right] + R = 0. \tag{8}$$

Subsequently, we consider the second order conditions: by MLRP, $\bar{a}_{y',b_i}$ is increasing in y' for a given b_i by assumption 1, $A'(H)$ is increasing in y', and

$\frac{A'(H)}{1-A'(H)}$ is increasing in y' for a given b_i. Therefore, $\frac{\partial^2 C(y'_1, y'_2)}{\partial (y'_1)^2}$, $\frac{\partial^2 C(y'_1, y'_2)}{\partial (y'_2)^2} < 0$. Moreover, an increase of y'_2 in equation (8) affects only $\frac{A'(H)}{1-A'(H)}$.

Therefore, we may assume that $\frac{\partial^2 C(y'_1, y'_2)}{\partial^2 y'_1} \frac{\partial^2 C(y'_1, y'_2)}{\partial^2 y'_2} - \left[\frac{\partial^2 C(y'_1, y'_2)}{\partial y'_1 \partial y'_2} \right]^2 > 0$ and, thus, the second order conditions holds.

Combining equations (7) and (8) yields:

$$\bar{a}_{y_1^*, b_1} = \frac{R/w}{1 + \frac{1}{(1/A'(H)) - 1}} < \frac{R}{w}, \tag{9}$$

$$\bar{a}_{y_2^*, b_2} = \frac{R/w}{1 + \frac{1}{(1/A'(H)) - 1}} < \frac{R}{w}. \tag{10}$$

Equations (9) and (10) show that, at the optimum, the average marginal return to education is below R due to the externality.

From equations (9) and (10), and assumption 2(b), we deduce that $y_2^* > y_1^*$. As such, the social optimum requires affirmative action, i.e., at the optimum, the threshold signal for agents with high background should be higher than the threshold signal for agents with lower background to compensate the latter for their noisy signals.

2.2. Individual Behavior, Equilibrium, and Restricted Admission

Before discussing individual decision under an effective restricted admission, we first consider the individual's choice under open admission.

2.2.1. Open Admission to Higher Education

Consider an individual $i \in G$ who faces the decision whether to acquire higher education, given R and w. In the first period, the individual decides whether to invest in higher education while his/her ability is still unknown (we assume that an individual's background is privately known and not publicly observable).[4] This decision is based on the noisy information about the agent's ability conveyed by his/her signal y^i and background b^i. We assume that a financial institution (student loans institution, SLI) offers income-contingent loan contracts to all individuals willing to invest in higher education. In doing so, the SLI uses publicly observable signals as a screening device, but takes into account the agent's background level, i.e., different terms of payment apply to individuals in different signal and background groups. If agent i decides to invest one unit of capital in the first period, he/she receives a loan of one unit with payment obligation $Ra^i / \bar{a}_{y^i,b^i}$ in the second period. The net income from this investment is

$$a^i \left[w - \frac{R}{\bar{a}_{y^i,b^i}} \right],$$

where $\bar{a}_{y^i,b^i}$ is the average ability of agents of background $b \left(b \in \{b_1, b_2\} \right)$ who received signal y^i.

Agent i would find the investment in higher education beneficial if and only if his/her signal satisfies

$$\bar{a}_{y^i,b^i} w \geq R \quad . \tag{11}$$

Observe that the SLI makes no profits. It just breaks even as it provides loans that share income risks, on fair terms within each signal-background group. We denote the signal for which (11) holds with the equality for an agent with background b_j $(j = 1,2)$ by $\hat{y}_j$:

$$\bar{a}_{\hat{y}_j,b_j} w = R . \tag{12}$$

Under open admission, each agent chooses investment in education according to (11). Due to assumption 2(b), it is easily verified that $\hat{y}_1 < \hat{y}_2$, that is, individuals with lower background find the return from an investment in higher education positive for lower signals.

[4] This assumption implies that higher education authorities screen students only according to their publicly observable signals (e.g., SAT) and do not consider socioeconomic background.

To consider the effect of an effective restriction on the admission to higher education, we assume that, in each background group, there are individuals who find investment in higher education beneficial; therefore, we assume that $\hat{y}_j < \bar{y} \ (j=1,2)$.

2.2.2. Restricted admission to higher education

From now on, we assume that a restricted admission policy is being applied. We denote the cutoff level to higher education by y'', that is, only agents who received a signal $y \geq y''$ are entitled to study at higher education institutions. We further assume that the higher education institutions set the admission threshold signals without considering candidate background.[5] For real-life compatibility, we assume that $\hat{y}_2 < y'' < \bar{y}$, i.e., the restriction affects both background groups. Note that, according to our assumption on the restriction, some agents that find investment in higher education beneficial will not be able to acquire higher education.

Due to the restricted admission, equation (11) holds with strict inequality for all individuals who received a signal $y \geq y''$. Therefore, they all invest in higher education. We denote by $Y_e = [y'', \bar{y}] := \{y \in Y | x(y) = 1\}$ the set of all individuals who invest in higher education.

The aggregate stock of human capital is

$$H = A(H) + \int_{y''}^{\bar{y}} \bar{a}_y \, d\mu(y), \tag{13}$$

and aggregate consumption is

$$C = A(H)w + \int_{y''}^{\bar{y}} (\bar{a}_y w - R) \mu(y) \, dy \cdot \tag{14}$$

At equilibrium, each agent who is endowed with signal level $y \geq y''$ invests in higher education, factor markets clear, and aggregate human capital follows accumulation equation (13).

[5]Although lower background can be correlated with observable racial characteristics or neighborhood not all factors that affect individuals' socioeconomic background are observable.

Definition 1: Given the international gross interest rate $R = 1 + r$ and the admission threshold y'', an equilibrium consists of a vector $(w, K, H) \in \mathbb{R}_+^3$ such that

(i) $\bar{a}_{y^i, b^i} w > R \ \forall \mathrm{y} \geq \mathrm{y}'', \forall b_i$;

(ii) The aggregate stock of human capital, H, satisfies (13);

(iii) The factor prices satisfy $w = F_L(K/H, 1)$ and $R = F_K(K/H, 1)$.

The equilibrium in definition 1 always exists and it is unique: for a given $R > 0$, the second equality in (iii) uniquely determines K/H. For a given K/H, the first equality in (iii) uniquely determines wage rate w. Finally, aggregate human capital H is determined by equation (13). At equilibrium, the process of aggregate human capital formation in inefficient; therefore, the economy underinvests in higher education.

Inefficiency stems from several reasons:

- At the social optimum, each beneficial investment in higher education is carried out; nevertheless, under restricted admission, some privately worthwhile investments will not be carried out.
- At the optimum, the positive externalities of education on aggregate human capital must be considered; nevertheless, each individual ignores such externalities.

In the next proposition, we establish that the restricted admission policy benefits mainly high background individuals.

Proposition 1: $Prob(y \geq y'' | b_2) > Prob(y \geq y'' | b_1)$.

Proof: See the appendix A.

We assume that signals are affected by the individuals' ability and background, both not observable by higher education institutions. Following proposition 1, we assume that, from the point of view of the higher education institutions, the signals predict ability, i.e.:

Assumption 5: $\forall\, y \in [y'', \bar{y}],\, y' > y \Rightarrow \bar{a}_{y'} > \bar{a}_y$.

That is, background does not distort the signal transmitted by the ability to such an extent that it makes the use of the signal (e.g., SAT scores) meaningless.

2.3. Higher Education Subsidization

The welfare loss resulting from underinvestment in higher education, especially among agents with lower background, raises the question of whether (and how) the government should subsidize individual educational investments in order to stimulate human capital formation. When addressing this question, we need to consider that a subsidy might not only affect investment decisions, but may also have implications for the distribution of incomes across signal-background groups.

In the following section, we consider several policy tools aimed at subsidizing higher education. First, we analyze the effect of a proportional subsidy to higher education on aggregate human capital and income distribution. We assume that the government supports each student with a subsidy that is proportional to his repayment obligation. The government finances the subsidy by a uniform tax rate levied on the net extra income resulting from acquiring higher education. Second, we consider the case of a uniform subsidy financed by a uniform tax on the extra gain from higher education. Throughout the discussion, we assume that the costs of acquiring higher education are tax deductible.

Assume that the government subsidizes the repayment obligation of each individual who invests in higher education by fixed proportion $s > 0$, that is, an agent with signal y and background b pays back $\frac{Ra}{\bar{a}_{y,b}}(1-s)$ if his/her ability turns to be a. To finance the costs of subsidization, the government levies a uniform tax rate τ_p on the net gains from higher education.

An agent in signal group y with background b and ability a who invests in higher education realizes a net return

$$(1-\tau_p)\left[\; a\left(w - \frac{R(1-s)}{\bar{a}_{y,b}} \right)\right] \tag{15}$$

on his investment. The agent chooses to invest in higher education if his/her net return from investing in higher education in non-negative regardless of his/her preferences; nevertheless, due to the admission threshold, the net return is strictly positive for all agents with signals $y \geq y''$, i.e.,

$$w\bar{a}_{y,b} > R(1-s). \tag{16}$$

We denote the set of individuals who attend higher education after subsidization by Y_e^p.

The tax rate τ_p is determined by the government budget constraint, which requires that the total tax revenues equal the total subsidy payments:

$$\begin{aligned} &\tau_p \int_{Y_e^p} \left[w\bar{a}_y - R(1-s) \right] d\mu(y) = Rs\mu\left(Y_e^p\right), \\ &\Leftrightarrow \frac{\tau_p}{1-\tau_p} \int_{Y_e^p} \left[w\bar{a}_y - R \right] d\mu(y) = Rs\mu\left(Y_e^p\right) \quad . \end{aligned} \tag{17}$$

The subsidization policy (s, τ_p) is said to be feasible if it satisfies budget constraint (17). By comparing (11) and (16), we find the following.

Proposition 2: The introduction of tax-financed proportional subsidy for investment in higher education (s, τ_p), $s > 0$ does not lead to a higher investment in higher education and thereby does not lead to higher stock of aggregate human capital.

Proof of proposition 2: See the appendix A.

According to proposition 2, after the introduction of a proportional subsidy, the set of individuals who are able to attend higher education remains unchanged, namely $Y_e = Y_e^p = \left[y'', \bar{y}\right] := \left\{ y \in Y \middle| x(y) = 1 \right\}$. Although more individuals find the investment in higher education attractive, the admission threshold enables only individuals whose signal is equal or greater than y'' to attend higher education. The subsidy does not alter the signal and, therefore, does not alter the set of individuals who study at higher education institutions.

Subsequently, we study the effect of the proportional subsidy on the inequality of the income distribution across signal groups. Our analysis focuses on the distribution of mean income in the various signal groups. This distribution is identical to the distribution of expected incomes, conditional on ex-interim signals, i.e., after signals are observed but before individual incomes are known. We call the distribution of mean income conditional on signals "interim income distribution." If the government does not subsidize higher education, average income $I(y)$, in the signal group y is:

$$I(y) = \begin{cases} A(H)w\,;\ y < y'' \\ \left(A(H) + \bar{a}_y\right)w - R\,;\ y \geq y'' \end{cases} . \tag{18}$$

Under a policy of proportional subsidy (s, τ_p), the average income $I_p(y)$ in signal group y is as follows:

$$I_p(y) = \begin{cases} A(H_p)w;\ y \notin Y_p \\ A(H_p)w + (1-\tau_p)\left[\bar{a}_y w - R(1-s)\right];\ y \in Y_p \end{cases} . \tag{19}$$

Note that $I(y)$ and $I_p(y)$ are both monotone increasing in y. We say that an interim income distribution $\hat{I}(y)$ is more socially desirable than another income distribution $\bar{I}(y)$ if the former distribution dominates the latter one in the generalized Lorenz sense [see Shorrocks (1983)]. Ramos, Ollero, and Sordo (2000) have shown that two income distributions can be ordered in the generalized Lorenz sense if they differ by a mean-decreasing spread. Our subsequent analysis is therefore based on the following criterion, which implies the generalized Lorenz order [for more details see Theorem 2.1 in Ramos, Ollero, and Sordo (2000)],

Definition 2: Let $\hat{I}(y)$ and $\bar{I}(y)$, $y \in Y$, be two distributions of the average income across signal groups. We say that $\hat{I}(y)$ is socially more desirable than $\bar{I}(y)$ if

(i) the inequality

$$\int_Y \hat{I}(y)\,d\mu(y) \geq \int_Y \bar{I}(y)\,d\mu(y) \tag{20}$$

holds and

(ii) there is some $\hat{y}$ in Y such that

$$\hat{I}(y) \geq \bar{I}(y) \quad for \quad y \in [\underline{y}, \hat{y}] \quad and \quad \hat{I}(y) \leq \bar{I}(y) \, for \quad y \in (\hat{y}, \bar{y}] \tag{21}$$

is satisfied.

According to definition 2, the transition from an interim income distribution $\bar{I}(y)$ to a more socially desirable interim income distribution $\hat{I}(y)$ implies an increase of aggregate income (and therefore a higher aggregate consumption), as well as redistribution of expected incomes from top to bottom in a special sense: all signal groups that achieve income gain under the transition from $\bar{I}(y)$ to $\hat{I}(y)$ have a lower income than the signal groups that suffer income loss (if any).

Proposition 3: The introduction of a proportional subsidy leads to a more equal interim income distribution.

Proof of proposition 3: See the appendix A.

