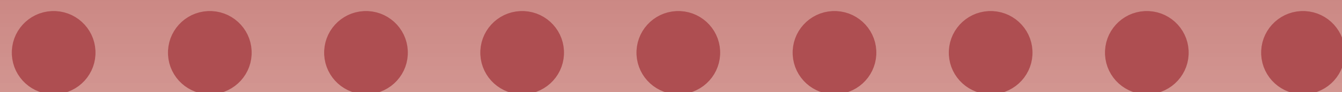
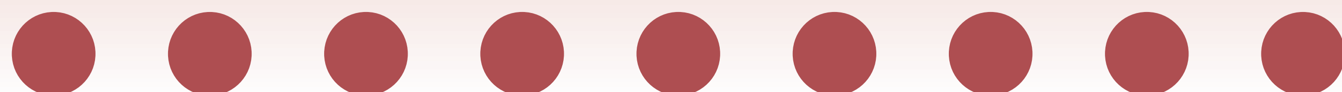
Samuel Neaman Institute
FOR ADVANCED STUDIES IN SCIENCE AND TECHNOLOGY

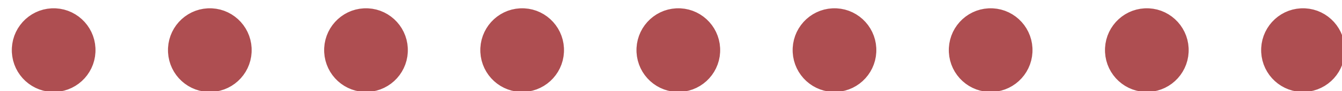
Technion
Israel Institute of Technology



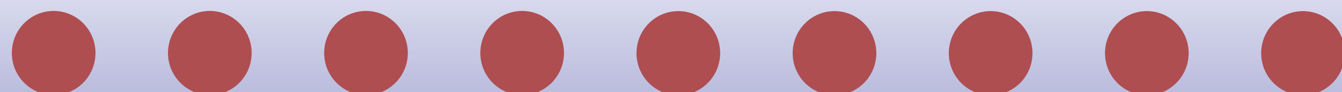
Equity and Efficiency Effects of Different Funding Arrangements for Higher education:
A Calibrated Analysis Applied to Israel

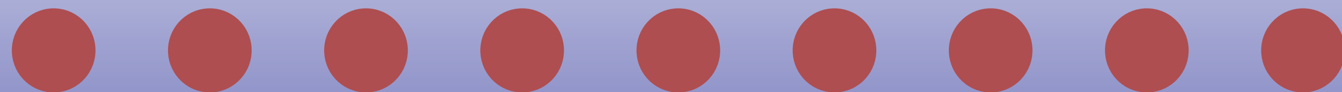
Yaakov Gilboa • Moshe Justman

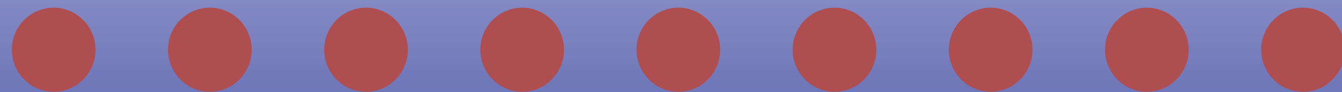




2 Economics of Higher Education







ABOUT THE INSTITUTE

The Samuel Neaman Institute for Advanced Studies in Science and Technology is an independent public-policy research institute, established in 1978 to assist in the search for solutions to national problems in science and technology, education, economy and industry, and social development. As an interdisciplinary think-tank, the Institute draws on the faculty and staff of the Technion, on scientists from other institutions in Israel, and on specialists abroad. The Institute serves as a bridge between academia and decision makers in government, public institutions and industry, through research, workshops and publications.

The main emphasis in the professional activity of the Samuel Neaman Institute is in the interface between science, technology, economy and society. Therefore the natural location for the Institute is at the Technion, which is the leading technological university in Israel, covering all the areas of science and engineering. This multi-disciplinary research activity is more important today than ever before, since science and technology are the driving forces for growth and economic prosperity, and they have a significant influence on the quality of life and a variety of social aspects.

The Institute pursues a policy of inquiry and analysis designed to identify significant public policy problems, to determine possible courses of action to deal with the problems, and to evaluate the consequences of the identified courses of action.

As an independent not-for-profit research organization, the Institute does not advocate any specific policy or embrace any particular social philosophy. As befits a democratic society, the choices among policy alternatives are the prerogative and responsibility of the elected representatives of the citizenry. The Samuel Neaman Institute endeavors to contribute to a climate of informed choice.

The Institute undertakes sponsored research, organizes workshops and implements continuing education activities on topics of significance for the development of the State of Israel, and maintains a publications program for the dissemination of research and workshop findings. Specific topics for research may be initiated by the Institute, researchers, government agencies, foundations, industry or other concerned institutions. Each research program undertaken by the Institute is designed to be a significant scholarly study worthy of publication and public attention.

Origins

The initiative for establishing this Institute in Israel was undertaken by Mr. Samuel Neaman. He nurtured the concept to fruition with an agreement signed in 1975 between himself, the Noon Foundation, the American Society for Technion, and Technion. It was ratified in 1978 by the Senate of the Technion. Mr. Neaman, a prominent U.S. businessman noted for his insightful managerial concepts and innovative thinking, as well as for his success in bringing struggling enterprises to positions of fiscal and marketing strength, devoted his time to the activities of the Institute, until he passed away in 2002.

Organization

The Director of the Samuel Neaman Institute, appointed jointly by the President of the Technion and by the Chairman of the Institute Board, is responsible for formulating and coordinating policies, recommending projects and appointing staff. The current Director is Professor Nadav Liron. The Institute Board of directors is chaired by Prof. Zehev Tadmor. The Board is responsible for general supervision of the Institute, including overall policy, approval of research programs and overseeing financial affairs. An Advisory Council made up of members of the Technion Senate and distinguished public representatives, reviews research proposals and consults on program development.

Equity and Efficiency Effects of Different Funding Arrangements for Higher Education: A Calibrated Analysis Applied to Israel

Yaakov Gilboa
Sapir Academic College

Moshe Justman
Ben-Gurion University of the Negev

Abstract

We construct a macro-model of an economy with skilled and unskilled labor, and a centralized system of higher education, calibrate it to the parameters of Israel's economy and university system, and then use it to simulate different modes of financing higher education so as to gauge their effect on output, distribution and mobility. We find that student loans by themselves have a small effect on access to higher education. Substantial increases in enrollment and graduation rates of students from low-income households require targeted tuition and living subsidies, and even these leave substantial gaps in enrollment and graduation rates between students from different social strata. Efforts to achieve more egalitarian access to higher education should begin at an earlier age.

Prepared for the Program on the Economics of Higher Education, the Samuel Neaman Institute for Advanced Studies in Science and Technology

1. Introduction

Budgetary pressures stemming from the "massification" of higher education are leading various countries to experiment with different funding arrangements through which, it is hoped, it will be possible to raise additional funds for the further expansion of higher education without sacrificing quality or limiting access. These reforms are generally structured on the principle that students are charged cost-based tuition while being offered loans that remove liquidity constraints. In this paper we consider the effect of such arrangements through a calibrated macro-economic model of the Israeli economy.

In many countries higher education is widely viewed as an entitlement—a natural extension of elementary and high school education—for which tuition should not be charged. Indeed, some countries additionally offer, or have offered in the past, subsistence grants, recognizing that these costs often dwarf the modest fees charged by public universities. Removing these subsidies, it is argued, would allow only students from wealthier homes access to higher education and the employment opportunities that it opens up. These arguments are countered by the observation that access to higher education is limited in the first place by completion of a high school education, which is itself positively correlated with parental income. Consequently, large subsidies to higher education, beyond what is needed to fund university research, are inherently regressive as they favor the more affluent elements of society while, in effect, draining resources that might be better used to achieve more equitable outcomes in primary and secondary education.

