Inefficient self-selection into education and wage inequality in Italy.

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Abstract

This paper studies the impact of inefficient self-selection into education on wage inequality *within* college graduates in the presence of ability-complementary technology. We build an empirical analysis on data of Italian graduates and we report some evidence on the impact of mismatch, ability and education quality on wages of graduates. Using a signaling setting we argue that the heterogeneity of effort and competencies derived by attending different institutions, implies that the same years of education may give rise to different returns and signals. Our findings enter the debate on the role of schooling in determining inequalities. Our model predicts that public expenditure on education may reduce wage inequality *within* graduates as far as it is addressed toward high ability individuals.

Jel classification: J24, I20.

Key Words: Overeducation, Higher Education Quality, Selection Models.

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1 Introduction

The aim of this study is to illustrate some empirical evidence and to propose a theoretical explanation of wage inequality trends *within* college graduates. This phenomenon characterized most of the developed countries during the last thirty years, and Italy among them. The recent economic debate highlights the importance of detecting the causes of the existing wage dispersion *between* and *within* educational groups. Empirical evidence concerning *between* groups inequality has been presented in many works.[1] The economic literature has related wage dynamics to technological change and economic growth, leading to various explanations of the existing empirical evidence on *between* groups wage inequality (Aghion *et al.*, 1999). Much less effort has been devoted in the direction of understanding the companion of this phenomenon i.e., the rise in *within* groups inequality, especially among high educated workers. Changes in the *within* groups inequality have been reported in many empirical studies. Gould *et al.* (2001) show that in the US inequality *within* college graduates started increasing in the late 1970s and grew steadily through the 1980s and 1990s. Bourdabat *et al.* (2006) and Card and Lemieux (2001) report similar trends for the UK and Canada respectively. However, little is known about the determinants of such increasing inequality. Furthermore, as pointed out in some recent works (Budria, 2006; Budria and Moro-Egido, 2006) the analysis of wage inequality *within* higher educated workers cannot ignore that a large proportion of college graduates enters jobs that do not require the level of schooling that they have obtained. This empirical evidence has stimulated a flourishing of studies that point out the importance of considering the heterogeneity of educational quality and the role of unobserved individuals ability in order to explain *within* groups wage inequality and job mismatch (McGuinness and Bennet, 2007; Ordine and Rose, 2009). Higher dispersion in skill and ability requirements among individuals with higher education, and differences in types and qualities of qualifications awarded by universities could account for some of the observed variation. A complementary view is that higher education does not function as a screening device and, consequently, the group of college graduates is rather heterogeneous in terms of ability. Unfortunately, the existing theoretical works (Aghion, 2002; Galor and Moav, 2000; Crifo, 2008; Hendel *et al.*, 2005) aimed at investigating possible theoretical mechanisms driving wage inequality *within* college graduates are not able to cope with educational mismatch and/or overeducation or to predict a role for education quality heterogeneity. Moreover, while individuals ability is crucial in determining their results, most of the studies consider individuals' innate ability perfectly observed by firms.[2]

In this work we present a theoretical model that is i) compatible with overeducation/educational mismatch in the labor market; ii) able to keep into account the heterogeneity of the instructional quality; iii) consistent with the assumption that there exist asymmetric information on individuals' innate working ability. We show that wage inequality increases among graduates because of inefficient

[1] For a survey and some new insights see Autor *et al.* (2008).

[2] Only Hendel *et al.*, (2005) explicitly address the problem of asymmetric information.

self selection into education in the presence of ability-complementary technological progress and asymmetric information on individuals' innate working ability.

We report some statistics on trends of wage inequality in Italy for graduates using the SHIW panel of the Bank of Italy. We also present some evidence on the relevance of university quality and on the penalizing impact of mismatch on wages of graduates using data on a large sample of Italian graduates merged with data sets containing information on university characteristics from CIVR and the Censis-*La Repubblica* (2004) university quality indicators.[3]

The paper is organized as follows. Section 2 discusses some empirical issues. Section 3 describes the features of our theoretical model and Section 4 contains the main propositions concerning the possible equilibria. In Section 5 we discuss some concluding remarks.

2 Some Empirical Evidence for Italy

The recent empirical evidence on *within* groups wage inequality in OECD countries, points out the presence of increasing wage dispersion and sets some interesting hypotheses on the possible reasons which may be at the root of the observed phenomenon (Autor *et al.,* 2005,; Goos and Manning, 2007). Factors such as overeducation, ability-schooling interactions and school quality or different fields of study may be driving this result (Martins and Pereira, 2004). McGuiness and Bennet (2007), using data from a cohort of Northern Ireland graduates, try to find evidence on the links between ability and mismatch as a possible explanation for inequality among the group of high educated individuals. In practice, they associate the variability of the coefficient related to overeducation in a quantile regression of individual earnings, to the effect of unmeasured ability. The lack of significance of this coefficient, or its lower size in the top quantiles, should imply that mismatch is less penalizing for wages of high ability workers. In this case they implicitly assume substitutability between education and ability for individuals in the high earning quantiles. However, this intuition has been questioned by Arias *et al.* (2001) who point out that varying coefficients across quantiles can be the result of an endogeneity bias rather than evidence on actual ability-based differences in the returns to education. Indeed, Card (1995) already argued that a convex relationship between wage and education may arise if individuals with lower marginal costs of schooling obtain more education. The shape of the cross-sectional relation depends on the balance between the relative importance of ability and opportunity costs of education in the population. Some authors consider that the hypothesis of increasing returns to education may be due to the existence of complementarity between education and ability, especially in high wage occupations (Card, 1995). Recent works using Italian data relate wage inequality to skill-bias changes finding mixed results.[4]

[3] CIVR is the Italian commission for the academic research evaluation.