Assume that the government subsidizes higher education costs with a uniform subsidy $s > 0$ given to each agent who enrolls into higher education. Again, the subsidy is financed by a uniform tax rate levied on the net extra gain from higher education. Under open admission, the cutoff signal above which the investment in higher education nets gain is higher under uniform subsidy than under proportional subsidy.[6] Nevertheless, under restricted admission, the effects of a uniform subsidy are identical to those of a proportional subsidy, although the number of individuals who find the investment in higher education worthwhile but do not pass the admission threshold is greater under a proportional subsidy than under a uniform one.

In the subsequent section, we consider a policy aimed at improving the background distribution.

2.4. Signal Improvement Policy

Assume that the government initiates a policy aimed at increasing the background level of a fixed proportion $\beta \in (0,1)$ of the lower background population from background level b_1 to background level b_2. The cost of the background shift policy

[6] See Eckwert and Zilcha (2014).

is $c(\beta)$, where $c' > 0$ and $c'' > 0$. We also assume that the government randomly samples the population for the background improvement policy such that the distribution of abilities in the sample is identical to that of the population. In reality, this policy manifests as higher investment in elementary and secondary schools located in poor neighborhoods or supplementary schooling to children with low socioeconomic backgrounds. The government also levies a flat tax rate τ_b on the extra gain from higher education to finance the investment in lower background individuals. The tax rate is endogenous and chosen to balance the investment budget. An agent in signal group y and background b who invests in higher education realizes a net return of

$$(1-\tau_b)\left[aw-\frac{Ra}{\bar{a}_{y,b}}\right]. \tag{22}$$

Therefore, we can establish that each individual that receives a signal $y \geq y''$ will invest in higher education.

We can establish that, as a result of the signal improving policy, more individuals obtain the critical signal as follows.

Proposition 4: The policy of shifting a proportion β of the young lower background population from background level b_1 to background level b_2 results in an increase of investment in higher education.

Proof of proposition 4: See the appendix A.

The signal improvement policy ameliorates the signals of the lower background population; therefore, the distribution of signals among this population is akin to that of the high background population. As a result, more individuals achieve the admission threshold and invest in higher education.

The tax rate $\tau_b \in (0,1)$ is determined by the government budget constraint, which requires that the total tax revenues equal the total costs:

$$\tau_b \int_{Y_e} \left[w\bar{a}_y - R\right] d\mu(y) = c(\beta). \tag{23}$$

A policy (τ_b, β) is said to be feasible if it satisfies budget constraint (23). The signal improvement policy reduces underinvestment in higher education among the lower background individuals, and it can even result in overinvestment. We use $B \subset (0,1)$ to denote the set of all feasible β that do not lead to overinvestment. Particularly, any $\beta \in B$ increases aggregate consumption in (3).

Subsequently, we examine the effect of the government's policy on the interim income distribution.

Under a policy of background improvement (τ_b, β), the average income $I_b(y)$ in signal group y is:

$$I_b(y) = \begin{cases} A(H_b)w & ;\ y \notin Y_e \\ A(H_b)w + (1-\tau_b)\left[\bar{a}_y w - R\right] & ;\ y \in Y_e \end{cases}, \tag{24}$$

Proposition 5: The introduction of a signal improvement policy $\beta \in B$ leads to a socially desirable income distribution.

Proof of proposition 5: See the appendix A.

In the next subsection, we introduce the empirical examination of the model.

2.5.Research Hypotheses for Empirical Testing

Several research hypotheses are derived from the theoretical model:

a) Matriculation GPA is positively correlated with academic achievement.
b) Academic GPA is mainly affected by cognitive ability rather than socioeconomic background.
c) Matriculation GPA is positively correlated with the socioeconomic level.

Evidence that supports the three hypotheses indicates that signal improvement policy (i.e., a policy with a positive effect on matriculation GPAs) increases the number of individuals that acquire higher education and, thus, has a positive effect on aggregate consumption as well as the income distribution.

3. Empirical Analysis

3.1. Descriptive Statistics: Academic and Matriculation GPA

We collected data on academic and high school achievements, as well as series of proxies for cognitive ability and socioeconomic background characteristics. The data were collected from two identical surveys conducted among OU and standard university students who completed at least half of their academic requirements. Unlike standard research universities that admit candidates based on matriculation certificate GPA (on a scale of 55–120) and psychometric grade (on a scale of 200–800), the OU implements an open admission policy while maintaining high academic standards. Consequently, the OU provides the setting of a natural experiment of a system that removes the required signal provided by candidates as admission criteria.

The first survey was conducted in OU centers across Israel and included 718 subjects. This sample was drawn from a population of 11,539 OU students.[7] The second survey was conducted among 513 students of standard research universities. The students were asked a series of questions regarding their academic studies. A second group of questions referred to their high schooling. Finally, they were asked a series of economic and socioeconomic background questions. That is, our sample is unique in providing information about the sampled students during high school and university studies. Table 1 displays descriptive statistics on matriculation GPAs, university GPAs, and features of the matriculation certificate. Out of the 1,231 participants in the surveys, 718 participants (58.33%) were OU students, and 513 (41.67%) standard universities students. The descriptive statistics are stratified by entitlement to full matriculation certificates. The left column shows descriptive statistics of subjects who are not entitled to a matriculation certificate (and, thus, do not meet the elementary requirements for registration at standard universities),[8] and the middle (right) column displays descriptive statistics of OU (standard universities) students who are entitled to a matriculation certificate.

[7] The total number of registered OU students equals 48,000, where only less than one-quarter completed at least half of their academic studies. This provides further evidence to the high level of OU academic education.

[8] According to the Statistical Abstract of Israel 2015 (published by the Central Bureau of Statistics), 91.1% of those who lack full matriculation certificates did not acquire higher education.

Out of the 718 OU respondents to the survey, 615 (85.65%) are entitled to the full matriculation certificate (FULL_MATRICULATION).[9]

The matriculation GPA of 615 OU respondents with full matriculation certificates equals 88.33 points (MATR_GPA). The corresponding figure for the 513 standard universities respondents is significantly higher (at the 1% significance level) at 102.44 points.

The academic GPA of OU respondents who have (who do not have) a full matriculation certificate equals 81.71 points (82.02 points) (ACADEMIC_GPA). The difference of -0.31 is statistically insignificant. Table 2 shows that this result also remains robust when academic achievements are segmented across faculties.

Table 1 and the upper part of Table 2 indicate that the average academic GPA of standard university respondents is significantly higher than that of OU respondents with full matriculation certificates (at the 1% significance level) and equals 84.80 points (compared with 81.71 points). Nevertheless, stratification by faculty yields mixed results (in terms of statistical significance). A significant gap (at the 1% significance level) is observed in social science (85.92 points compared with 83.40 points) and economics and management (84.69 points compared with 81.00 points). On the other hand, the gap is statistically insignificant in humanities (85.11 points compared with 83.31 points) and marginally significant at the 10% significance level in exact sciences (84.28 points compared with 82.34 points). The lower part of Table 2 shows that, in contrast to the matriculation GPA, the differences in academic GPA across faculties and universities are statistically insignificant.

The psychometric grade (the equivalent of SAT in the United States) is one of the signals provided by candidates and used as admission criteria in standard universities. OU students are not required to provide any signal in order to be accepted. Consequently, a large share of OU students did not take the psychometric exam. Table 1 indicates that 100% of the 513 standard university respondents reported their psychometric grades. Out of the 615 (103) OU respondents with (without) full matriculation certificate only 54.87% (23.30%) reported their psychometric grades.

[9] The figures in our OU sample (in all categories) are insignificantly different from the figures obtained from unpublished internal OU reports (available to us) relating to the full population of students who completed at least 50% of their academic requirements for a bachelor degree.

The difference between groups is statistically significant at the 1% significance level. The psychometric grade is on a scale of 200 to 800 points. The average reported grade of OU respondents with (without) full matriculation certificate is 574.52 points (563.83 points) and the difference is statistically insignificant. The average reported grade of standard universities (OU) respondents with full matriculation certificates is 667.48 points (574.52 points) and, as anticipated, the difference is statistically significant at the 1% significance level. Given the self-selection associated with the report of psychometric grades, we employ only the matriculation GPA as an explanatory variable in the subsequent analysis. However, an analysis that incorporates the psychometric grade as an additional explanatory variable is available upon request. The results of this analysis indicate that matriculation GPA better explains the academic GPA than the psychometric grade among both standard and OU respondents.

The grades in Mathematics and English provide important signals for standard universities; therefore, we use the level in Mathematics and English in the matriculation exams as proxies for cognitive ability.[10] Column 2 in Table 17 and Table 18 (see appendix B) show that OU students with high level in Mathematics and English in the matriculation exams (5 points level) achieved significantly higher academic grades (see also correlation martices in Table 20 and Table 21).[11] Additionally, as expected, the tables show that the level in Mathematics and English in the matriculation exams is positively correlated with the matriculation average grade (due to the bonus).

Table 19 (see appendix B) shows that, despite the lack of admission criteria, OU students use their matriculation achievements to sort themselves into faculties.

3.2. Matriculation GPAs as Predictors of University GPAs

The objective of this section is twofold. First, we provide statistical evidence supporting the use of matriculation GPA as an admission criterion. Second, the results support the hypothesis that the academic level of the OU is similar to that of standard universities.

[10] Kimhi and Horovitz (2015) estimated that the returns associated with studying high-level Mathematics at high school (5 points level) equal 10%.

[11] The matriculation exams in Mathematics and English are classified into points (3–5) according to the level of questions and scope of material. Universities awarded at the time of the survey (2013) bonus of 10 points to the grade in an exam at a 4 points level and 20 points for an exam in a 5 points level.

If matriculation GPA is a perfect predictor of academic GPA, we can perfectly predict success in academic studies solely based on this criterion. Therefore, both academic and matriculation GPA provide the same proxy for ability. Figure 1 and Figure 2 compare the kernel densities of normalized academic and matriculation GPAs of standard universities and OU students with a matriculation certificate. The normalized values are obtained by transforming values to the standard normal distribution. The objective is to eliminate the different scaling of academic and matriculation GPA. The distributions of academic and matriculation GPAs among OU respondents are symmetric.[12] The skewness of ACADEMIC_GPA and $100\cdot$ (MATR_GPA/120) is 0.07 and 0.10 respectively (see Table 13 in appendix B).[13] For both distributions, the null hypothesis of symmetrical distribution (i.e., skewness equals zero) is not rejected (calculated p-values of $47.75\cdot 10^{-2}$ and $32.43\cdot 10^{-2}$).[14] Asymptotic symmetry and marginal homogeneity (Stuart-Maxwell) tests are designed to examine whether the frequency matrix of the joint density distribution of $100\cdot$ (MATR_GPA/120) and ACADEMIC_GPA (see Table 14 at appendix B) is symmetrical and whether the marginal probabilities of each category are equal (i.e., the relative frequencies to obtain 50–59, 60–69, 70–79, 80–89, 90–99 points in matriculation and academic GPAs scaled to 0–100 points are equal). Rejections of the null hypotheses imply that a matriculation GPA is not a good predictor of academic GPA. As expected from an institute with an open admission policy, both tests reject the null hypothesis of symmetry and equality of marginal probabilities at the 1% significance level. The calculated Chi-squared value of the symmetry (marginal homogeneity) with nine (four) degrees of freedom is 294.78 (271.57).

The distribution of matriculation GPA among standard universities students (Figure 2) reflects the selectivity of standard universities. This distribution is clearly skewed to the left, implying a high frequency of high matriculation GPA above 100 points. The skewness of ACADEMIC_GPA and $100\cdot$(MATR_GPA/120) is -0.41 and -0.84, respectively. For both distributions, the null hypothesis of symmetrical distribution (i.e., skewness equals zero) is rejected at the 1% significance level (see

[12] Out of the sample of 615 OU students with full matriculation certificates, only 17.07% achieved matriculation GPA above 100 points (on a scale of 0–120). For standard universities students, the equivalent percent rises to 70.57% (out of 513 respondents).

[13] The multiplication of MATR_GPA by (100/120) is designed to enable a comparison to ACADEMIC_GPA.

[14] Note that the Kolmogorov-Smirnov test rejects the null hypothesis of equality of distributions.