Charging students the cost of their tuition while offering them loans to cover both tuition fees and living expenses while they study should make it politically easier to

mobilize additional resources for public higher education, as these will be used for funding loans rather than subsidies, matched by students' willingness to take on long-term financial commitments to finance their education. To further ensure that access is not compromised but indeed broadened, repayment of these loans is generally dependent on the students' income: annual repayment is limited to a given fraction of income and may be forgone in years when income drops below some threshold; and sometimes there is an age limit on repayment at which any remaining debt is forgiven. Such arrangements recognize that investing in higher education, while profitable on average, carries substantial risks for the individual. Students form low-income background may lack the complementary assets that help translate higher education into higher earnings and would find it especially difficult to absorb the financial loss entailed in an education that does not lead to higher earnings.

There is already some preliminary empirical evidence that such schemes need not compromise access to higher education. In the United States, where public universities charge significant tuition compared to European universities (though it is of course much lower than tuition charged at most private universities) empirical analysis indicates that only a small fraction of students are denied access due to liquidity constraints. In Australia and New Zealand, where such policies are already in place, tertiary enrollment rates no lower than in countries such as Denmark, France, Germany, Ireland and Sweden that charge little or no tuition (Table 1).[1]

Table 1. Net tertiary enrollment rates (percent)

Australia	65	Korea	49
Austria	34	Mexico	26
Belgium	32	Netherlands	54
Czech Republic	30	New Zealand	76
Denmark	44	Norway	62
Finland	72	Poland	67
France	37	Slovakia	40
Germany	32	Spain	48
Hungary	56	Sweden	69
Iceland	61	Switzerland	33
Ireland	38	Turkey	20
Italy	44	United Kingdom	45
Japan	41	United States	42

Source: OECD (2003, table C2.1)

We consider this question by simulating different funding arrangements for higher education within the framework of a calibrated overlapping-generations macroeconomic model of the Israeli economy that incorporates a centralized system of higher education. Production is a function of skilled and unskilled labor, as well as capital structures and equipment, and the model allows education to affect earnings through both the accumulation of human capital and a signaling effect. Our calibration follows Krusell et al. (2000), which found a greater elasticity of substitution between capital equipment and unskilled labor than between capital equipment and skilled labor. Consequently, wages are affected by four factors: the marginal productivity of a unit of human capital in one's occupation (skilled or unskilled); one's own human capital; the average human capital of others in the same occupation; and a random effect.[2] Entry to higher education is regulated by academic admissions standards and payment of a tuition

fee and it is assumed that students cannot earn money while they are studying. Obtaining a degree that opens the door to employment in the skilled occupation depends also on passing a final examination the difficulty of which is held fixed throughout our analysis.[3] Liquidity constraints are modeled by assuming that absent government intervention, the rate of interest at which one can borrow money to finance tuition and living expenses during higher education is a decreasing function of parental income. Prospective students have expectations regarding future earnings and knowledge of their probability of successfully graduating, on which they base their decisions whether to study or not. We focus on an equilibrium in which their expectations are realized.

We begin by calibrating a benchmark case reflecting current practice in the higher education sector in Israel, in which an annual tuition of just under $2000 is charged and admission is regulated by academic criteria. We then employ the calibrated model to gauge the effect of different pricing policies for higher education while offering student-loans in the full sum of tuition and living expenses priced at the market rate of interest: current tuition, a 50% increase in current tuition, a 100% increase in current tuition, graduated tuition dependent on parental income, graduated tuition and living stipend dependent on parental income, and tuition insurance that forgives repayment of the debt if the student fails to graduate. In each case we consider policy implications for enrolment rates, graduation rates, intergenerational income mobility, and wage inequality, when these policies are applied over the time required for a full turnover of the labor force.

The approach presented in this paper builds on two important economic perspectives on education: macroeconomic analyses of how the accumulation of human

capital affects intergenerational mobility and wage inequality (e.g., Becker and Tomes, 1979; Loury, 1981; Bénabou, 1996; Durlauf, 1996; Hassler and Rodriguez-Mora, 2000) to which we add structural detail; and more structured analyses of higher education (Arrow, 1973; Spence, 1973; Stiglitz, 1975; Danziger, 1990; Loury and Garman, 1993; Fernandez and Gali, 1999; Epple, et al., 2003), which we extend here to consider macroeconomic tradeoffs between output, equality and mobility in a general equilibrium context.[4] More directly, the present paper is closely related to our previous analysis of the effect of admissions standards on output, inequality and mobility (Gilboa and Justman, 2005); to work by Bertocchi and Spagat (2004) and Checchi et al. (1999), which analyzes the impact of education systems on income inequality and social mobility; and to empirical analyses of the impact of different funding schemes on access to higher education, such as Keane (2002) and Chapman and Ryan (2005), and Barr's (2004) integrative essay.

The paper is organized as follows: Section 2 describes the analytical model; Section 3 calibrates it to observed empirical values; Section 4 compares different funding policies as they affect enrolment, graduation, output, distribution and mobility; and Section 5 concludes.

2. The model

We define an overlapping-generations model in which parents automatically bequeath innate abilities to their children and invest economic resources in their early development. Children then reach young adulthood with a record of prior achievement that indicates their academic potential. A centralized system of higher education

regulates admissions on the basis of this prior indicator, and possibly parental income. Those offered admission must then decide whether to enroll, which requires paying tuition and forgoing paid employment for the duration of studies. In the benchmark case, these costs are funded through the family at an interest rate that decreases with parental income; subsequently other funding schemes are considered. Those who choose to study and receive a passing grade earn a degree, which opens the door to employment in skilled jobs. Workers earn a wage determined by the average marginal productivity of their occupation (skilled or unskilled) and of their own human capital. Young adults anticipate their future wages in deciding whether to study or not, and we require that in equilibrium their anticipations are realized.

2.1 The household, before higher education

Consider an economy with a continuum of households, each comprising a parent and a child. Denote the lifetime disposable (after-tax) income of the parent in household i by y_i, and assume it is distributed lognormally in the population with mean μ_y and variance σ_y^2, $\ln y_i \sim N(\mu_y, \sigma_y^2)$. Denote by a_i the unobservable innate ability of the child in household i and assume that it is positively correlated with parental income:[5]

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

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

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

$$\ln h_i \;=\; A \;+\; \alpha \ln a_i \;+ \gamma \ln D + \;\delta \ln b_i \qquad (2)$$

where A, α, γ, and δ are constants. Assume parents' investment of economic resources b_i in their children's early development cannot be financed by borrowing against their children's future income (this is a capital market imperfection that cannot be resolved); and assume that parents maximize a utility function that is logarithmic in consumption and education spending. Then each parent spends a fixed proportion of income on supplementing pre-college public education,[6] $b_i \;=\; \xi y_i$ where ξ is a positive constant less than one. Using this to substitute for b_i in (2), and using (1) to substitute for a_i , we have

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

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

$$\mu_h = A \;+\; \gamma \ln D \;+ \delta \ln \xi \;+\; (\alpha + \delta)\, \mu_y \qquad (4)$$

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

We assume that individuals know their own human capital h_i but that the admissions process has access only to a stochastic entry score t_i that summarizes their record of prior academic achievement and is positively correlated with h_i

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

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

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

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

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

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

2.2 Higher education

There is a centralized system of higher education in the economy that offers a single degree. Admissions requirements to higher education are a function of the observable entry score t_i and parental income y_i. To fix ideas we focus on admissions criteria of the form

$$\phi t_i + (1 - \phi) \ln y_i \geq \theta \qquad (10)$$

where θ primarily determines the size of the student body and ϕ its composition. We assume that ϕ is positive, so that the left-hand side is always increasing in the entry score t_i, and consider two types of admissions policies with regard to parental income: income-neutral "merit-based" policies that ignore parental income and consider only prior academic achievement ($\phi = 1$); and income-based affirmative action policies that weigh parental income negatively, giving applicants from lower-income households an advantage in admissions ($\phi > 1$).[7] The minimal entry score that an applicant with parental income y_i needs to gain admission is:

$$\underline{t}(y_i, \phi, \theta) = [\theta - (1 - \phi) \ln y_i] / \phi \qquad (10a)$$

A student who is admitted and enrolls must pay an annual tuition fee P, and we assume that while studying maintains a basic consumption level of c_0. To graduate, students must attend school for T_e years, during which time they cannot work, and must earn a passing grade $\underline{s}$. Grades are a stochastic function of human capital:

$$s_i = \ln h_i + u_{si} \qquad (11)$$

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

and h, $\mu_s = \mu_t = \mu_h$, and a variance of:

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

Students who fail to attain a passing grade drop out of school after T_d years ($T_d \leq T_e$) and enter the labor market as non-graduates performing unskilled jobs. Graduation opens the door to skilled jobs.[8] If the student graduates, full tuition and living costs must be funded; failure occurs before the full course of study is completed so only partial tuition and living costs are incurred. In either case, we assume that the capital market for such funding is imperfect and that the relevant rate of interest decreases with parental income. We posit the functional form

$$r_i(y) = \max\{ r_a - r_b y_i , r_0\} \tag{13}$$

for the rate of interest paid by a household with parental income y_i , where r_0 is the market rate of interest and r_a and r_b are positive constants.