Table 15 in appendix B). The asymptotic symmetry and marginal homogeneity (Stuart-Maxwell) tests do not reject the null hypothesis of symmetry and equality of marginal probabilities (see Table 16 in appendix B). The calculated Chi-squared value with eight (four) degrees of freedom is 4.55 (3.72). The calculated p-value is 0.71 (0.44). These outcomes also support hypothesis (a). As such, they support the use of matriculation GPA as a screening mechanism by standard universities.[15]

We test the correlation between academic and matriculation GPA by applying the following model separately on the group of OU respondents with full matriculation certificates and standard university respondents:

$$ACADEMIC\_GPA = \alpha_i + \beta_i (MATR\_GPA - 60) + u_i , \qquad (25)$$

where α_i, β_i are parameters with $i = 1, 2$, where 1 represents the group of OU respondents with full matriculation certificates and 2 the group of standard university respondents; and u is the random disturbance term. Given the definition of the independent variable in terms of (MATR_GPA-60), the constant terms are interpreted as the projected academic GPA for a matriculation GPA of 60 points. The β parameters are interpreted as the projected increase in academic GPA resulting from a one-point increase in matriculation GPA. We examine whether the matriculation GPA is a good predictor of academic GPA by conducting an efficiency test. If the matriculation GPA serves as a perfect predictor, the projected increase in academic GPA associated with a one-point increase in matriculation GPA would be exactly one point. Given the different scales (academic GPA: 0–100 points, matriculation GPA: 0–120 points), the constant term should be -20 points (so that the projected academic GPA for individual with matriculation GPA of 120 points would be 100 points). Therefore, the null hypothesis to be examined is $\alpha_i = -20$ and $\beta_i = 1$.[16]

Figure 3 displays the projected ACADEMIC_GPA regressed against MATR_GPA, separately for OU respondents with full matriculation certificates and standard

[15] We conducted the same test when PSYCH_GRADE is employed as the predictor of ACADEMIC_GPA. The results (available upon request) show that PSYCH_GRADE is not a good predictor of ACADEMIC_GPA.
[16] A similar test was carried out by Smith, Suchanek, and Williams (1988).

university students.[17] Table 3 displays the regression analysis of academic GPA as a dependent variable and (MATR_GPA-60) as an independent variable. The lower part of the table clearly demonstrates a rejection of the efficiency hypothesis ($\alpha_i = -20$ and $\beta_i = 1$) for both groups. Further results indicate that, given the same minimal baseline matriculation GPA of 60 points, the projected academic GPA among OU respondents with full matriculation certificates is lower and equals 76.82 points (compared with 82.02 points among standard university students). The 5.20 points difference is statistically significant at the 1% significance level. On the other hand, a one-point increase in the matriculation GPA is associated with a higher increase in academic GPA among OU respondents with full matriculation certificates compared with the standard university respondents (0.17 points compared with only 0.07 points). The 0.10 difference is statistically significant at the 5% significance level. The beta coefficient is obtained by normalizing the dependent and independent variables to the standard normal distribution. The objective is to scale both variables to the same unit for a better comparison of coefficients across groups. The beta coefficient obtained from the regression applied to the group of OU respondents with full matriculation certificates equals 0.28 (compared with only 0.08 for standard university respondents).

The results demonstrate that a 100% increase in the matriculation GPA of OU respondents (from 60 points to 120 points) is reduced to only a 13.28% gap in projected academic GPA (from 76.82 points to 87.02 points). In this context, Liberman and Tversky (1996) pointed out, that projected values (generated after removal of random components affecting performance) provide better approximations of subjects' cognitive abilities. Consequently, the signals provided by candidates for academic studies (via matriculation certificates) tend to overstate the real gaps

[17] To provide a formal justification for the linear model choice, we conducted a Box Cox test separately on each group, based on the following specification (see, for example, Kmenta 1997 pp. 517–526): $\frac{(ACADEMIC\_GPA/100)^{\lambda}-1}{\lambda} = \alpha + \beta \frac{(MATR\_GPA/100)^{\lambda}-1}{\lambda} + u$ (α, β, λ are parameters and u is the random disturbance term). For the group of 615 OU respondents with full matriculation certificates, we cannot reject the null hypothesis that the linear specification best fits the data ($H_0 : \lambda = 1$), where the calculated LR Chi-square statistic with one degree of freedom is 1.14. For the group of 513 standard university respondents, we reject the null hypothesis that the linear specification best fits the data ($H_0 : \lambda = 1$), where the calculated LR Chi-square statistic with one degree of freedom is 14.82. However, compared with $H_0 : \lambda = 0$ and $H_0 : \lambda = -1$, the power of the test is the lowest for the linear specification (respective LR Chi-square statistics with one degree of freedom of 36.39 and 68.79).

between cognitive abilities.[18] These outcomes provide further support to hypothesis (a). Put differently, matriculation GPAs are weak predictors of academic achievement, but have some explanatory power.

To further examine the predictive power of the matriculation certificate in explaining academic achievements across groups, we use a treatment-effect model: the PSMATCH estimator might balance the covariate of matriculation GPAs across OU and standard university groups of respondents. The left-hand side of Figure 4 shows that the matriculation GPAs of standard university respondents are higher and less dispersed than those of OU students. The right-hand side shows that, after weighting based on the PSMATCH estimator, the average and standard deviation of the matriculation GPAs of both groups become similar. Subsequently, we present the outcomes of the treatment-effect regression analysis, and employ a formal statistical test: the over-identification test for covariate balance of Imai and Ratkovic (2014). The estimates in Table 4 show that, for a similar admission criterion (matriculation GPA), the average academic GPA of OU students is significantly lower by 1.47–1.67 points (at the 1% significance level). The Imai–Ratkovic identification test formally supports the null hypothesis of balanced covariate (*p*-value of 0.92). These outcomes demonstrate the high level of the OU even under equal conditions.

Table 1 shows that the matriculation and academic GPAs of standard university respondents are higher. Nevertheless, the 15.22% difference in the matriculation GPA is reduced to only 3.73% in academic GPA. However, unlike matriculation GPA, academic exams might differ across different institutions. To address this concern, the analysis in Table 5 is adjusted to the same level of matriculation GPA by running two regressions, separately on each group, and calculating two projected academic GPAs for each group of respondents. Note that, among standard university students with the same matriculation GPA, a shift from the standard university to the OU is expected to significantly decrease their academic GPA by 0.76 points (significant at the 1% significance level). At the same time, a shift of OU students with the same matriculation GPA from the OU to a standard university is expected to significantly increase their academic GPA by 2.16 points (significant at the 1% significance level).

[18] To test the robustness of regression outcomes, we stratified the sample into four faculties: humanities, social sciences, economics and management, and exact and life sciences. With one exception (humanities), the results, available upon request, are similar to those reported in Figure 3 and Table 3.

This result provides additional statistical evidence that the academic level of the OU is not different from that of standard universities. Table 5 also provides some justification to standard universities' admission policy of screening candidates based on matriculation GPA. If both student groups would have studied in the same type of academic institute, the academic achievements of standard university students are expected to be significantly higher by 1.09%–2.95% (at the 1% significance level).

3.3. Tests of Ability and Background: Methodology and Results

Having demonstrated that matriculation GPAs provide a weak signal for academic achievements, we now examine matriculation and university GPAs (as dependent variables). We show that, while matriculation GPA is explained by cognitive ability as well as socioeconomic characteristics, the academic GPA is mainly explained by cognitive ability. Measuring cognitive ability is difficult (see for example Corbin and Heckman 2016) therefore we use proxies that reflect cognitive performance at high school and university but we also utilize an external test - Frederick's cognitive reflection test (Frederick 2005).

3.3.1. Descriptive Statistics: Proxies of Cognitive Ability

Table 6 displays the descriptive statistics of proxies for cognitive ability (see also correlation matrices in Table 20 and Table 21 in appendix B between selected variables). The number of courses taken per semester may provide a proxy for cognitive ability. As the number of courses per semester increases, the workload increases, and under equal conditions, it might require a higher cognitive ability. According to this table, OU respondents with (without) full matriculation certificates take, on average, 2.44 (2.69) courses per semester. Standard university respondents take an average of 6.65 courses per semester. The differences are statistically significant at the 1% significance level (COURSES).

The frequency of respondents who do not use private tutoring may indicate their cognitive ability and self-learning skills. According to Table 6, out of the 615 (103) OU respondents with (without) full matriculation certificate, 409 respondents (66.50%) (75 respondents, 72.82%) did not use private tutoring during their university studies. Out of the 513 standard university respondents, 363 respondents (70.76%) did not take private tutoring during their university studies. The differences across groups are found to be statistically insignificant (NO_PRIVATE_UNIV). Out of the 615 OU respondents with full matriculation certificates, 264 (42.93%) did not take private tutoring during their high school studies. Out of the 513 standard university respondents, 232 (45.22%) did not take private tutoring during their high school studies. The difference across groups is statistically insignificant (NO_PRIVATE_HIGH).

Another proxy of cognitive ability is the score in Frederick's CRT (Frederick 2005). We conducted the CRT among 337 OU and standard university students.[19] Table 7 shows that despite differences in matriculation GPA, the differences in the academic GPA and the CRT scores among OU and standard university students are insignificant. Table 8 shows that the academic grades at the OU, where students sort themselves, are positively correlated with the matriculation GPA and particularly with the CRT score. The projected Academic GPA of OU respondents with full matriculation certificate significantly increase by 2.068 points (Exact Sciences) and by 2.627 points (Economics and Management) with each additional correct answer in Frederick's CRT. The projected Academic GPA of OU respondents with and without full matriculation certificate significantly increases by 2.107 points (Exact Sciences), by 3.165 points (Economics and Management) and by 2.609 points (Social Science) with each additional correct answer in Frederick's CRT.

3.3.2. Descriptive Statistics of Proxies for Background Characteristics

Table 9 displays the descriptive statistics of socioeconomic variable proxies. The table demonstrates that, compared with OU respondents, standard university respondents have better socioeconomic characteristics. Out of the entire sample of 615 [103] OU respondents with (without) full matriculation certificates, the tuition fees of only 109 respondents (17.72%) [13.59%] are fully financed by their parents (FULL_FINANCE).[20] The equivalent figure for the 513 standard university respondents is 185 respondents (36.06%).

[19] The test consists of three questions: 1) A bat and a ball together cost 110 NIS. The bat is more expensive than the ball by 100 NIS. What is the price of the ball (intuitive and wrong answer: 10 NIS; correct answer: 5 NIS). 2) In a lake, there is a patch of lily pads. Every day, the patch doubles its size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake (intuitive and wrong answer: 24 days; correct answer: 47 days). 3) It takes 5 machines 5 minutes to produce 5 widgets. How long would it take 100 machines to produce 100 widgets? (intuitive wrong answer: 20 minutes; correct answer: 5 minutes).

[20] Annual basic tuition fee in research universities was 10,000 NIS for bachelor degree studies in 2014 (Council for Higher Education, Planning and Budgeting Committee) where 1 NIS roughly equals 0.29 USD. According to a Central Bureau of Statistics press release, the average monthly gross wage per

From the entire sample of 615 [103] OU respondents with (without) full matriculation certificates, 255 respondents (41.46%) [37 respondents, 35.92%] have at least one parent with academic education (EDU_HIGH). The equivalent figure for the 513 standard university respondents is 374 (72.90%).

From the 615 [103] OU respondents with (without) full matriculation certificate, 535 respondents (86.99%) [85 respondents, 82.52%] grew up in a family where their parents were married to each other. The equivalent figure in terms of percentage points for the 513 standard university respondents is 374 respondents (87.91%). The differences across groups are statistically insignificant (MARRIED).

Of the OU respondents, 65.96% (48.54%) with (without) full matriculation certificates participated in at least one after school activity (scouts, sports, etc.). The difference between OU respondents with and without full matriculation certificate is statistically significant at the 1% significance level. The equivalent figure for the standard university respondents is 69.01%. The difference between standard university and OU respondents with full matriculation certificates is statistically significant at the 5% significance level (ACTIVITIES).

Moreover, 14.31% (18.45%) of OU respondents with (without) full matriculation lived in a rented housing unit during high school. This percent drops to 8.38% of standard universities respondents. This decrease is statistically significant at the 1% significance level (RENTER).

Of the OU respondents, 74.96% (71.84%) with (without) full matriculation lived in a single housing unit owned by their parents during high school compared to 73.29% of standard university respondents. All differences are statistically insignificant (RESIDENCE_HOMEOWNER).

Of the OU respondents, 10.73% (9.71%) with (without) full matriculation certificates have parents who were homeowners to at least two housing units during high school. This percentage doubles to 18.32%, among standard university respondents. This increase is statistically significant at the 1% significance level (INVEST_HOMEWNER).

Israeli worker in 2013 equaled 9,200 NIS. Therefore, the tuition fee accounts for 9.06% of the annual average salary of 110,400 NIS (9,200 NIS per month $\cdot$ 12 months).

The OU respondents with (without) full matriculation certificates lived in housing units with an average number of 4.32 (4.03) rooms. The difference across groups is statistically significant at the 5% significance level. Standard university respondents lived in housing units with an average number of 4.73 rooms. The differences are statistically significant at the 1% significance level (ROOMS).

The OU respondents with (without) full matriculation certificates lived in households containing on average 4.93 (4.70) persons. Standard university respondents lived in households with an average of 4.93 members. The differences across groups are statistically insignificant (PERSONS).

Division of the number of rooms by the number of persons yields a measure of density for each respondent during high school. This measure shows that, compared with OU respondents, standard university respondents had a larger dwelling space during high school. OU respondents with (without) full matriculation certificate had a space of 0.92 (0.92) rooms per person during high school. The equivalent figure for standard universities respondents is 1.02 rooms per person, and the difference is statistically significant at the 1% significance level (ROOMS_PER_CAPITA).

Of the OU respondents, 57.07% (46.60%) with (without) full matriculation certificates are female. The equivalent figure for the standard university respondents is 52.83%. The differences across groups are statistically insignificant (FEMALE).

Finally, compared with standard university respondents, OU respondents are older on average. The average age of OU respondents with (without) full matriculation certificates is 29.46 years (33.31 years). The equivalent figure for standard university respondents is 24.99 years, and the difference is statistically insignificant (AGE).