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

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

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

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

$$\rho_{hs} = \sigma_h / \sigma_s \tag{14d}$$

$$\rho_{ht} = \sigma_h / \sigma_t \tag{14e}$$

$$\rho_{ts} = \sigma_h^2 / [\sigma_t \sigma_s] \tag{14f}$$

2.3 Production and wages

Following Krusell et al. (2000) we assume that production in the economy is undertaken by a continuum of identical firms producing a single homogeneous good using the same constant returns-to-scale production function. Aggregate output equals

$$Y = F(H_u, H_s, K_e, K_s) \tag{15}$$

where H_u is the unskilled human capital of non-graduates, H_s is the skilled human capital of graduates, K_e is the stock of capital equipment, and K_s the stock of capital structures. Let w_u denote the average wage per unit of unskilled human capital; w_s the average wage per unit of skilled human capital; p_e the rental cost of a unit of capital equipment; and p_s the rental cost of a unit of capital structure. We assume that employers cannot fully or immediately observe individual human capital and so workers earn an income that is a weighted average of the value of their own marginal product and the average marginal product of all workers in their occupation, denoted h_k, $k = u,s$.[9] Let $0 < \upsilon < 1$ be the weight of own marginal product in this weighted average.[10] Then worker i in occupation $k = u,s$ earns an annual wage of:

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

An individual who does not attend college works for T_u years; one who studies and graduates, studies for T_e years and works for $T_s = T_u - T_e$ years; and one who studies and fails, studies for T_d years and works for $T_f = T_u - T_d$ years.

2.4 The decision to study

Assume that the lifetime utility of individual i is a discounted integral of temporal utility U at the subjective discount rate η where temporal utility $U = U(c_{it})$ is an increasing

concave function of consumption by individual i at time t. Individuals seek to maximize their expected utility given their anticipation of future graduate and non-graduate wage rates and of average graduate and non-graduate human capital, and we assume they all share the same anticipated values, $\omega = (w_s^e, w_u^e, h_s^e, h_u^e)$. Consider first a person who does not attend university. To simplify the analysis, assume that the borrowing rate of interest she faces is no lower than η and her lending rate is no higher than η so that she has no incentive to shift income from one period to the next. Then her lifetime utility—conditioned on her human capital h_i and on ω—is given by:

$$V_u(h_i, \omega) = \int_0^{T_u} U(w_u^e[\upsilon h_i + (1-\upsilon)h_u^e])e^{-\eta t} dt \tag{17}$$

Next, consider skilled workers who will have attended university and incurred a debt to cover their tuition and living expenses. Absent government intervention, the size of the debt upon graduation and entry into the workforce depends on parental income and equals:

$$D_s(y_i) = \int_0^{T_e} (P + c_0)e^{-r(y)t} dt \tag{19}$$

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

$$R_s(y_i) = D_s(y_i)\, r_0 \,/\, (1 - e^{-r_0(T_u - T_e)}) \tag{20}$$

The lifetime utility of a graduate, conditioned on having graduated, on parental income, on own human capital and on anticipated ω is then:

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

Similarly, one who enrolls in higher education but fails to graduate, incurs a debt of

$$D_f(y_i) = \int_0^{T_f} (P + c_0) e^{-r(y)t} dt \tag{22}$$

which is repaid by a continuous constant stream of

$$R_f(y_i) = D_f(y_i)\, r_0 / (1 - e^{-r_0(T_u - T_f)}) \tag{23}$$

Expected lifetime utility of one who studies but fails to graduate, similarly conditioned, then equals:

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

A person with parental income y_i and entry score t_i that meet the admissions requirements will choose to enroll in higher education if it increases her expected lifetime utility, taking into account her probability of graduating, and conditioned on her human capital h_i, her parental income y_i, and ω. Denoting the cumulative density function of s conditioned on h_i by $G(s \mid h_i)$, a prospective student expects to gain from attending college if

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

As both the probability of successfully graduating and the benefit of a degree increase monotonically in human capital, there is for every value of y_i a unique threshold level of human capital $\underline{h}(y_i, \omega)$ that satisfies (25) with equality, and such that individual i applies to study in higher education if and only if $h_i \geq \underline{h}(y_i, \omega)$.

2.5 Equilibrium

We assume that each cohort has measure one and that all capital, labor and product markets are competitive, except for the funding of education, and that the supply of

capital equipment and capital structures is perfectly elastic at the exogenous prices p_e and p_s.[11] We focus on an equilibrium in which the value of the marginal product of each of the factor inputs equals its price or wage; all anticipations are realized; markets clear; and the distribution of human capital across graduate and non-graduate labor in each cohort is the same.

To characterize the supply of skilled and unskilled labor, let $g(y, h, t, s)$ denote the joint density of y, h, t and s and assume that the admission criterion (10) and the graduation threshold $\underline{s}$ are given. Then the share of graduates in a cohort, given a vector of anticipated values ω, is

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

where, as above, $\underline{t}\,(y) = \underline{t}\,(y, \phi, \theta)$ is the minimal entry score that an applicant with parental income y needs to gain admission, and $\underline{h}\,(y,\omega)$ is the threshold level of human capital given by (25), above which a young adult with parental income y decides to enroll. The share of those who enter university but fail is:

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

The share of those who do not attend university, either because they choose not to or because they do not meet the entry requirements, is the remainder[12]

$$\varphi_n(\omega) = 1 - \varphi_s(\omega) - \varphi_f(\omega) \tag{28}$$

It follows that the measure of skilled workers in the workforce in steady-state equilibrium is $T_s\ \varphi_s\ (\omega)$, the measure of unskilled workers who enrolled in higher

education but failed to graduate is $T_f\,\varphi_f(\omega)$, and the measure of unskilled workers who did not enroll in higher education is $T_n\,\varphi_n(\omega)$.

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

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

so that the average human capital of a skilled worker is

$$h_s(\omega) = H_s(\omega) / [T_s\, \varphi_s(\omega)] \tag{30}$$

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

$$H_f(\omega) = T_f \int_{-\infty}^{\infty} \int_{\underline{h}(y,\omega)}^{\infty} \int_{\underline{t}(y)}^{\infty} \int_{-\infty}^{\underline{s}} h\, g\,(y,h,t,s)\, ds\, dt\, dh\, dy \tag{31}$$

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

$$\begin{aligned} H_n(\omega) = T_n \Bigg[& \int_{-\infty}^{\infty} \int_{-\infty}^{\underline{h}(\omega)} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} h\; g\,(y,h,t,s)\, ds\, dt\, dh\, dy \\ & + \int_{-\infty}^{\infty} \int_{\underline{h}(\omega)}^{\infty} \int_{-\infty}^{\underline{t}(y)} \int_{-\infty}^{\infty} h\; g\,(y,h,t,s)\, ds\, dt\, dh\, dy \Bigg] \end{aligned} \tag{32}$$