3.3.3. The Econometric Model and Regression Outcomes

To further validate that cognitive ability characteristics are positively related to academic GPA, we apply an econometric model estimated by quantile regression. We separately apply the model on the OU and standard university respondent groups. The model is given by

$$\begin{aligned} ACADEMIC\_GPA = ABILITY \cdot \omega_1 + BACKGROUND \cdot \omega_2 \\ + COHORT\_AND\_GENDER \cdot \omega_3 + \omega_4 + \mu_1 \end{aligned}, \quad (26)$$

where:

$$ABILITY = [MATH5, ENGLISH5, COURSE\_NUMBER, NO\_PRIVATE], \quad (27)$$

$$\begin{aligned} BACKGROUND = [&FULL\_FINANCE, EDU\_HIGH, MARRIED, \\ &ACTIVITIES, INVEST\_OWNER, \\ &ROOM\_PER\_CAPITA], \end{aligned} \quad (28)$$

$$COHORT\_AND\_GENDER = [FEMALE, AGE], \quad (29)$$

where $\omega_1, \omega_2, \omega_3$ are column vectors of parameters; ω_4 is the constant term; and μ_1 is the random disturbance term that satisfies the classical assumption. The dependent variable is academic GPA. ABILITY, BACKGROUND, and COHORT_AND_GENDER are given by (27)–(29).

To further demonstrate that background characteristics contribute to improving the signal provided by matriculation GPA, we employ a second model estimated by quantile regression and applied only to respondents with full matriculation certificates. The model is given by:

$$\begin{aligned} MATR\_GPA = &ABILITY \cdot \delta_1 + BACKGROUND \cdot \delta_2 \\ &+ COHORT\_AND\_GENDER \cdot \delta_3 + \delta_4 + \mu_2 \end{aligned}, \quad (30)$$

where $\delta_1, \delta_2, \delta_3$ are the column vectors of the parameters; δ_4 is the constant term; μ_2 is the random disturbance term that satisfies the classical assumptions; and ABILITY, BACKGROUND, and COHORT_AND_GENDER are given by equations (27)–(29). The model is the same as the one in equation (26), except for the replacement of the dependent variable by MATR_GPA.[21]

Table 10 displays the outcomes obtained from the quantile regression only for subjects with full matriculation certificates. Columns (1)–(8) (Columns (9)–(16)) refer to the regression outcomes where the dependent variable is ACADEMIC_GPA (MATR_GPA). The different columns represent different quintiles of academic and matriculation GPA (defined as *q*, where $q = 20\%, 40\%, 60\%, 80\%$). We use these different quintiles to observe differences across groups based on their academic and

[21] Given the non-symmetrical distribution of matriculation GPAs, ensuing from outliers, particularly among standard university students, the use of the quantile regression methodology is justified (see, for example, Greene 2012 pages 243–250). Additionally, due to the lack of matriculation GPAs, respondents who do not have a full matriculation certificate have been excluded from the sample.

matriculation outcomes.[22] The odd (even) columns refer to the sample of OU respondents with full matriculation certificates (standard university respondents). Finally, note that only significant coefficients (at the 5% and 1% levels) are reported.

The proxies of cognitive ability as explanatory variables yield the following outcomes. For $q = 20\%,\ 40\%, 60\%, 80\%$, a modification from elementary or intermediate level (MATH3 or MATH4) to high Mathematics level (MATH5) is associated with a significant increase of 2.00–3.00 points in projected academic GPA for OU respondents with full matriculation certificates (significant at the 1% - 5% level). For $q = 20\%, 40\%, 60\%$, a modification from elementary or intermediate level (ENGLISH3 or ENGLISH4) to high English level (ENGLISH5) is associated with a significant increase of 1.79–2.00 points in projected academic GPA for OU respondents with full matriculation certificates (significant at the 1% significance level). These relations may reflect that these variables at least partly related to several aspects of higher cognitive ability.

For $q = 20\%,\ 40\%, 60\%, 80\%$, in both groups (OU and standard university respondents) the modification from MATH3 (elementary level) or MATH4 (intermediate level) to MATH5 (the highest level) is associated with a significant increase of 4.67-8.00 points in matriculation GPA. For $q = 20\%,\ 40\%, 60\%, 80\%$, in both groups the modification from ENGLISH3 (elementary level) or ENGLISH4 (intermediate level) to ENGLISH5 (the highest level) is associated with a significant increase of 3-6.5 points in matriculation GPA. Given the 10–20 points bonus, these outcomes are not surprising.

For $q = 20\%$ (only for OU respondents) and $q = 40\%, 60\%, 80\%$ in both groups (OU and standard university respondents) increasing the workload by adding a course per semester yields a significant increase in projected academic GPA by 0.43–1.33 points (significant at the 5% and 1% significance levels). This outcome may reflect self-selection: those more capable are willing to commit to a higher number of courses per semester. As anticipated in this case, for $q = 20\%, 40\%, 60\%, 80\%$ and both groups (OU and standard university respondents) the effect of additional workload during university studies on matriculation GPA is statistically insignificant.

[22] See, for example, Greene (2012) pages 243–250. This is an accepted methodology in the field.

For $q = 40\%$ (only standard universities respondents) and $q = 60\%, 80\%$ for both groups (OU and standard university respondents) not taking private tutoring yields a significant increase in projected academic GPA by 1.76–3.33 points (significant at the 1% significance level). These results may reflect the fact that individuals who do not need to take private tutoring are more capable. For $q = 20\%,\ 40\%, 60\%, 80\%$ and for both groups, the effect of not taking private tutoring on matriculation GPA is statistically insignificant.

To summarize the effect of cognitive ability proxies, on the one hand, all four explanatory variables have a significant effect on the academic GPA of OU respondents while two of them have a significant effect on the academic GPA of standard university respondents. On the other hand, with the exception of MATH5 and ENGLISH5, which provide 20-point bonuses each to matriculation GPA, there is no significant effect of the four explanatory variables on matriculation GPA.

The proxies of background characteristics as explanatory variables yield the following outcomes. For $q = 20\%,\ 40\%, 60\%, 80\%$, a modification from partial or no finance to fully financing the academic tuition fees (i.e., FULL_FINANCE = 1) has an insignificant effect on the academic GPA of standard university respondents. For $q = 60\%$ the same modification is associated with a significant increase of 1.88 points in OU respondents' academic GPA. For $q = 20\%$, the modification is associated with a significant increase of 2.00 points in the standard universities respondents' matriculation GPA.

For $q = 20\%,\ 40\%, 60\%, 80\%$ and for both groups (standard university and OU respondents) the effect of modification from no parent with academic education to at least one parent with academic education (i.e., EDU_HIGH = 1) on the academic GPA is statistically insignificant. For $q = 20\%, 40\%, 60\%$, the same modification is associated with a significant increase of 2.00 points in the standard university respondents' matriculation GPA (significant at the 5% significance level).

For $q = 20\%,\ 40\%, 60\%, 80\%$ and for both groups (standard university and OU respondents), the effect of modification from unmarried parents to married parents during high school (i.e., MARRIED = 1) on the academic GPA is statistically insignificant. For $q = 20\%$, the same modification is associated with a significant increase of 2.80 points in the standard university respondents' projected matriculation GPA. For $q = 60\%$, the modification is associated with a significant increase of 3.50 points in the projected matriculation GPA of OU respondents.

For $q = 20\%, 40\%, 60\%, 80\%$ and for both groups, the effect of modification from homeownership of one dwelling unit to homeownership of at least two dwelling units (i.e., INVEST_OWNER = 1) on the academic GPA is statistically insignificant. For $q = 60\%$, this shift is associated with a significant increase of 3 points in the matriculation GPA of OU respondents.

The two COHORT_AND_GENDER explanatory variables yield the following outcomes. For $q = 40\%$ and for the group of standard university respondents, compared with males, the academic GPA of females is significantly higher by 1.71 points (significant at the 1% significance level). For $q = 60\%$ and for the group of OU respondents, compared with males, the academic GPA of females is significantly higher by 1.24 points (significant at the 1% significance level). Finally, for $q = 20\%$ and the group of OU respondents, compared with males, the matriculation GPA of females is significantly higher by 4.07 points (significant at the 1% significance level).

As for the cohort effect, on one hand, for $q = 20\%, 40\%, 60\%, 80\%$ and for both groups (standard university and OU respondents) the effect of an increase in the age group on academic GPA is statistically insignificant. For $q = 20\%, 40\%, 60\%, 80\%$ and for both groups (with one exception, $q = 80\%$, standard university respondents), a one-year increase in the age of the respondent is associated with a significant decrease of 0.33–0.55 points in matriculation GPA.

In summary, a prominent feature of the outcomes presented in Table 10 is the positive (insignificant) effect of cognitive ability characteristics on academic GPA (matriculation GPA) and the insignificant (positive) effect of background characteristics on academic GPA (matriculation GPA). Combined with pervious findings, these results provide support for hypotheses (b) and (c).

3.4. Spatial Distribution of Place of Residence at High School

We further examine the effect of the socioeconomic background on signal production by employing data on the place of residence during high school. This information is available from the Israeli CBS.[23] We generated four new proxies based on the reported place of residence during high school and the information available from the Israeli CBS. The available information includes: 1) the total population (POP); 2) persons per km^2 (POP_DENSITY); 3) the socioeconomic ranking of cities and towns (multiplied by 10) whose population is above 3,000 persons on a scale of 0 (the lowest) to 100 (the highest ranking) (SOCIAL_RANKING);[24] and 4) the Gini coefficients (multiplied by 100) of cities and towns whose population is above 3,000 persons on a scale of 0 (total equality) to 100 (total inequality of income level) (GINI100).[25]

3.4.1. Descriptive Statistics of Location Characteristic Proxies

The lower part of Table 9 provides descriptive statistics of the four proxies. The sample is stratified into three groups (i.e., OU respondents with and without full matriculation certificate, and standard university respondents). Given that this information is not available for each reported city and town, the number of observations has reduced to 85%–91% of the original samples.

The table shows that, compared with standard universities respondents, OU respondents originate from less populated cities with a population of 190,944–223,838. The equivalent figure for standard university respondent is 240,607 persons and the difference is statistically significant at the 1% significance level (POP). Compared with standard university respondents, OU respondents originate from less populated cities, with lower population densities of 5,499–5,536 persons per km^2. The equivalent figure for standard university respondents is 5,937 persons per km^2, and the difference is statistically significant at the 10% significance level (POP_DENSITY). Compared with standard university respondents, OU respondents

[23] The Israeli CBS stratifies all settlements populated by 3,000 and more habitants according to a socioeconomic ranking index (1–10). We used this index multiplied by 10 as an explanatory variable. A complete table of cities, towns, and other places of residence (e.g., Kibbutzim) are available upon request. The socioeconomic ranking of municipalities is available for 1995, 2003, 2006, and 2008.

[24] See, for example, the Central Bureau of Statistics. Press Release 2013, and Characterization and Classification of Geographical Units by the Socio-Economic Level of the Population - Press Release. (2008).

[25] The Gini index for municipalities stratified by years is available on the Israeli CBS internet site.

originate from lower socioeconomic backgrounds (56.46–57.84 points). The equivalent figure for standard university respondents is 61.15 points, and the difference is statistically significant at the 1% significance level (SOCIAL_RANKING). These data provide further evidence that the socioeconomic background affects signal production (matriculation GPA). Compared with standard university respondents, OU respondents originate from places of residence with more equal income distribution (43.19–43.82). The equivalent figure for standard university respondents is 44.33, and the difference is statistically significant at the 1% significance level (GINI100). However, as Table 20 indicates, the Pearson correlation between SOCIAL_RANKING and GINI100 (71.56%) is positive, very high, and significantly different from zero at the 1% significance level. This correlation implies that a higher socioeconomic ranking is associated with a higher level of income inequality.

3.4.2. Regression Analysis: Proxies of Location Characteristics

Table 11 displays a regression analysis that incorporates the explanatory variables SOCIAL_RANKING and GINI100, where the regression model includes a constant term and one explanatory variable. The model is applied to the pooled sample, and the pooled sample of respondents with full matriculation certificates.

Our findings suggest that proxies associated with location characteristics during high school better explain matriculation GPA. A 10-point increase in social ranking is associated with 0.2 points increase in projected academic GPA, and the coefficient is either statistically insignificant or marginally significant (at the 10% significance level). The same 10-point increase in social ranking translates to a 0.8 points increase in projected matriculation GPA, and the coefficient is statistically significant at the 1% significance level.

A 10% increase of the Gini index is associated with an increase of 1.2–1.3 points in projected academic GPA, and the coefficient is statistically significant at the 5% significance level. The same 10% increase in the Gini index is associated with a 3.9-point increase in projected matriculation GPA, and the coefficient is statistically significant at the 1% significance level.

Columns (7)–(10) in Table 11 show the effect of socioeconomic background (i.e., location) characteristics across groups. These columns demonstrate that, compared with OU respondents, standard university respondents have higher socioeconomic background. A modification from the group of standard university to OU respondents is associated with a decrease of 4.26–4.45 points in residence place projected socioeconomic ranking during high school (significant at the 1% significance level). A modification from the group of standard university to OU respondents is associated with a projected decrease of 1.05%–1.14% in the Gini index of the residence place during high school (significant at the 1% significance level).[26]

3.5. Probability of Receiving a Full Matriculation Certificate

We analyze the determinants of the probability of acquiring a full matriculation certificate. Given that, under any circumstances, respondents without full matriculation certificates cannot be accepted to universities and colleges other than the OU, the latter group is of special interest. The appropriate model is given by:

$$\begin{aligned} MATR\_FULL = {} & ABILITY_1 \cdot \gamma_1 + BACKGROUND_1 \cdot \gamma_2 \\ & + COHORT\_AND\_GENDER \cdot \gamma_3 + \gamma_4 + \mu_3 \end{aligned}, \tag{31}$$

where

$$ABILITY_1 = [ACADEMIC\_GPA, COURSE\_NUMBER, NO\_PRIVATE], \tag{32}$$

$$\begin{aligned} BACKGROUND_1 = {} & [FULL\_FINANCE, EDU\_HIGH, MARRIED, \\ & ACTIVITIES, INVEST\_OWNER, ROOM\_PER\_CAPITA] \end{aligned}, \tag{33}$$

$$COHORT\_AND\_GENDER = [FEMALE, AGE], \tag{34}$$

where MATR_FULL is the dependent variable (1 = subject has a full matriculation certificate, 0 = otherwise); ABILITY,[27] BACKGROUND,[28] and COHORT_AND_GENDER reflect ability, background, and age and gender characteristics, respectively, and are given by equations (32)–(34). $\gamma_1 - \gamma_3$ are column vectors of coefficients corresponding to the respective characteristics, γ_4 is

[26] Better locations are also associated with higher income inequality (measured by the positive and significant Pearson correlation of 71.56%).