Consequently, the total human capital of unskilled workers equals

$$H_u(\omega) = H_n(\omega) + H_f(\omega) \tag{33}$$

and their average level of human capital is:

$$h_u(\omega) = H_u(\omega) / \; [T_f\, \varphi_f(\omega) + T_n\, \varphi_n(\omega)\,] \tag{34}$$

An equilibrium is then a vector $\omega^* = (w_s^*, w_u^*, h_s^*, h_u^*)$ and stocks of capital equipment and structures, K_e^* and K_s^*, such that:

$$h_s(\omega^*) = h_s^* \tag{35}$$

$$h_u(\omega^*) = h_u^* \tag{36}$$

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

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

$$\frac{\partial F}{\partial K_e}(H_u(\omega^*), H_s(\omega^*), K_e^*, K_s^*) = p_e \quad (39)$$

$$\frac{\partial F}{\partial K_s}(H_u(\omega^*), H_s(\omega^*), K_e^*, K_s^*) = p_s \quad (40)$$

3. Calibration

Calibrating the model to observed empirical variables allows us to derive a quantitative indication of how changes in the financing of higher education and in admissions policy may affect output, distribution and mobility. We adopt the specific functional form in Krusell et al. (2000), a nested Constant Elasticity of Substitution production function:

$$Y = A(K_s)^{\kappa}\{\nu(H_u)^{\psi} + (1-\nu)[\lambda(K_e)^{\varsigma} + (1-\lambda)(H_s)^{\varsigma}]^{\psi/\varsigma}\}^{1-\kappa/\psi} \quad (41)$$

with the estimated elasticities: $\kappa = 0.117$, $\zeta = -0.495$, and $\psi = 0.401$. This implies an elasticity of substitution of 1.67 between skilled and unskilled labor, and between capital equipment and unskilled labor; and an elasticity of substitution of 0.67 between capital equipment and skilled labor. The remaining parameters are scaling parameters, which are calibrated to obtain factor shares that are roughly consistent with 2003 values for Israel's business sector. The (gross) returns on capital structures and equipment are set equal to $p_s = 6\%$ and $p_e = 12\%$. Wages are determined as an equally weighted average

of own human capital and the average human capital of similarly skilled workers, i.e., $\upsilon = 0.5$.

Income, human capital, entry scores and course grades—ln y, ln h, t and s—are assumed to follow a multivariate normal distribution,[13] the parameters of which are related to observed empirical values as follows:

- The mean and variance of the logarithm of parental income, μ_y and σ_y^2, are derived from the distribution of net household income in Israel in 2003.[14]
- The marginal distributions of entry scores and course grades are assumed to be standardized normal, with $\mu_t = \mu_s = 0$ and $\sigma_t^2 = \sigma_s^2 = 1$. This implies that the logarithm of human capital μ_h also has zero mean.
- The correlation ρ_{yt} between parental income and entry scores is set equal to 0.25—within the range of empirical estimates of the correlation between parental income and pre-college aptitude test scores.[15]
- The correlation between parental income and course grades is assumed to be the same as between parental income and entry scores:[16] $\rho_{ys} = \rho_{yt} = 0.25$.
- The correlation between entry scores and course grades is set equal to:[17] $\rho_{ts} =$ 0.5.

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

We assume that studying to graduation requires four years of study, $T_e = 4$; that total tuition for the degree equals about one half of the annual salary of an unskilled worker, which we spread over four years; and that living expenses for a year equal about one third of the average wage of an unskilled worker. A student who fails is assumed to

study for half the time, T_d = 2, and pay half the tuition. The total working life of a graduate, after graduation, is T_s = 40; hence T_f = 42 and T_u = 44. The household annual discount rate is η = 6% and the temporal utility function has a constant coefficient of relative risk aversion equal to 1.2: $U(c) = -c^{-0.2}$.

In calibrating the benchmark case, we assume that admissions are based solely on test scores. We set the entrance threshold equal to θ = –0.2, that is, one fifth of a standard deviation below the mean, and the final pass score $\underline{s}$ equal to 0, the mean score in the population as a whole. Education costs are self-financed, and we assume that the interest rate for financing them depends on household income y and is equal to: $r(y) = 0.06 + 0.06\, y_m / y$. The interest rate in subsequent periods is r_0 = 0.06, which is the same as the subjective inter-temporal discount rate. This yields an enrolment share in higher education of 41.4%, which is slightly lower than the first-year enrolment share in tertiary education in Israel, 43.6%; and a share of graduates equal to 27.1%, slightly higher than the share of graduates in Israel's workforce, which is about 25% (Statistical Abstract of Israel, 2005, Table 14.7). The ratio of average wages of non-graduates to graduates equals 0.4, compared to 0.54 in the workforce between workers with less than a college education and workers with a college education or more (Statistical Abstract of Israel, 2005, Table 12.42).[18] The Gini coefficient of lifetime wage income we obtain equals 0.217, which is lower than observed values of the Gini coefficient computed for annual income: a lower value is to be expected if annual income is more variable than permanent income, and presumably also reflects the simpler structure of the model, which allows only two skill levels. We measure relative social mobility through the intergenerational correlation of the logarithm of incomes between parents and their

children. It equals 0.389 in the benchmark case, which is well within the range of values obtained for advanced industrialized economies.[19] The distribution of college enrollment and graduation shares by quintile of parental income is given in Table 2, along with the distribution of enrollment rates in Israel in 2003, by the socio-economic quintile of the local authority of residence, from the 2005 *Statistical Abstract of Israel*.

Table 2: Distribution of rates of enrolment and graduation in higher education: Simulation benchmark and observed values

Quintile	Enrolment rate by parent's income quintile (model benchmark)	Enrolment rate by local authority's socio-economic ranking (observed)	Share of graduates by parent's income quintile (model benchmark)
I	18.4%	23.4%	11.0%
II	31.4%	28.5%	19.5%
III	41.2%	42.1%	26.3%
IV	51.0%	52.5%	33.7%
V	64.7%	63.0%	45.8%
Total	41.4%	43.6%	27.1%

4. Simulation of alternative funding policies

We now apply our calibrated model to simulate different university funding policies and gauge their effect on output, distribution and social mobility after a full turnover of the labor force. Output is measured as indices of gross domestic product (GDP) and of labor income net of tuition costs, in relation to the benchmark case; distribution is measured as the Gini coefficient of lifetime labor income; relative mobility is measured as the intergenerational correlation of income; and absolute social mobility is measured through enrolment and graduation rates by quintiles of parental income. Unless

otherwise specified we assume that tuition and living costs to be financed at the uniform interest rate $r_0 = 0.06$ irrespective of parental income; we refer to this a perfect capital market (and denote it PCM) though clearly it will generally be the government that extends or guarantees at least some of the necessary credit. Entrance and graduation requirements are held fixed throughout.

The following tables and figures present three sets of comparisons. In the first set we consider the impact of removing liquidity constraints while possibly raising tuition. Three cases are considered and compared to the benchmark case: current tuition is charged (denoted PCM in the tables and figures); a 50% increase in current tuition (PCM+50%); and a 100% increase in current tuition (PCM+100%). For each of these, and the benchmark case (B), we present, in Table 3, enrolment and graduation rates, the Gini coefficient of lifetime incomes among a cohort,[20] the intergenerational correlation of incomes, gross domestic product, and labor income less education costs; and in Tables 4 and 5, enrolment and graduation rates by quintile.