[27] Given the incorporation of OU respondents without full matriculation certificates, the variables MATH3, MATH4, MATH5, ENGLISH3, ENGLISH4, and ENGLISH5 have been excluded from the model.

[28] The coefficients of alternative proxies of location variables (GINI100, POP, and POP_DENSITY) are found to be statistically insignificant.

the constant terms column vector, and μ_3 is the column vector of the random disturbance term.

In Table 12, we examine the probability of receiving a full matriculation certificate as a function of ability, background, and cohort and gender effect. Columns (1) and (3) (Columns (2) and (4)) provide estimates of the full (step-wise) model (i.e., only significant coefficients at the 5% and 1% significance levels). Columns (1) and (2) include the pooled sample. Columns (3) and (4) include only OU respondents.

The results show a positive relation between background characteristics and the probability of receiving a full matriculation certificate. A shift from no after-school activities to at least one after-school activity significantly increases the projected probability of receiving a full matriculation certificate by 3%–7% (significant at the 5% and 1% significance levels).

For the pooled sample, an additional course per semester is associated with a significant 2% increase in the projected probability of receiving a full matriculation certificate (significant at the 1% significance level). This effect disappears and becomes statistically insignificant (or marginally significant at the 10% significance level) when the sample is reduced to include only OU respondents with and without full matriculation certificates.

Finally, referring to the cohort effect, a one-year increase in the respondent's age is associated with a 1% decrease in the projected probability to obtain a full matriculation certificate (significant at the 1% significance level). Compared with males, the projected probability of females to obtain a full matriculation certificate is higher by 2%–5% (marginally significant at the 10% significance level).

4. Summary and Conclusions

We presented a model of investment in higher education, where individuals are differentiated by their unobservable innate ability and their socioeconomic background, which can be either low or high. Each agent receives a publicly observable signal (e.g., SAT or matriculation test scores) correlated with his/her cognitive ability; nevertheless, this is also affected by socioeconomic background. We showed a case for affirmative action, that is, a lower admission threshold should be applied to individuals from lower socioeconomic backgrounds. We considered the effect of a subsidized income-contingent loan to higher education programs and showed that it yields neither higher human capital stock nor higher aggregate consumption. Its only effect was shown to be income redistribution, mainly among the upper class. The results showed that under restricted admission to higher education, policies aimed at improving the socioeconomic background of lower background individuals yield higher human capital stock and aggregate consumption and result in income redistribution from bottom to top of the income distribution.

In the second part of the paper, we provided empirical evidence to support the theoretical model. We used surveyed data on academic and high school achievements, as well as a series of proxies for cognitive ability and socioeconomic background. The sample includes two groups of students who completed at least half of their academic studies. The treatment group consists of OU students with and without full matriculation certificates. The control group consists of standard university students with full matriculation certificates. Unlike standard universities, who assort candidates, OU implements an open admission policy.

We showed that high school matriculation GPA is a weak predictor of academic achievements, that is, the signals provided by candidates to academic studies (via matriculation GPA) tend to overstate real gaps between the cognitive abilities proxied by academic achievements. Moreover, in our sample, the lack of a full matriculation certificate does not seem to influence academic achievements.

We further demonstrated that, while high school matriculation GPA is consistently explained by both cognitive ability and socioeconomic background characteristics, academic GPA is solely explained by cognitive ability characteristics. Finally, we found evidence that a lower probability of getting a full matriculation certificate is associated with inferior socioeconomic background characteristics.

We conclude this section by several reservations. Cognitive ability is neither a directly observable variable nor a well-defined one, as individuals can be gifted in one area and not in others. To proxy cognitive ability, we employed variables such as CRT test scores, level of Mathematics and English in matriculation tests, academic achievements, and other variables. We conjecture that, compared with matriculation GPA, academic GPA better reflects cognitive ability, since in the academic world (especially under open admission) an individual chooses an area that suits his or her tendencies and field of interest.

The socioeconomic background level is also difficult to define, as it is affected by both monetary and non-monetary factors (such as physical or emotional abuse). Moreover, the magnitude of the effect of each factor can vary among individuals. To overcome this problem, we used a long series of proxies. Another reservation is the limitation of our sample to non-dropouts, who are most likely going to finish their academic studies. That is, we did not sample the socioeconomic characteristics of those who dropped out of their academic studies at the OU or standard universities, nor their matriculation GPA.

Considering the above limitations, we provided evidence that the standard screening mechanism implemented in the higher education systems around the world misses some candidates, especially those originating from inferior socioeconomic backgrounds. Vast literature stresses the role of parental investment, environment and good schooling in creating cognitive and noncognitive skills, which jointly enhance lifetime achievements, especially during early childhood (Cunha et al. 2006; Cunha and Heckman 2007; Heckman 2007; Fryer and Katz 2013; Heckman, Pinto, and Savelyev 2013; Heckman and Mosso 2014; Corbin and Heckman 2016). Indeed, there is a known correlation in the US between the quality of the university, its tuition fee, and the economic status of its students. Nevertheless, Conley and Önder (2014) found that graduating from top economic departments is neither a necessary nor a sufficient condition for becoming a successful economics researcher. In line with our findings, if the screening mechanism misses candidates at the highest academic level, it probably does so at the BA level as well. Therefore, our evidence suggest that an increased investment in primary and secondary schooling for lower socioeconomic background individuals will increase the quality of academic education, raise aggregate human capital, and decrease income inequality.

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Table 1: Descriptive Statistics: Features of University Studies and Matriculation Certificate

		Open University		Standard Universities
Variable	**Definition**	**Without Full Matriculation Certificate**	**With Full Matriculation Certificate**	**With Full Matriculation Certificate**
ACADEMIC_GPA	University GPAs on a scale of 60 to 100	82.02	81.71	84.80***
HUMANITIES	1=Humanities studies 0=Otherwise	9.71%	4.23%+	8.97%***
SOCIAL_SCIENCES	1=social science studies 0=otherwise	35.92%	21.14%+++	19.88%
MANAGEMENT	1=Economics, Management and Accounting 0=otherwise	49.51%	66.99%+++	29.43%***
EXACT_AND_LIFE	1=Exact Sciences studies 0=otherwise	4.86%	7.64%	41.72%***
PSYCH_REPORT	1=Reported on Psychometric grades on a scale of 200 to 800 0=otherwise	23.30%	54.87%+++	100.00%***
PSYCH_GRADE	Psychometric grades on a scale of 200 to 800	563.83	574.52	667.48***
MATR_GPA	High-school matriculation GPA on a scale of between 55 to 120 (for those who passed the official ministry of education matriculation exams and thus have a high- school certificate)	–	88.33	102.44***
MATH3	1= elementary math-level of matriculation exam 0= Otherwise	–	37.24%	16.18%***
MATH4	1= intermediate math-level of matriculation exam 0= Otherwise	–	38.70%	35.67%
MATH5	1= highest math-level of matriculation exam 0= Otherwise	–	24.06%	48.15%***
ENGLISH3	1= elementary English-level of matriculation exam 0= Otherwise	–	9.76%	0.00%***
ENGLISH4	1= intermediate or highest English-level of matriculation exam 0=Otherwise	–	41.13%	19.49%***
ENGLISH5	1= intermediate or highest English-level of matriculation exam 0=Otherwise	–	49.11%	80.51%***
OU	1=respondent studies in the Open University 0=Otherwise (respondent studies in a standard university)	1.00	1.00	0.00
FULL_MATRICULATION	1=respondent has full matriculation 0=otherwise	0.00	1.00	1.00
Total = 718 subjects OU+513 subjects in Standard Universities		103	615	513

Notes: + significant difference between OU students with and without full matriculation certificate at a 10% significance level, ++ significant difference between OU students with and without full matriculation certificate at a 5% significance level, +++ significant difference between OU students with and without full matriculation certificate at a 5% significance level, * significant difference between Standard and OU students with full matriculation certificate at a 10% significance level 10%, ** significant difference between Standard and OU students with full matriculation certificate at a 5% significance level and *** significant difference between Standard and OU students with full matriculation certificate at a 1% significance level

Table 2: Academic and Matriculation GPA stratified by Faculties

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	ACADEMIC_GPA									
OU_FULL	81.71***	81.71***	83.31***	83.31***	83.40***	83.40***	81.00***	81.00***	82.34***	82.34***
	(0.26)	(0.26)	(1.32)	(1.32)	(0.54)	(0.54)	(0.31)	(0.31)	(0.94)	(0.94)
OU_PARTIAL	82.02***	0.31	81.90***	-1.41	82.57***	-0.83	81.53***	0.52	83.20***	0.86
	(0.62)	(0.68)	(2.13)	(2.51)	(1.02)	(1.16)	(0.87)	(0.92)	(2.89)	(3.04)
STANDARD	84.80***	3.09***	85.11***	1.80	85.92***	2.52***	84.69***	3.68***	84.28***	1.94*
	(0.28)	(0.38)	(0.99)	(1.66)	(0.61)	(0.82)	(0.51)	(0.59)	(0.44)	(1.04)
Faculties	Total	Total	HUMANITIES	HUMANITIES	SOCIAL	SOCIAL	MANAGEMENT	MANAGEMENT	EXACT	EXACT
Observations	1,231	1,231	82	82	269	269	614	614	266	266
R-squared	0.99	0.05	0.99	0.03	0.99	0.05	0.99	0.06	0.99	0.01

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
FACULTIES:	ACADEMIC_GPA						MATR_GPA			
HUMANITIES	81.90***	81.90***	83.31***	83.31***	85.11***	85.11***	83.12***	83.12***	96.15***	96.15***
	(2.36)	(2.36)	(1.21)	(1.21)	(0.92)	(0.92)	(1.98)	(1.98)	(1.05)	(1.05)
SOCIAL	82.57***	0.67	83.40***	0.09	85.92***	0.81	87.72***	4.60**	100.87***	4.72***
	(1.23)	(2.66)	(0.54)	(1.33)	(0.61)	(1.10)	(0.88)	(2.17)	(0.70)	(1.26)
MANAGEMENT	81.53***	-0.37	81.00***	-2.30*	84.69***	-0.42	88.09***	4.98**	102.58***	6.42***
	(1.05)	(2.58)	(0.30)	(1.25)	(0.51)	(1.05)	(0.50)	(2.04)	(0.58)	(1.20)
EXACT+LIFE	83.20***	1.30	82.34***	-0.97	84.28***	-0.83	95.02***	11.91***	104.45***	8.29***
	(3.34)	(4.09)	(0.90)	(1.51)	(0.42)	(1.01)	(1.47)	(2.46)	(0.49)	(1.15)
Matriculation	Partial	Partial	Full	Full	Full	Full	Full	Full	Full	Full
universities	OU	OU	OU	OU	STANDARD	STANDARD	OU	OU	STANDARD	STANDARD
Observations	103	103	615	615	513	513	615	615	513	513
R-squared	0.99	0.01	0.99	0.03	0.99	0.01	0.99	0.04	1.00	0.10

Notes: Academic GPA is on a scale of 60-100 points. Matriculation GPA is on a scale of 55-120 points. SOCIAL includes social sciences and law. MANAGEMENT includes Economics, Management and Accounting. EXACT includes life and exact sciences. OU_PARTIAL (OU_FULL) equals 1 if the respondent studies in the Open University and has partial or no (full) matriculation certificate, and 0 otherwise. STANDARD equals 1 if the respondent studies in a university with standard admission criteria (i.e., full matriculation certificate and psychometric grades) and 0 otherwise. In the odd columns (2), (4), (6), (8) and (10) we excluded the base categories (OU_FULL, HUMANITIES, , OU_FULL). Standard errors are given in parentheses. * significant at a 10% significance level, ** significant at a 5% significance level, and *** significant at a 1% significance level.

Table 3: Regression Analysis: Academic GPA compared to Matriculation GPA

VARIABLES	(1) ACADEMIC_GPA	(2) ACADEMIC_GPA	(3) Difference of Coefficients
Constant	76.82***	82.02***	5.20***
	(0.71)	(1.58)	(1.71)
MATR_GPA–60	0.17***	0.07*	–0.10**
	(0.02)	(0.04)	(0.04)
Faculties	TOTAL	TOTAL	TOTAL
Universities:	OU	STANDARD	STANDARD–OU
Observations	615	513	1,128
R-squared	0.08	0.01	0.10
beta coefficient	0.28***	0.08*	–0.36**
F-Statistics coef. of:			
(1) (MATR_GPA–60)=1	1,234.00***	649.52***	–
(2) Const=(60-20)	2,690.18***	707.19***	–
(2)=40; (1)=1	2,143.00***	361.85***	–

Notes: Standard errors are given in parentheses. Matriculation GPA is on a scale of 60-120 points. Academic GPA is on a scale of 60-100 points. MATR–60 equals MATRICULATION_GPA–60. * significant at a level of 10%, ** significant at a level of 5% and *** significant at a level of 1%.