Table 3:
Education, output, inequality and mobility under different pricing policies

	B	PCM	PCM+50%	PCM+100%
Enrolment rate in higher education	41.4%	42.4%	41.3%	40.2%
Share of graduates in the workforce	27.1%	27.7%	27.2%	26.7%
Income ratio, non-graduates to graduates	0.389	0.398	0.391	0.383
Intergenerational income correlation	0.367	0.369	0.367	0.366
Gini coefficient of lifetime income	0.217	0.213	0.216	0.219
Gross domestic product	100.0	100.2	100.0	99.9
Labor income net of education costs	100.0	100.1	99.9	99.7

Table 4. Enrolment rates by quintile, different pricing policies

Quintile	B	PCM	PCM+50%	PCM+100%
I	18.4%	20.2%	19.2%	18.1%
II	31.4%	33.2%	32.0%	30.7%
III	41.2%	42.6%	41.4%	40.1%
IV	51.0%	51.9%	50.8%	49.7%
V	64.7%	64.9%	64.1%	63.4%

Table 5. Graduate shares by quintile, different pricing policies

Quintile	B	PCM	PCM+50%	PCM+100%
I	11.0%	11.8%	11.3%	10.9%
II	19.5%	20.3%	19.7%	19.1%
III	26.3%	26.9%	26.4%	25.8%
IV	33.7%	34.1%	33.7%	33.2%
V	45.8%	45.9%	45.5%	45.2%

As Tables 4 and 5 show, removing liquidity constraints causes a modest expansion in overall enrollment and graduation rates, with substantially larger relative increases in the lowest quintiles of parental income, these latter increases representing an increase in absolute social mobility. The increase in the share of skilled workers in the economy leads to a small increase in the ratio of unskilled to skilled wages, which slightly reduces inequality. Output and labor income net of education costs rise slightly. Relative income mobility declines very slightly, measured as a small increase in the intergenerational correlation of income: the smaller gap between unskilled and skilled

wages renders higher education a less effective tool of relative income mobility. Raising tuition by 50% while removing liquidity constraints, results in conditions that are very similar to the benchmark case. Raising tuition by 100% slightly reduces enrolment and graduation rates with a consequent fall in output, a rise in inequality and a rise in mobility, however all three effects are weak.

In the second set of comparisons we consider the effect of graduated tuition, dependant on parental income, under a balanced budget constraint; and the effect of "tuition insurance". When only tuition is graduated (denoted G T in the tables and figures), students with parents in the lowest income quintile pay 25% of normal tuition; those with parents in the second quintile pay 75%; in the third, 100%; in the fourth 115%; and in the highest quintile, 125%. When tuition and living expenses are graduated (G T+L), those whose parents are in the lowest quintile receive a stipend that covers 60% of tuition and living costs; those whose parents are in the second quintile receives a stipend covering 25% of all costs; the third quintile receives no stipend, paying 100% of tuition and living expenses; students born to parents in the fourth income quintile are charged a tuition of 140%, which raises their total costs by 15%; and those born to parents in the highest quintile, are charged a tuition of 175%, which raises their total costs by 25%. We consider the effect of each schedule under the benchmark condition of an imperfect capital market (ICM) and with a perfect capital market (PCM). The effect of "tuition insurance" (denoted TI in the tables and figures) is considered under a perfect capital market, where no subsidy is offered but the debt incurred for tuition is forgiven if the student fails to graduate. Again, aggregate measures are presented in Table 6 and enrolment and graduation rates by quintile are presented in

Tables 7 and 8. We include again for comparison the case of a perfect capital market without stipends or insurance (PCM).

Table 6: Aggregate measures of equity and efficiency: Graduated tuition and stipends; tuition insurance

	PCM	G T ICM	G T PCM	G T+L ICM	G T+L PCM	TI PCM
Enrolment rate in higher education	42.4%	41.5%	42.7%	42.3%	43.4%	44.0%
Share of graduates in the workforce	27.7%	27.3%	27.8%	27.5%	28.0%	28.4%
Income ratio, non-graduates to graduates	0.398	0.392	0.400	0.397	0.403	0.408
Gini coefficient	0.213	0.215	0.212	0.214	0.211	0.209
Intergenerational income correlation	0.369	0.368	0.369	0.368	0.370	0.371
Gross domestic product	100.2	100.0	100.2	100.1	100.2	100.4
Labor income net of education costs	100.1	100.0	100.1	100.0	100.1	100.1

Tuition insurance raises enrolment and graduation rates in all quintiles, and so slightly reduces the Gini coefficient while raising output and slightly reducing relative mobility (as indicated by the rise in the intergenerational correlation of income). However, these effects may be countervailed by the element of moral hazard that tuition insurance introduces, which does not figure in our analysis. Graduated stipends for tuition and living expenses have a weak effect on aggregate measures but strongly improve access to higher education for the lowest quintile, where enrolment and graduation rates are respectively increased by 44% and 30% over a perfect capital market without grants, and by 58% and 39% over the benchmark case. In all cases, the differences between quintiles in enrolment and graduation rates remain large.

Table 7. Enrolment rates by quintile:
Graduated tuition and living expenses ; tuition insurance

Quintile	PCM	G T ICM	G T PCM	G T+L ICM	G T+L PCM	T I PCM
I	20.2%	21.7%	23.2%	28.4%	29.0%	21.9%
II	33.2%	32.4%	34.2%	35.6%	36.8%	35.2%
III	42.6%	40.8%	42.3%	40.2%	41.9%	44.4%
IV	51.9%	49.9%	51.0%	47.4%	49.0%	53.4%
V	64.9%	63.8%	64.0%	61.1%	61.6%	65.9%

Table 8. Graduation shares by quintile:
Graduated tuition and living expenses ; tuition insurance

Quintile	PCM	G T ICM	G T PCM	G T+L ICM	G T+L PCM	T I PCM
I	11.8%	12.4%	13.1%	15.1%	15.3%	12.5%
II	20.3%	19.9%	20.7%	21.3%	21.8%	21.1%
III	26.9%	26.1%	26.8%	25.9%	26.6%	27.7%
IV	34.1%	33.3%	33.8%	32.1%	32.8%	34.8%
V	45.9%	45.4%	45.5%	44.1%	44.3%	46.3%

Figures 1 and 2 present a graphic summary of the effect of these different funding policies on enrolment rates, and Figures 3 and 4 present a summary of these effects on the share of university graduates by parent's income quintile.

5. Conclusions

In this paper we constructed a macro-model of an economy with skilled and unskilled labor, and with a centralized system of higher education that trains skilled labor. After

calibrating the model to the parameters of Israel's economy and its higher education system, we used the model to simulate different modes of financing higher education that combined, in different permutations: student loans, variation in general tuition levels, graduated tuition and living stipends dependent on parental income, and tuition insurance. We find that student loans generally have a small effect on access to higher education, and a negligible effect on aggregate measures of output, distribution or relative social mobility, while offering the possibility of substantially raising tuition with little adverse effect on access. We also find that absorbing some of the risk of higher education by conditioning loans on successful graduation has a small positive effect on enrollment and graduation rates at all income levels, though this effect may be countervailed by the element of moral hazard that tuition insurance introduces, which we do not incorporate in our analysis. Finally, our results indicate that substantial increases in enrollment and graduation rates of students from low-income households can be achieved through targeted tuition and living subsidies.[21] However, even when such measures are introduced, the enrollment and graduation rates of students from more advantaged households remain much higher. By the time students reach college age much has already been determined: efforts to achieve a more egalitarian access to higher education must begin at an earlier age.

Figure 1. Enrolment rates, by income quintile

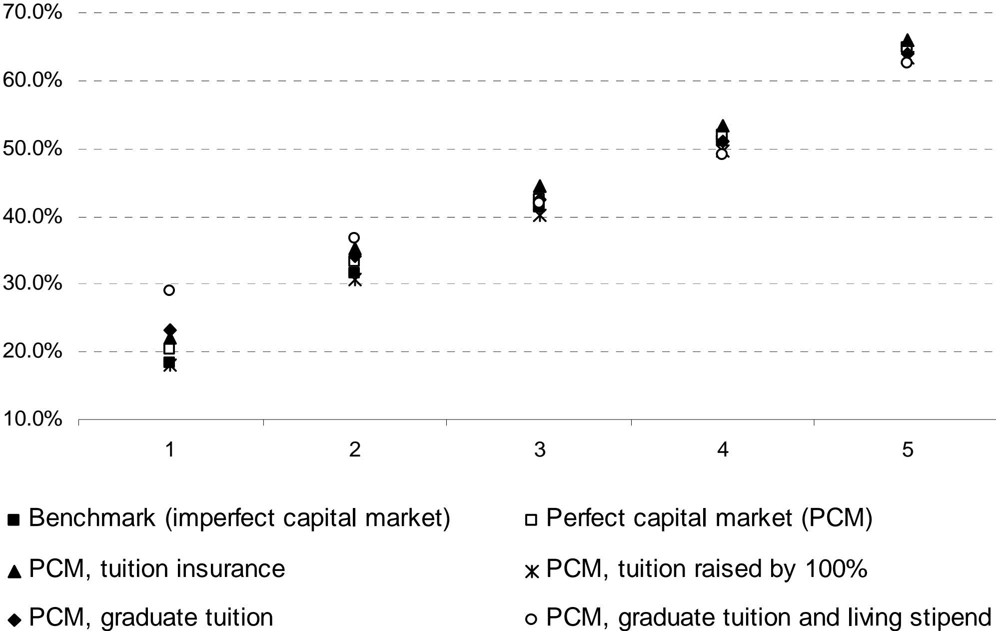


Figure 2. percent change in enrolment, by quintile

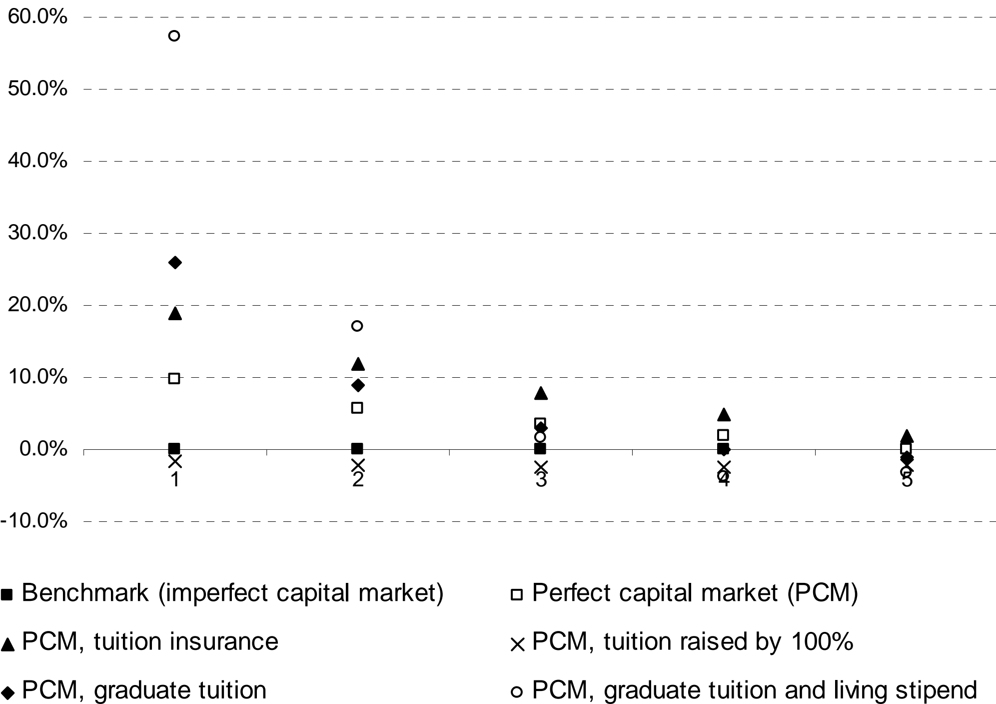


Figure 3. Share of graduates in quintile

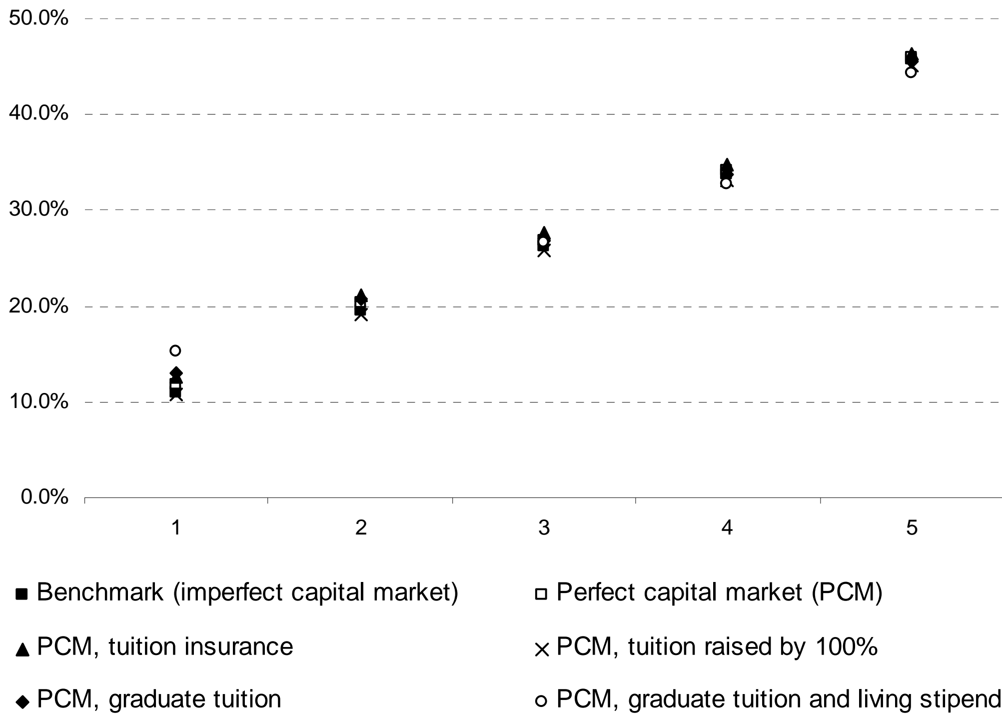
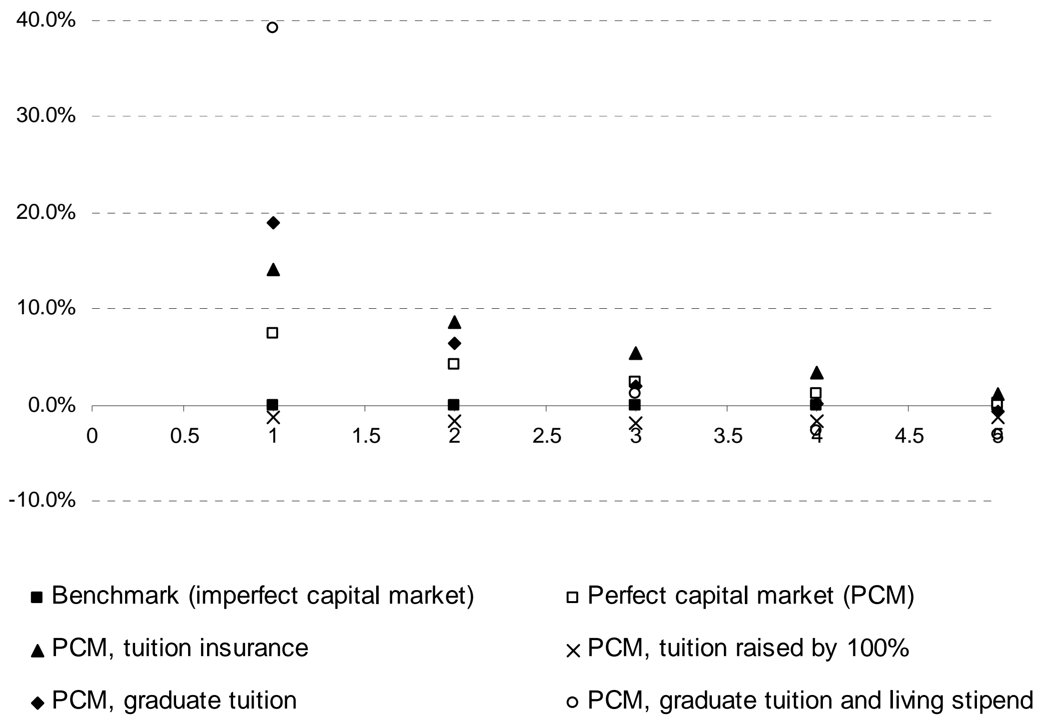


Figure 4. Percent change in share of graduates



Appendix A

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

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

From equation (13a) we obtain

$$1 + \gamma \;=\; \rho_{yt}\, \sigma_t / \sigma_y \qquad \text{(A.1)}$$

and substituting this in equation (13c) gives

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

implying that

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

after substituting the calibration values from the text. From equation (13f):

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

and from equation (13d):

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

Similarly, from equation (13e):

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

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

Appendix B

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

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

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

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

and variance-covariance matrix

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

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

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

References

Admissions to Higher Education Steering Group (2003). “Consultation on key issues relating to fair admissions to higher education." http://www.admissions-review.org

Aitken, Norman D. (1982). “College Student Performance, Satisfaction and Retention: Specification and Estimation of a Structural Model.” *Journal of Higher Education*, 53, 32-50.