Table 4: Treatment Effect Models

VARIABLES	(1) ACADEMIC_GPA	(2) ACADEMIC_GPA	(3) ACADEMIC_GPA	(4) ACADEMIC_GPA
Constant (Potential Mean)	84.21***	84.21***	N.A.	N.A.
	(0.36)	(0.34)	N.A.	N.A.
OU	-1.47***	-1.47***	-1.67***	-1.53***
	(0.49)	(0.47)	(0.50)	(0.52)
Estimator	AIPW	IPWRA	NNMATCH	PSMATCH
p-value: Over-identification test for covariate balance	0.92	0.92	Irrelevant	Irrelevant
Observations	1,128	1,128	1,128	1,128

Notes: The table displays the outcomes obtained from the treatment-effect models, where the outcome is the academic GPA, and the treatment (control) group consists of OU (standard universities) students. The AIPW and IPRWA are the Inverse-Probabilities Estimators, which weight the inverse probability of each subject. Estimated probabilities are obtained from the logit regression' where the dependent variable is OU and the independent variable is matriculation GPA. We use the over-identification test for covariate balance developed by Imai and Ratkovich (2014). The NNMATCH and PSMATCH are estimators, which are based on matching individuals with similar features (i.e., academic or matriculation GPAs) across groups. Numbers in parentheses are robust standard errors. *** significant at the 1% significance level. Standard errors are given in parentheses.

Table 5: Difference in Difference (DD) Analysis**:** Matriculation vs. Projected Academic GPA

		(0)	(1)	(2)	(3)=(1)–(2)
			Proj (ACADEMIC_GPA)		
	Standard Universities vs. Open University	**Matriculation GPA**	**From Regression of Standard Universities**	**From Regression of Open University (OU)**	**Difference**
(4)	**Group of Standard University Students with full Matriculation Certificate (obs.=513)**	102.44*** (101.79, 103.09) [101.59, 103.30]	84.80*** (84.76, 84.84) [84.75, 84.86]	84.04*** (83.94, 84.15) [83.90, 84.19]	0.76*** (0.64, 0.87) [0.60, 0.91]
(5)	**Group of Open University Students with full Matriculation certificate(obs.=615)**	88.33*** (87.52, 89.15) [87.26, 89.41]	83.88*** (83.83, 83.94) [83.81, 83.95]	81.72*** (81.58, 81.85) [81.54, 81.90]	2.16*** (2.02, 2.31) [1.97, 2.36]
(6)=(4)-(5)	**Difference (Points)**	14.11*** (13.07, 15.15) [12.74, 15.48]	0.92*** (0.85, 0.99) [0.83, 1.01]	2.33*** (2.15, 2.51) [2.09, 2.56]	−1.40*** (−1.52,−1.30) [−1.55, −1.27]
$\ln\left[\frac{(6)}{(5)}\right]$	**Difference (Percent)**	15.22*** (14.08, 16.36) [13.72, 16.72]	1.09*** (1.02, 1.18) [0.99, 1.20]	2.95*** (2.73, 3.17) [2.66, 3.24]	−1.85*** (−1.71 −1.99) [−1.67, −2.04]

Notes: Projected values were obtained from regressing ACADEMIC_GPA on MATR_GPA for each group separately (Standard Universities vs. OU). Projected values are thus adjusted to the same level of MATR_GPA. 95% (99%) confidence intervals are given in round (square) brackets. *** significant at the 1%-level.

Table 6: Descriptive Statistics: Proxies of Ability

		Open University		Standard Universities
Variable	**Definition**	**Without Full Matriculation Certificate**	**With Full Matriculation Certificate**	**With Full Matriculation Certificate**
ACADEMIC_GPA	University GPAs on a scale of 60 to 100	82.02	81.71	84.80***
MATR_GPA	High-school matriculation GPA on a scale of 60 to 120 (for those who passed the official ministry of education matriculation exams and thus have a high- school certificate)	–	88.33	102.44***
MATH3	1= elementary math-level of matriculation exam 0= Otherwise	–	37.24%	16.18%***
MATH4	1= intermediate math-level of matriculation exam 0= Otherwise	–	38.70%	35.67%
MATH5	1= highest math-level of matriculation exam 0= Otherwise	–	24.06%	48.15%***
ENGLISH3	1= elementary English-level of matriculation exam 0= Otherwise	–	9.76%	0.00%***
ENGLISH4	1= intermediate or highest English-level of matriculation exam 0=Otherwise	–	41.13%	19.49%***
ENGLISH5	1= intermediate or highest English-level of matriculation exam 0=Otherwise	–	49.11%	80.51%***
COURSE_NUMBER	Number of courses per semester	2.44	2.69^{+++}	6.65***
NO_PRIVATE_UNIV	1=The respondent did not take private tutoring during his or her academic studies 0=Otherwise	72.82%	66.50%	70.76%

NO_PRIVATE_HIGH	1=The respondent did not take private tutoring during high school 0=Otherwise	–	42.93%	45.22%
OU	1=respondent studies in the Open University 0=Otherwise (respondent studies in a standard university)	1.00	1.00	0.00
FULL_MATRICULATION	1=respondent has full matriculation 0=otherwise	0.00	1.00	1.00
Total = 718 subjects OU+513 subjects in Standard Universities		103	615	513

Notes: + significant difference between OU students with and without full matriculation certificate at a 10% significance level, ++ significant difference between OU students with and without full matriculation certificate at a 5% significance level, +++ significant difference between OU students with and without full matriculation certificate at a 5% significance level, * significant difference between Standard and OU students with full matriculation certificate at a 10% significance level 10%, ** significant difference between Standard and OU students with full matriculation certificate at a 5% significance level and *** significant difference between Standard and OU students with full matriculation certificate at a 1% significance level.

Table 7: Descriptive statistics - CRT

Full Matriculation	**Mean Academic GPA**	**Mean Matriculation GPA**	**Mean CRT Score**	**0**	**1**	**2**	**3**	**Obs.**
OU: No	84.56 (6.89)	–	1.77 (1.07)	14.75%	26.23%	26.23%	32.79%	63
OU: Yes	83.85 (6.86)	90.70 (10.78)	1.67 (1.18)	24.24%	18.79%	23.03%	33.94%	168
Standard	85.29 (5.95)	100.72*** (10.11)	1.77 (1.16)	21.62%	15.32%	27.03%	36.03%	106
Overall	84.45 (6.59)	93.79 (14.25)	1.72 (1.15)	21.66%	18.99%	24.93%	34.42%	337
Frederick, 2005 (Table 1)			**Mean CRT Score**	**0**	**1**	**2**	**3**	**Obs.**
MIT	–	–	2.18	7.00%	16.00%	30.00%	48.00%	61
Overall	–	–	1.24	33.00%	28.00%	23.00%	17.00%	3,428

Notes: Standard errors are given in parentheses. *significant difference between Standard and OU students with full matriculation certificate at a 10% significance level 10%, ** significant difference between Standard and OU students with full matriculation certificate at a 5% significance level and *** significant difference between Standard and OU students with full matriculation certificate at a 1% significance level.

Table 8: Regression analysis - CRT

VARIABLES	Academic GPA	Academic GPA	Academic GPA	Academic GPA	Academic GPA	Academic GPA	Academic GPA	Academic GPA	Academic GPA	Academic GPA	Academic GPA	Academic GPA
Constant	72.64*** (3.010)	82.09*** (5.822)	80.82*** (0.773)	75.25*** (3.599)	74.51*** (9.245)	78.65*** (1.775)	66.51*** (6.111)	86.21*** (7.606)	78.62*** (1.189)	66.65*** (9.475)	83.95*** (16.33)	81.73*** (1.408)
Matriculation GPA	0.0910*** (0.0335)	0.0189 (0.0580)	_	0.0383 (0.0366)	0.0708 (0.0908)	_	0.145** (0.0682)	-0.0306 (0.0740)	_	0.166 (0.110)	0.0459 (0.170)	_
Frederick Grade	1.803*** (0.422)	0.618 (0.506)	1.904*** (0.378)	2.068** (0.794)	1.237 (0.924)	2.107*** (0.715)	2.627*** (0.678)	0.940 (0.612)	3.165*** (0.592)	1.883 (1.228)	1.131 (1.284)	2.609*** (0.953)
University	OU – With matriculation	standard	OU Total	OU – With matriculation	standard	OU Total	OU – With matriculation	standard	OU Total	OU – With matriculation	standard	OU Total
Faculty	Total	Total	Total	Exact	Exact	Exact	Management	Management	Management	Social science	Social science	Social science
F-values	15.01***	0.87	25.45	4.18**	1.34	8.450	12.54***	1.31	28.59	3.217	0.627	7.5
Observations	168	106	226	54	55	70	75	31	90	34	10	54
R-squared	0.154	0.017	0.2012	0.141	0.049	0.111	0.258	0.085	0.245	0.172	0.152	0.126

Notes: Standard errors are given in parentheses. * significant at a 10% significance level. ** significant at a 5% significance level. *** significant at a 1% significance level.

Table 9: Descriptive Statistics: Proxies of socioeconomic background

		Open University		Standard Universities
Variable	**Definition**	**Without Full Matriculation Certificate**	**With Full Matriculation Certificate**	**With Full Matriculation Certificate**
FULL_FINANCE	1=university tuition fee is fully financed by parents. 0=Otherwise	13.59%	17.72%	36.06%***
EDU_HIGH	1 = At least one parent has above high-school education 0 = Otherwise	35.92%	41.46%	72.90%***
MARRIED	1 =Parents were married 0 = otherwise	82.52%	86.99%	87.91%
ACTIVITIES	1=At least one external activity after school hours (e.g., Scouts, Sport, etc.) 0=otherwise	48.54%	65.96%+++	69.01%**
RENTER	1=Parents are renters 0=Otherwise	18.45%	14.31%	8.38%***
RESIDENCE_OWNER	1=Parents owned one apartment during high-school 0=Otherwise	71.84%	74.96%	73.29%
INVEST_OWNER	1=Parents owned at least two apartments during high-school 0=Otherwise	9.71%	10.73%	18.32%***
ROOMS	Number of Rooms in High School	4.03	4.32++	4.73***
PERSONS	Number of Persons in a household during high school	4.70	4.93	4.93
ROOM_PER_CAPITA	Persons divided by number of rooms	0.92	0.92	1.02***
FEMALE	1=female, 0=male	0.47	0.57	0.53
AGE	Age in years	33.31	29.46	24.99
OU	1=respondent studies in the Open University 0=Otherwise (respondent studies in a standard university)	1.00	1.00	0.00
FULL_MATRICULATION	1=respondent has full matriculation 0=otherwise	0.00	1.00	1.00
Total = 718 subjects OU+513 subjects in Standard Universities		103	615	513
POP	Total population in high school place of residence	223,838	190,944	240,607***
POP_DENSITY	Persons per square KM in high school residence	5,536	5,499	5,937*
Total = 644 subjects OU+437 subjects in Standard Universities		89	555	437
Ratio=(Frequency of Population density)/(Total Frequency)		0.86	0.90	0.85
SOCIAL_RANKING	The social ranking of the high school place of residence on a scale of between 20 to 100	57.84	56.46	61.15***
GINI100	The Gini Coefficient of the high school place of residence on a scale of between 0 (total equality) to 100 (total inequality)	43.82	43.19	44.33***
Total = 645 subjects OU+436 subjects in Standard Universities		88	557	436
Ratio=(Frequency of social ranking)/(Total Frequency)		0.85	0.91	0.85

Notes: + significant difference between OU students with and without full matriculation certificate at a 10% significance level, ++ significant difference between OU students with and without full matriculation certificate at a 5% significance level, +++ significant difference between OU students with and without full matriculation certificate at a 5% significance level, * significant difference between Standard and OU students with full matriculation certificate at a 10% significance level 10%, ** significant difference between Standard and OU students with full matriculation certificate at a 5% significance level and *** significant difference between Standard and OU students with full matriculation certificate at a 1% significance level.