Alwin, Duane F. and Arland Thornton (1984). “Family Origins and the Schooling Process: Early vs. Late Influence of Parental Characteristics.” *American Sociological Review*, 49, 784-802.

Arrow, Kenneth (1973). “Higher Education as a Filter.” *Journal of Public Economics*, 2, 193-216.

Barr, Nicholas (2004) "Higher Education Funding." *Oxford Review of Economic Policy* 20(2), 264-283.

Becker, Gary S. and Nigel Tomes (1979). “An Equilibrium Theory of the Distribution of Income and Intergenerational Mobility.” *Journal of Political Economy*, 87, 1153-1189.

Bénabou, Roland (1996). “Heterogeneity, Stratification, and Growth: Macroeconomic Implications of Community Structure and School Finance.” *American Economic Review*, 86, 584-609.

Bénabou, Roland and Efe Ok (2001). “Mobility as Progressivity: Ranking Income Processes to Equality of Opportunity.” NBER Working Paper 8431.

Bertocchi, Graziella and Michael Spagat (2004). “The Evolution of Modern Education Systems: Technical vs. General Education, Distributional Conflict and Growth.” *Journal of Development Economics*, 73, 559-582.

Betts, Julian R. (1998). “The Impact of Education Standards on the Level and Distribution of Earnings.” *American Economic Review*, 88, 266-275.

Bowen, William G. and Derek Bok (1998). *The Shape of the River*. Princeton University Press.

Bridgman, Brent, Laura McMaley-Jenkins, and Nancy Ervin (2000). “Prediction of Freshman Grade-Point Average from the Revised and Recentered SAT I: Reasoning Test.” College Board Research Report No. 2000-1, College Entrance Examination Board, New York.

Bureau of Labor Statistics and Bureau of the Census (1999). *Annual Demographic Survey* (March supplement) www.bls.census.gov/cps/ads/sdata.htm .

Cameron, Stephen and Christopher Taber (2004). “Estimation of Educational Borrowing Constraints Using Returns to Schooling.” *Journal of Political Economy*, 112, 132-182.

Carneiro, Pedro and James J. Heckman (2002). “The Evidence on Credit Constraints in Post-Secondary Schooling.” NBER Working Paper 9055.

Chapman, Bruce and Chris Ryan (2005) "The access implications of income-contingent charges for higher education: Lessons from Australia" *Economics of Education Review* 24 (2005) 491–512.

Checchi, Daniele, Andrea Ichino, and Aldo Rustichini (1999). “More Equal but Less Mobile? Education Financing and Intergenerational Mobility in Italy and in the US.” *Journal of Public Economics*, 74, 351-393.

Costrell, Robert M. (1994). “A Simple Model of Educational Standards.” *American Economic Review*, 84, 956-971.

Costrell, Robert M. (1993). “An Economic Analysis of College Admission Standards.” *Education Economics*, 1, 227-241.

Danziger, Lief (1990). “A Model of University Admission and Tuition Policy.” *Scandinavian Journal of Economics*, 92, 415-36.

Department for Education, Science and Training (2004). *HECS Information 2004*. http://www.hecs.gov.au/pubs/hecs2004/contents.htm

Department for Education Services (2004). “Higher education funding – International comparisons.” http://www.dfes.gov.uk/hegateway/uploads/HEfunding_internationalcomparison.pdf

Durlauf, Steven N. (1996). “A Theory of Persistent Income Inequality.” *Journal of Economic Growth*, 1, 75-93.

The Economist (2004). “Pay or decay.” January 24, p. 11.

Ehrenberg, Ronald G. (2004). “Econometric Studies of Higher Education.” *Journal of Econometrics*, 121, 19-37.

Epple, Dennis, Richard Romano and Holger Sieg (2003). “Peer Effects, Financial Aid and Selection of Students into Colleges and Universities: An Empirical Analysis.” *Journal of Applied Econometrics*, 18, 501-526.

Fernandez, Raquel and Jordi Gali (1999). “To Each According to … ? Markets, Tournaments, and the Matching Problem with Borrowing Constraints.” *Review of Economic Studies*, 66, 799-824.

Fields, Gary S. and Ok, Efe (1999). “The Measurement of Income Mobility: An Introduction to the Literature,” in J. Silber, ed., *Handbook of Inequality Measurement*, pp. 557-596. Kluwer Academic Publishers.

Gilboa,Yaakov and Justman Moshe (2005). “Academic Admission Standards: Implications for Output, Distribution, and Mobility.” *Journal of the European Economic Association*, 3(5), 1105-1133.

Harrison, Alan (1981). “Earnings by Size: A Tale of Two Distributions.” *Review of Economic Studies*, 48, 621-631.

Hassler, John and Jose V. Rodriguez-Mora (2000). “Intelligence, Social Mobility, and Growth.” *American Economic Review*, 90, 888-908.

Hearn, James C. (1984). “The Relative Roles of Academic, Ascribed, and Socioeconomic Characteristics in College Destinations.” *Sociology of Education*, 57,

22-30.

Hearn, James C. (1991). “Academic and Nonacademic Influences on the College Destination of 1980 High School Graduates.” *Sociology of Education*, 64, 158-171.

House of Commons (2004). *Higher Education Bill*. Introduced 8th January 2004, http://www.publications.parliament.uk/pa/cm200304/cmbills/035/2004035.htm

Iyigun, Murat. F. (1999). “Public Education and Intergenerational Economic Mobility.” *International Economic Review*, 40, 697-710.

Johnston, Jack (1972). *Econometric Methods*, 2nd ed. McGraw-Hill.

Judson, Ruth (1998). “Economic Growth and Investment in Education: How Allocation Matters.” *Journal of Economic Growth*, 3, 337-359.

Kane, John and Lawrence M. Spizman (1994). “Race, Financial Aid Awards and College Attendance: Parents and Geography Matter.” *American Journal of Economics and Sociology*, 53, 85-97.

Kennet-Cohen, Tamar, Shmuel Bronner, and Carmel Oren (1998). “The Predictive Validity of Different Combinations of Components of the Process of Selection for Higher Education in Israel.” National Institute for Testing and Evaluation, Report no. 249, Jerusalem, Israel.

Keane, Michael P. (2002) "Financial Aid, Borrowing Constraints, and College Attendance: Evidence from Structural Estimates" *American Economic Review* 92(2):293-297.

Krusell, Per, Lee E. Ohanian, Jose-Victor Rios-Rull, and Giovanni L. Violante (2000). “Capital-Skill Complementarity and Inequality: A Macroeconomic Analysis.” *Econometrica*, 68, 1029-1053.

Loury, Glenn C. (1981) “Intergenerational Transfers and the Distribution of Earnings.” *Econometrica*, 49, 843-867.

Loury, Linda Datcher and David Garman (1993). “Affirmative Action in Higher Education.” *American Economic Review Papers and Proceedings*, 83, 99-103.

Ministry of Education/Tertiary Education Commission (2003) *A Guide to Tertiary Education Funding*. http://www.minedu.govt.nz/index.cfm?layout=document&documentid=7474&indexid=1203&indexparentid=1028

OECD (2003) *Education at a Glance 2003*. http://www.oecd.org/document/52/0,2340,en_2649_34515_13634484_1_1_1_1,00.html

Owen, David (1985). *None of the Above*. Houghton Mifflin.