Table 10: Quantile Regressions: Academic and Matriculation GPA by Quintiles

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
VARIABLES	ACADEMIC_GPA								MATRICULATION_GPA							
Constant	71.33***	80.00***	76.00***	77.86***	73.61***	79.67***	82.00***	83.50***	85.74***	96.40***	97.50***	106.50***	98.00***	105.67***	106.00***	104.00***
	(1.19)	(0.25)	(1.01)	(1.16)	(2.33)	(1.43)	(1.24)	(1.24)	(2.98)	(4.03)	(2.11)	(3.74)	(2.74)	(4.31)	(2.93)	(0.66)
MATH5	2.00**	–	2.00***	–	2.61***	–	3.00***	–	6.30***	6.40***	8.00***	5.50***	7.50***	4.67***	6.50***	5.00***
	(0.80)	–	(0.67)	–	(0.76)	–	(0.78)	–	(1.30)	(0.77)	(0.96)	(0.75)	(1.10)	(0.87)	(1.33)	(0.61)
ENGLISH5	2.00***	–	2.00***	–	1.79***	–	–	–	4.07***	3.80***	3.00***	4.00***	4.50***	4.00***	6.50***	2.00***
	(0.68)	–	(0.58)	–	(0.64)	–	–	–	(1.12)	(0.99)	(0.83)	(0.97)	(0.95)	(1.12)	(1.15)	(0.77)
COURSES_NUM	1.33***	–	1.00***	0.43***	0.94**	0.67***	1.00**	0.50***	–	–	–	–	–	–	–	–
	(0.41)	–	(0.35)	(0.15)	(0.40)	(0.19)	(0.41)	(0.16)	–	–	–	–	–	–	–	–
NO_PRIVATE	–	–	–	2.86***	1.76***	3.33***	2.00***	4.50***	–	–	–	–	–	–	–	–
	–	–	–	(0.65)	(0.66)	(0.82)	(0.71)	(0.71)	–	–	–	–	–	–	–	–
FULL_FINANCE	–	–	–	–	1.88**	–	–	–	–	2.00***	–	–	–	–	–	–
	–	–	–	–	(0.82)	–	–	–	–	(0.77)	–	–	–	–	–	–
EDU_HIGH	–	–	–	–	–	–	–	–	–	2.00**	–	2.00**	–	2.00**	–	–
	–	–	–	–	–	–	–	–	–	(0.84)	–	(0.81)	–	(0.94)	–	–
MARRIED	–	–	–	–	–	–	–	–	–	2.80**	–	–	3.50***	–	–	–
	–	–	–	–	–	–	–	–	–	(1.12)	–	–	(1.34)	–	–	–
ACTIVITIES	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
INVEST_OWNER	–	–	–	–	–	–	–	–	–	–	–	–	3.00**	–	–	–
	–	–	–	–	–	–	–	–	–	–	–	–	(1.47)	–	–	–
ROOMS_PER_CAPITA	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
FEMALE	–	–	–	1.71***	1.24**	–	–	–	4.07***	–	–	–	–	–	–	–
	–	–	–	(0.59)	(0.62)	–	–	–	(1.08)	–	–	–	–	–	–	–
AGE	–	–	–	–	0.12**	–	–	–	-0.37***	-0.40***	-0.50***	-0.50***	-0.50***	-0.33**	-0.50***	–
	–	–	–	–	(0.05)	–	–	–	(0.09)	(0.15)	(0.07)	(0.15)	(0.08)	(0.17)	(0.09)	–
University	OU	Standard	OU	Standard	OU	Standard	OU	Standard	OU	Standard	OU	Standard	OU	Standard	OU	Standard
Observations	615	513	615	513	615	513	615	513	615	513	615	513	615	513	615	513
Quantile	0.200	0.200	0.400	0.400	0.600	0.600	0.800	0.800	0.200	0.200	0.400	0.400	0.600	0.600	0.800	0.800

Notes: Standard errors are given in parentheses. All the regressions were run by a step-wise procedure. * significant at a 10% significance level. ** significant at a 5% significance level. *** significant at a 1% significance level.

Table 11: Regression Analysis based of Place of Residence at High School

VARIABLES	(1) ACADEMIC_GPA	(2) ACADEMIC_GPA	(3) MATR_GPA	(4) ACADEMIC_GPA	(5) ACADEMIC_GPA	(6) MATR_GPA	(7) SOCIAL_RANKING	(8) GINI100	(9) SOCIAL_RANKING	(10) GINI100
Constant	81.51***	81.87***	89.73***	77.59***	77.33***	77.68***	60.91***	44.33***	60.91***	44.33***
	(0.73)	(0.75)	(1.34)	(2.42)	(2.46)	(4.40)	(0.78)	(0.17)	(0.78)	(0.17)
SOCIAL_RANKING	0.02*	0.02	0.08***	–	–	–	–	–	–	–
	(0.01)	(0.01)	(0.02)	–	–	–	–	–	–	–
GINI100	–	–	–	0.12**	0.13**	0.39***	–	–	–	–
	–	–	–	(0.06)	(0.06)	(0.10)	–	–	–	–
OU	–	–	–	–	–	–	-4.26***	-1.05***	-4.45***	-1.14***
	–	–	–	–	–	–	(1.01)	(0.22)	(1.04)	(0.23)
Sample	Pooled	Pooled with full Matriculation		Pooled	Pooled with full Matriculation		Pooled	Pooled	Pooled with full Matriculation	
Observations	1,085	997	997	1,082	993	993	1,085	1,082	997	993
R-squared	0.00	0.00	0.01	0.00	0.01	0.01	0.02	0.02	0.02	0.02
Beta Coefficient	5.91%*	4.94%	12.01%***	6.67%**	7.30%**	12.18%***	-12.76%***	-14.31%***	-13.45%***	-15.61%***

Notes: Standard errors are given in parentheses. SOCIAL_RANKING is measured by the Israeli Central Bureau of Statistics for each city or town with population above 3,000 persons on a scale of between 0 (the worst social ranking) to 100 (the best social ranking. GINI100 is the Gini coefficient of each city or town with population above 3,000 persons and multiplied by 100. The Beta Coefficient equals to the Pearson Correlation. * significant at a 10% significance level. ** significant at a 5% significance level. *** significant at a 1% significance level.

Table 12: Determinants of Probability of Receiving a Full Matriculation Certificate

VARIABLES	(1)	(2)	(3)	(4)
	FULL_MATR			
Constant	0.91***	0.69***	0.96***	0.90***
	(0.13)	(0.08)	(0.06)	(0.02)
ACADEMIC_GPA	-0.00	–	-0.00	–
	(0.00)	–	(0.00)	–
COURSES_PER_SEMESTER	0.02***	0.02***	0.03*	–
	(0.00)	(0.00)	(0.02)	–
NO_PRIVATE	-0.00	–	-0.01	–
	(0.01)	–	(0.03)	–
FULL_FINANCE	-0.00	–	-0.01	–
	(0.01)	–	(0.04)	–
EDU_HIGH	0.00	–	0.00	–
	(0.01)	–	(0.03)	–
MARRIED	0.01	–	0.04	–
	(0.01)	–	(0.04)	–
ACTIVITIES	0.03**	0.03**	0.07**	0.07***
	(0.01)	(0.01)	(0.03)	(0.03)
INVEST_OWNER	0.00	–	0.01	–
	(0.01)	–	(0.04)	–
ROOMS_PER_CAPITA	-0.02	–	-0.05	–
	(0.01)	–	(0.04)	–
FEMALE	0.02*	–	0.05*	–
	(0.01)	–	(0.03)	–
AGE−20	-0.00***	-0.00***	-0.01***	-0.01***
	(0.00)	(0.00)	(0.00)	(0.00)
Groups	POOLED	POOLED	OU=1	OU=1
Pseudo R-Squared	0.20	0.19	0.07	0.05
Observations	1,231	1,231	718	718

Notes: We employed the probit methodology. Coefficients are in terms of marginal probabilities. Columns (1) and (3) ((2) and (4)) provide estimates of the full (step-wise) model (i.e., only significant coefficients at the 5% and 1% significance levels). Standard errors are given in parentheses. *significant at a 10% significance level. ** significant at a 5% significance level. *** significant at a 1% significance level.

Figure 1: Kernel Density: Normalized Values of Matriculation and Academic GPA: Open University Students with Full Matriculation Certificate

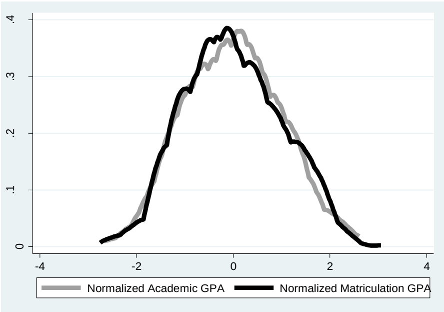

Figure 2: Kernel Density: Normalized Values of Matriculation and Academic GPA: Standard University Students with Full Matriculation certificate

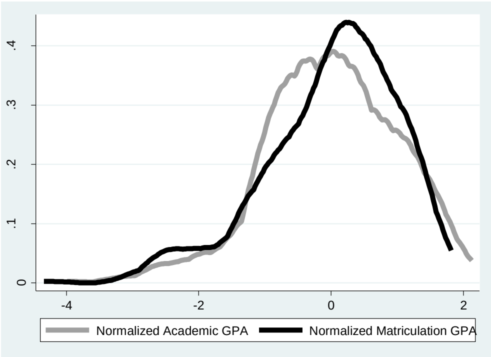

Figure 3: Regression Analysis: University GPA compared to Matriculation GPA

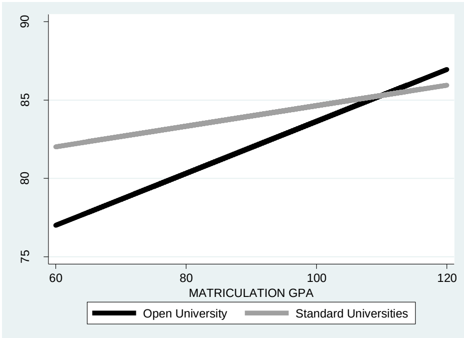

Figure 4: Covariate Balance Plot of Matriculation GPA

Notes: The Raw (Matched) plot refers to the distribution of matriculation GPA before and after the weighting based on the PSMATCH estimator.

Appendix A:

Here, we prove propositions 1–5:

Proof of proposition 1: The proof follows immediately from assumption 2 and the assumption that $\nu(a|b)=\nu(a)$. □

Proof of proposition 2: Under restricted admission, the investment in higher education depends on the signal. The introduction of a proportional subsidy does not change the signals; therefore, it does not induce more individuals to invest in higher education and does not lead to higher aggregate human capital stock. □

Proof of proposition 3: According to proposition 2, the introduction of a proportional subsidy does not change the investment in higher education; therefore, condition (i) is fulfilled with a strict equality. For any $y \in \left[\underline{y}, y''\right)$, we have $A(H)w = A(H_p)w$, and for any $y \in [y'', \bar{y}]$, we have $I_p(y) - I(y) = Rs - \tau_p\left(\bar{a}_y w - R(1-s)\right) = \tau_p\left(R - \bar{a}_y w\right)$. From equation (17), the fiscal budget must be balanced and, by assumption 5, $\bar{a}_y$ is increasing with y for any $y \in [y'', \bar{y}]$. Therefore, there is a signal $\hat{y} \in (y'', \bar{y})$ such that $I_p(y) - I(y) > 0 \ \forall\, y \in [y'', \hat{y})$ and $I_p(y) - I(y) < 0 \ \forall\, y \in (\hat{y}, \bar{y}]$. As such, condition (ii) is satisfied. □

Proof of proposition 4: We use $Y_{e,b_i} = [y'', \bar{y}] := \left\{ y \in Y \,\middle|\, x(y) = 1, b = b_i \right\}$ to denote the set of all individuals of background level $i \ (i = 1, 2)$ who invest in higher education.

From proposition 1, we know that $p_{b_2}^e \equiv \dfrac{\mu\left(Y_{e,b_2}\right)}{\mu(b_2)} > \dfrac{\mu\left(Y_{e,b_1}\right)}{\mu(b_1)} \equiv p_{b_1}^e$. By shifting a proportion β of the lower background population to a higher background level, the investment in higher education increases by $\beta\mu(b_2)\left(p_{b_1}^e - p_{b_2}^e\right)$. □

Proof of proposition 5: From proposition 4 and since aggregate consumption equals aggregate income, condition (i) is satisfied.

For all $y \in \left[\underline{y}, y''\right)$, $I_b(y) - I(y) = A(H_b)w - A(H)w > 0$ holds. For any $y \in [y'', \bar{y}]$, $I_b(y) - I(y) = w\left(A(H_b) - A(H)\right) - \tau_b\left(\bar{a}_y w - R\right)$. From equation (23), the fiscal budget is balanced, and based on assumption (5), $\bar{a}_y$ increases with y; therefore, $-\tau_b w \frac{\partial \bar{a}_y}{\partial y} < 0$ holds. Thus, we can state that there is either a signal $\hat{y} \in [y'', \bar{y}]$ such that $I_b(y) - I(y) > 0 \ \forall\, y \in [y'', \hat{y})$ and $I_b(y) - I(y) < 0 \ \forall\, y \in (\hat{y}, \bar{y}]$ or $I_b(y) - I(y) > 0 \ \forall\, y \in [y'', \bar{y}]$. Therefore, condition (ii) is satisfied. □

Appendix B:

Table 13: Distribution characteristics: Normalized Values of Matriculation and Academic GPA - Open University Students with Full Matriculation Certificate

Statistics	Academic GPA	$100 \cdot$ (MATR/120)
Observations	615.00	615.00
Minimum	65.00	50.00
Median	82.00	73.33
Mean	81.71	73.61
Maximum	98.00	93.33
Skewness	0.07	0.10
Calculated p-value for rejection of symmetrical distribution	$47.75 \cdot 10^{-2}$	$32.43 \cdot 10^{-2}$

Table 14: The joint distribution of academic GPA and matriculation GPA - Open University Students with Full Matriculation Certificate

		$100 \cdot$ (MATR/120)					
ACADEMIC GPA		50-59	60-69	70-79	80-89	90-99	Total
	50-59	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	60-69	0.00%	0.33%	0.49%	0.65%	0.00%	1.46%
	70-79	3.25%	12.20%	14.15%	4.23%	0.65%	34.47%
	80-89	0.16%	13.01%	25.53%	12.03%	1.14%	51.87%
	90-99	0.16%	2.44%	5.20%	3.41%	0.98%	12.20%
	Total	3.58%	27.97%	45.37%	20.33%	2.76%	100.00%

An asymptotic symmetry and marginal homogeneity tests are designed to test whether the matrix of joint distributions is symmetrical and whether the marginal probabilities of each category are equal. Both reject the null hypothesis of symmetry and equality of marginal probabilities at the 1%-level. The calculated Chi-squared value of the symmetry (marginal homogeneity) test with 9 (4) degrees of freedom is 294.78 (271.57).

Table 15: Distribution characteristics: Normalized Values of Matriculation and Academic GPA – Standard University Students

Statistics	Academic GPA	$100 \cdot$ (MATR/120)
Observations	513.00	513.00
Minimum	60.00	58.33
Median	85.00	86.66
Mean	84.79	85.36
Maximum	98.00	96.67
Skewness	-0.41***	-0.84***
Calculated p-value for rejection of symmetrical distribution	0.00	0.00

Table 16: The joint distribution of academic GPA and matriculation GPA - Standard University Students

		$100 \cdot$ (MATR/120)					
ACADEMIC GPA		50-59	60-69	70-79	80-89	90-99	Total
	50-59	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	60-69	0.00%	0.00%	0.19%	0.78%	0.19%	1.17%
	70-79	0.00%	0.19%	1.36%	8.75%	3.31%	13.62%
	80-89	0.19%	1.36%	9.92%	34.82%	14.20%	60.51%
	90-99	0.00%	0.19%	4.28%	11.28%	8.95%	24.71%
	Total	0.19%	1.75%	15.76%	55.64%	26.65%	100.00%

An asymptotic symmetry and marginal homogeneity tests are designed to test whether the matrix of joint distributions is symmetrical and whether the marginal probabilities of each category are equal. Both tests support the null hypothesis of symmetry and equality of marginal probabilities. The calculated Chi-squared value of the symmetry (marginal homogeneity) test with 7 (4) degrees of freedom is 4.55 (3.72). The calculated p-value is 0.71 (0.44). *** significantly different from zero at the 1% significance level.

Table 17: Stratification of Academic and Matriculation GPA by Math Level of Matriculation Exam

		(1)	(2)		(3)	(4)
VARIABLES	observations	ACADEMIC_GPA	ACADEMIC_GPA	observations	ACADEMIC_GPA	ACADEMIC_GPA
MATH3	229 [37%]	81.09	81.09***	83 [16%]	84.46	84.46***
		(0.41)	(0.41)		(0.68)	(0.68)
MATH4	238 [39%]	81.00	-0.09	183 [36%]	84.61	0.15
		(0.40)	(0.57)		(0.46)	(0.82)
MATH5	148 [24%]	83.82	2.73***	247 [48%]	85.06	0.60
		(0.51)	(0.65)		(0.40)	(0.79)
universities	OU	OU	OU	STANDARD	STANDARD	STANDARD
Observations	615 [100%]	615	615	513 [100%]	513	513
R-squared		0.99	0.04		0.99	0.00

		(1)	(2)		(3)	(4)
VARIABLES	observations	MATR_GPA	MATR_GPA	observations	MATR_GPA	MATR_GPA
MATH3	229 [37%]	83.55	83.55***	83 [16%]	95.39	95.39***
		(0.62)	(0.62)		(0.70)	(0.70)
MATH4	238 [39%]	88.75	5.20***	183 [36%]	100.80	5.42***
		(0.60)	(0.86)		(0.47)	(0.85)
MATH5	148 [24%]	95.07	11.52***	247 [48%]	106.03	10.64***
		(0.77)	(0.98)		(0.41)	(0.81)
universities	OU	OU	OU	STANDARD	STANDARD	STANDARD
Observations	615 [100%]	615	615	513 [100%]	513	513
R-squared		0.99	0.18		1.00	0.27

Notes: Academic GPA is on a scale of 60-100 points. Matriculation GPA is on a scale of 60-120 points. MATH3, MATH4, MATH5 equals 1 if the respondent chose to take the elementary, intermediate and high level of Mathematics matriculation test. OU (STANDARD) equals 1 if the respondent has a full matriculation certificate and studies in an Open (Standard) university. In columns (1) and (3) ((2) and (4)) we included (excluded) the base category (MATH3). Standard errors [relative frequencies] are given in round [squared] parentheses. * significant at a 10% significance level, ** significant at a 5% significance level, and *** significant at a 1% significance level.

Table 18 Stratification of Academic and Matriculation GPA by English Level of Matriculation Exam

		(1)	(2)		(3)	(4)
VARIABLES	observations	ACADEMIC_GPA	ACADEMIC_GPA	observations	ACADEMIC_GPA	ACADEMIC_GPA
ENGLISH3	60 [10%]	79.62	79.62***	0 [0%]	–	–
		(0.79)	(0.79)		–	–
ENGLISH4	253 [41%]	80.75	1.14	100 [19%]	83.99	83.99***
		(0.39)	(0.88)		(0.62)	(0.62)
ENGLISH5	302 [49%]	82.93	3.31***	413 [81%]	85.00	1.01
		(0.35)	(0.87)		(0.31)	(0.69)
universities	OU	OU	OU	STANDARD	STANDARD	STANDARD
Observations	615 [100%]	615	615	513 [100%]	513	513
R-squared		0.99	0.04		0.99	0.01

		(1)	(2)		(3)	(4)
VARIABLES	observations	MATR_GPA	MATR_GPA	observations	MATR_GPA	MATR_GPA
ENGLISH3	60 [10%]	81.90	81.90***	0 [0%]	–	–
		(1.25)	(1.25)		–	–
ENGLISH4	253 [41%]	85.68	3.78***	100 [19%]	97.92	97.92***
		(0.61)	(1.39)		(0.71)	(0.71)
ENGLISH5	302 [49%]	91.84	9.94***	413 [81%]	103.54	5.62***
		(0.56)	(1.36)		(0.35)	(0.80)
universities	OU	OU	OU	STANDARD	STANDARD	STANDARD
Observations	615 [100%]	615	615	513 [100%]	513	513
R-squared		0.99	0.11		1.00	0.09

Notes: Academic GPA is on a scale of 60-100 points. Matriculation GPA is on a scale of 60-120 points. ENGLISH3, ENGLISH4, ENGLISH5 equals 1 if the respondent chose to take the elementary, intermediate and high level of English matriculation test. OU (STANDARD) equals 1 if the respondent has a full matriculation certificate and studies in an Open (Standard) university. In columns (1) and (3) ((2) and (4)) we included (excluded) the base category (ENGLISH3 and ENGLISH4). Standard errors [relative frequencies] are given in round [squared] parentheses. * significant at a 10% significance level, ** significant at a 5% significance level, and *** significant at a 1% significance level.

Table 19: Correlation between the Choice of faculties and of High Math and English Levels in high school

	(1)	(2)	(3)	(4)
VARIABLES	MATH5	ENGLISH5	MATH5	ENGLISH5
Constant	0.10***	0.15**	0.27***	0.74***
	(0.02)	(0.07)	(0.04)	(0.06)
SOCIAL	–	0.43***	–	0.05
	–	(0.09)	–	(0.06)
MANAGEMENT	0.17***	0.35***	0.16***	-0.05
	(0.04)	(0.10)	(0.06)	(0.06)
EXACT	0.59***	0.48***	0.40***	0.17***
	(0.07)	(0.06)	(0.05)	(0.05)
	OU	OU	STANDARD	STANDARD
Observations	615	615	513	513
Pseudo R-Squared	0.08	0.03	0.09	0.06

Notes: To generate the results we use the probit regression. Coefficients of variables are given in terms of marginal probabilities. MATH5 (ENGLISH5) equals 1 if the respondent chose to take the highest level of Mathematics (English) matriculation test. SOCIAL includes social sciences and law. MANAGEMENT includes Economics, Management and Accounting. EXACT includes exact and life sciences. The base category is HUMANITIES and SOCIAL. OU (STANDARD) equals 1 if the respondent has a full matriculation certificate and studies in an Open (Standard) university. Standard errors are given in parentheses. * significant at a 10% significance level, ** significant at a 5% significance level, and *** significant at a 1% significance level.

Table 20: Correlation Matrix: Proxies of Location at High School Period

	GPA								
	ACADEMIC	MATR	MATH3	MATH4	MATH5	POP	POP_DENSITY	SOCIAL_RANKING	GINI100
ACADEMIC_GPA	100.00%								
	1128								
MATR_GPA	30.36%***	100.00%							
	0.00%								
	1128	1128							
MATH3	-10.90%***	-43.26%***	100.00%						
	0.02%	0.00%							
	1128	1128	1128						
MATH4	-6.62%**	-5.12%*	-47.72%***	100.00%					
	2.62%	8.58%	0.00%						
	1128	1128	1128	1128					
MATH5	16.93%***	45.76%***	-45.39%***	-56.65%	100.00%				
	0.00%	0.00%	0.00%	0.00%					
	1128	1128	1128	1128	1128				
POP	0.32%	4.98%	-0.43%	2.63%	-2.27%	100.00%			
	91.67%	10.06%	88.63%	38.55%	45.42%				
	1088	1088	1088	1088	1088	1088			
POP_DENSITY	-1.45%	3.07%	2.48%	-1.85%	-0.45%	19.57%	100.00%		
	64.81%	33.35%	43.43%	56.08%	88.72%	0.00%			
	992	992	992	992	992	992	992		
SOCIAL_RANKING	4.94%	12.01%***	-8.50%***	-5.30%*	13.26%***	22.63%***	9.00%***	100.00%	
	11.88%	0.01%	0.73%	9.43%	0.00%	0.00%	0.46%		
	997	997	997	997	997	997	992	997	
GINI100	7.30%**	12.18%***	-9.66%***	-2.08%	11.10%***	17.86%***	-7.05%**	71.56%***	100.00%
	2.14%	0.01%	0.23%	51.17%	0.05%	0.00%	2.67%	0.00%	
	993	993	993	993	993	993	988	993	993

Notes: The table provides the correlation matrix of proxies of location at high school period for the pooled sample of respondents with full matriculation certificate. For each element of the matrix, the upper row provides the Pearson correlation, the middle row (in brackets) provides the calculated p-value for rejection of the null hypothesis of zero correlation, the lower row provides the number of observations. * significant at a 10% significance level. ** significant at a 5% significance level. *** significant at a 1% significance level.

Table 21: Correlation Matrix: Proxies of Selected Ability and Background Characteristics

	GPA								
	ACADEMIC	MATR	MATH3	MATH4	MATH5	FULL_FINANCE	EDU_HIGH	MARRIED	ACTIVITIES
ACADEMIC_GPA	100.00%								
	1231								
MATR_GPA	30.36%***	100.00%							
	(0.00%)								
	1128	1128							
MATH3	–10.90%***	–43.26%***	100.00%						
	(0.02%)	(0.00%)							
	1128	1128	1128						
MATH4	–6.62%**	–5.12%*	–47.72%***	100.00%					
	(2.62%)	(8.58%)	(0.00%)						
	1128	1128	1128	1128					
MATH5	16.93%***	45.76%***	–45.39%***	–56.65%***	100.00%				
	(0.00%)	(0.00%)	(0.00%)	(0.00%)					
	1128	1128	1128	1128	1128				
FULL_FINANCE	9.15%***	20.36%***	–8.27%***	–3.64%	11.45%***	100.00%			
	(0.13%)	(0.00%)	(0.54%)	(22.13%)	(0.01%)				
	1231	1128	1128	1128	1128	1231			
EDU_HIGH	8.83%***	28.36%***	–12.76%***	–3.23%	15.24%***	22.34%***	100.00%		
	(0.19%)	(0.00%)	(0.00%)	(27.80%)	(0.00%)	(0.00%)			
	1231	1128	1128	1128	1128	1231	1231		
MARRIED	–1.04%	5.26%*	–5.81%*	7.18%**	–1.83%	8.38%***	–3.60%	100.00%	
	(71.48%)	(7.74%)	(5.11%)	(1.58%)	(53.82%)	(0.32%)	(20.63%)		
	1231	1128	1128	1128	1128	1231	1231	1231	
ACTIVITIES	2.00%	6.68%**	–11.62%***	5.93%**	4.89%	9.15%***	17.52%***	1.62%	100.00%
	(48.35%)	(2.48%)	(0.01%)	(4.66%)	(10.07%)	(0.13%)	(0.00%)	(57.11%)	
	1231	1128	1128	1128	1128	1231	1231	1231	1231
INVEST_OWNER	5.02%*	14.13%***	–5.26%*	–5.10%*	10.11%***	17.11%***	15.13%***	–5.53%*	4.60%
	(7.82%)	(0.00%)	(7.76%)	(8.66%)	(0.07%)	(0.00%)	(0.00%)	(5.22%)	(10.67%)
	1231	1128	1128	1128	1128	1231	1231	1231	1231
ROOMS_PER	6.77%**	16.58%***	–11.17%***	–2.28%	12.78%***	19.70%***	20.79%***	–18.75%***	12.02%***
_CAPITA	(1.75%)	(0.00%)	(0.02%)	(44.42%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)
	1231	1128	1128	1128	1128	1231	1231	1231	1231

Notes: The table provides the correlation matrix of proxies of selected ability and background characteristics for the pooled sample of respondents with full matriculation certificate. For each element of the matrix, the upper row provides the Pearson correlation, the middle row (in brackets) provides the calculated p-value for rejection of the null hypothesis of zero correlation, the lower row provides the number of observations. * significant at a 10% significance level. ** significant at a 5% significance level. *** significant at a 1% significance level.