Paulhus, Delroy and David R. Shaffer (1981). “Sex Differences in the Impact of the Number of Older and Number of Younger Siblings on Scholastic Aptitude.” *Social Psychology Quarterly*, 44, 363-368.

Solon, Gary (2002), “Cross-Country Differences in Intergenerational Earnings Mobility.” *Journal of Economic Perspectives*, 16(3), 59-66.

Spence, A. Michael (1973). “Job Market Signaling.” *Quarterly Journal of Economics*,

87, 355-374.

Stiglitz, Joseph E. (1975). “The Theory of ‘Screening,’ Education, and the Distribution of Income.” *American Economic Review*, 65, 283-300.

Weiss, Andrew (1995). “Human Capital vs. Signaling Explanations of Wages.” *Journal of Economic Perspectives*, 9(4), 133-154.

Acknowledgements: We gratefully acknowledge the support of the Program on the Economics of Higher Education, the Samuel Neaman Institute for Advanced Studies in Science and Technology, and thank Manuel Trajtenberg and program participants for their comments and suggestions.

Email addresses: Gilboa <yaakovg@bgu.ac.il>; Justman <justman@bgu.ac.il>

[1] On higher education funding in Australia, see Department for Education Science and Training (2004); on New Zealand, see Ministry of Education/Tertiary Education Commission (2003); for an overview of higher education funding in various countries see Department for Education Services (2004). In the United States, empirical evidence indicates that liquidity constraints have largely been resolved through a combination of student loans, work-study programs, need-based grants and subsidized tuition (Carneiro and Heckman, 2002; Cameron and Taber, 2004).

[2] This introduces peer-group externalities in the labor market. Peer-group externalities in the education process do not figure in the model. They are important for analyzing competition among individual institutions (Epple et al., 2003) but less so for a centralized public system of education.

[3] We assume that acquiring skill by graduating from university is a dichotomous variable and that the direct cost of a degree is constant. Moreover, graduation is a stochastic process affected only by innate ability—we do not model student effort or other aspects of the education process (cf. Costrell, 1993, 1994; Betts, 1998). Econometric estimates of the production function of higher education, linking school inputs and selectivity in

admissions to measures of education output such as early career earnings or entry to select graduate schools, yield ambiguous results (Ehrenberg, 2004).

[4] In other related work, Iyigun (1999) emphasizes the importance, for income mobility, of allocating sufficient public resources to elementary and high school education in the early stages of economic development; and Judson (1998) links micro and macro perspectives on the allocation of resources to primary education.

[5] This correlation may stem from genetic or cultural factors that result in a positive correlation between the learning abilities of parents and heir children and a positive correlation between parents' learning abilities and earnings.

[6] Denoting consumption spending by c_i, each household solves the constrained optimization problem: max $U_i = \ln c_i + m \ln h_i$ subject to equation (2) and the budget constraint $b_i + c_i = y_i$. This yields: $b_i = m\delta y_i / (1 + m\delta)$. (If investment in education is motivated by a desire to increase the child's earning power, the logarithmic form of the utility function implies that parents' spending on education does not depend on the child's innate ability.)

[7] Ranking applicants by expected human capital implies weighing parental income *positively* ($\phi < 1$). Analytically, this follows from the observation that the conditional mean of human capital E ($\ln h_i \mid t_i, \ln y_{it}$) is an increasing function of parental income after controlling for entry scores (see Appendix B for details). Empirically, it is consistent with Aitken (1982) and Kane and Spizman (1994), among others, who find a positive association between first-year college grades and parental socio-economic status after controlling for psychometric test scores, and with Bowen and Bok (1998), who find

that SAT tests tend to over-predict African-American students' performance.

[8] Graduation is a dichotomous variable—employers do not look at grades, and do not distinguish between those who fail at college and those who do not enroll. The model could be extended to allow graduation to enhance human capital by a variable factor of $\beta > 1$, so that a person entering college with human capital h_i graduates with human capital βh_i, where β is a function of university inputs. However, it is not possible to identify β from macro data in the present formulation, as skilled and unskilled labor are distinct factors of production; and identifying it from micro data would require an econometric estimate of the production function of higher education, on which there is as yet no agreement (Ehrenberg, 2004, and notes 3 and 5, above). The absence of a quantitative empirical link between education quality and the cost of education prevents us from applying our approach to explore related issues of optimal quality in higher education.

[9] For a review of empirical evidence on the relative importance of human capital and signaling in determining wages see Weiss (1995).

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

[11] In effect we are assuming that the time it takes for the work force to turn over is sufficient for capital to adjust without a change in its price.

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

[13] The multivariate normal distribution provides a tractable framework for parametrizing

the joint distribution of these variables. The assumption that income follows a lognormal distribution is common in empirical work, though other assumptions are clearly possible (see, e.g., Harrison, 1981).

[14] Mean household income was IS 10,385 and median income was 9,200 (Statistical Abstract of Israel, 2005, Table 5.31).

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

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

[17] Estimated correlations of approximately 0.5 between pre-college aptitude test scores and first-year college grades provide a point of reference for this value (Bridgman, McCameley-Jenkins and Ervin, 2000; Kennet-Cohen, Bronner and Oren, 1998).

[18] We were not able to calibrate the model with the lower, observed, wage ratio. This is consistent with skilled jobs having other advantages besides better pay such as better working conditions ("indoor work with no heavy lifting", in the words of Senator Robert Dole, explaining why he sought the vice presidency of the United States) and higher social status.

[19] This last measure is closely related to the most common econometric measure of intergenerational mobility—the elasticity of income with respect to parental income. If ε denotes the intergenerational earnings elasticity obtained from a simple regression of son's log earnings y on father's log earnings x, s_y and s_x respectively denote their sample

standard deviations, and r_{xy} denotes their correlation coefficient, then $r_{xy} = \varepsilon \; s_x \; / \; s_y$ (Johnston, 1972, p. 34). Thus if the variances in log earnings are about the same for parents and their children, the two are roughly equal (Solon, 2002). We use the correlation of log incomes to measure relative mobility, rather than the earnings elasticity, in order to distinguish more clearly between mobility and distribution. For other approaches to measuring social mobility see the survey by Fields and Ok (1999), who observe that "the mobility literature does not provide a unified discourse of analysis", and a proposal by Benabou and Ok (2001).

[20] These values, which measure inequality in permanent income, are considerably smaller than regularly reported Gini coefficients, which refer to annual income. Conceptually, inequality of permanent income is more relevant; annual income is commonly used because it is easier to measure.

[21] Barr (2004) similarly concludes that capital market reform is not enough for improving access for low-income households: "active measures" targeted at disadvantaged populations are needed.

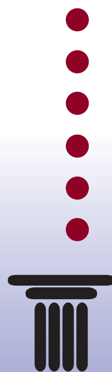
Working and Position Papers

1) Romanov, D., Zussman N., Furman, O., and Caplan T. : "Do All Diplomas Look Alike? Comparing First Three Years of Israeli College and University Graduates on the Labor Market." Economy of Higher Education Program (EHE) Working Papers Series EHE-WP-1-, January 2007.

2) Gilboa, Y., and Justman, M. : "Equity and Efficiency Effects of Different Funding Arrangements for Higher Education: A Calibrated Analysis Applied to Israel." Economy of Higher Education Program (EHE) Working Papers Series EHE-WP-2-, April 2007.

Yaakov Gilboa has been a member of kibbutz Zeelim for over thirty years, and is a founding member of the Economics Department at Sapir Academic College. His main areas of research are the Economics of Education and Labor Economics. He specializes in questions of equality, equality of opportunity and nurturing children from low-income families.

Moshe Justman is Professor of Economics at Ben Gurion University. His main area of research is the Economics of Education. He has written on education and culture, equal opportunity in education, and the demand for religious education. A book, The Political Economy of Education (coauthored with M. Gradstein and V. Meier) was recently published by MIT Press.



Samuel Neaman Institute
for Advanced Studies in Science and Technology
Technion-Israel Institute of Technology
Technion City, Haifa 32000, Israel
Tel: 04-8292329, Fax: 04-8231889
www.neaman.org.il