[4] Recent studies on wage inequality in Italy include Bratti *et al.* (2008), Naticchioni *et al* (2008).

Figure 1: Wage trends in Italy by quantile for full-time graduate workers, 1977-2006.

In order to provide fresh evidence on the existing trend of wage inequality *within* graduates in Italy, in Figure 1 and Figure 2 we report the monthly wage quantiles and the earning ratios among $90^{th}/50^{th}$, $90^{th}/10^{th}$ and $50^{th}/10^{th}$ quantiles of the earning distribution, of full-time graduate workers for the period 1977-2006. These series are computed using individual data of graduates from several waves of the SHIW data set. It is apparent, that recently wage inequality increased and that while the $90^{th}/10^{th}$ quantile ratio drifts upward, the others quantile ratios are much flatter and seem to converge. This empirical evidence appears to be consistent with the hypothesis of polarization of the wage distribution considered in the recent literature.

Some further empirical evidence on possible determinants of wage inequality *within* groups in Italy may be derived by exploiting the information of a survey carried out by the Italian National Statistical Institute on the labor market outcomes of a representative sample of 26,000 students who completed university in 2001 and were interviewed in 2004. We merge these data with the CIVR data set that ranks universities in terms of research and provides data on structural features of the universities. The CIVR data refer to the period 2001-2004, hence, although they do not exactly match the period of university attendance of the students in our sample we may consider they are a good proxy of universities characteristics as far as they do not change in the years just after the degree completion. To check the robustness of our results we also use a newspaper' college ranking (Censis-*LaRepubblica*, 2004) to build an alternative university

Figure 2: Quantile ratios of wage distribution in Italy for full-time graduate workers, 1977-2006.

quality indicator. We point out that the universities in our sample are mainly public universities charging very similar tuition fees and without binding selectivity criteria.[5] This data set presents some advantages with respect to the Bank of Italy's Survey of Household Income and Wealth (SHIW) often used to measure returns to education in Italy.[6] In particular, it allows to control for the specific university attended by individuals and to check if he/she is working in an occupation where its degree qualification is actually required. Moreover, we have information on pre-college students' performances which are necessary in order to control for ability in our empirical analysis.

To the end of explaining some possible sources of this pattern of variability we intend to estimate a wage equation where we attempt to single out the impact of explanatory variables that represent innate ability, schooling ability, university quality and educational mismatch. Hence we estimate the following wage equation:

$$W_i = \alpha_0 + \beta_0 O_i + \beta_1 P_i + \beta_2 Q_i + \beta_3 J_i + \beta_4 E_i + u_{1i}$$

where we relate the log of wages W_i to a set of explanatory variables including the occurrence of overeducation O_i, a vector of variables summarizing the

[5] A detailed description of the Italian university system and a comparison with other systems is contained in Jongbloed (2004).

[6] Among others see Brunello and Miniaci (1999); Martins and Pereira (2004).

individual and household attributes and characteristics P_i, a vector of variables measuring the quality of education Q_i, the characteristics of the job J_i, and a set of variables controlling for different socioeconomic environments E_i. The variables are fully described in Table 1. A problem that we need to take into account is the possible selection of wage observations for working individuals. This problem is mentioned in the empirical literature.[7] In our particular case, we observe both wage and the occurrence of overeducation only for those individuals that were actually working at the time of the interview. As a consequence we have a *sample selection* problem of this form:

$$\begin{aligned} W_i &= \alpha_0 + \beta_0 O_i + \beta_1 P_i + \beta_2 Q_i + \beta_3 J_i + \beta_4 E_i + u_{1i} \\ O_i &= \delta_1 Z_{1i} + u_{2i} \\ L_i &= \delta_{21} Z_{2i} + u_{2i} \end{aligned} \quad (1)$$

where Z_{1i} are variables explaining the occurrence of overeducation O_i, Z_{2i} are explanatory variables for L_i which is a variable associated to a binary outcome which takes the value one if the individual is working and zero otherwise. So, although O_i may be exogenous in the wage equation we observe W_i and O_i only if L_i is actually observed. In line with the solution proposed in Wooldridge (2002), we include in the wage equation the inverse Mills ratio derived from the estimation of L_i to avoid the bias due to the existence of possible selection problems.

Before turning to the discussion of the results of our empirical model, we should clarify some crucial points and definitions. An extremely important variable in our theoretical model is the university quality. As recently pointed out in Epple *et al.* (2006) and Ordine and Rose (2009), balance sheets figures may be used to represent university quality. We use balance-sheets data to build an index of quality based on current revenue per student. In our case, however, we do not have information on expenditures and on the source of revenue (public funding or college fees). We also report estimates derived using a performance indicator published by *La Repubblica* newspaper which summarizes the results of a survey conducted by the Centre for Social Studies (Censis) on universities' features in 2004. This indicator covers research outcomes, student participation, teaching and internationalization. We refrain from using outcome or structure indicators such as the proportion of students who graduate on time or the average university grade. These measures may be biased by "grade inflation" phenomena since we could observe an inverse correlation between university quality and the number of students who graduate on time or the average score at the exams. Turning to our measure of overeducation we point out that this is a subjective one, since we consider overeducated graduates who affirm that their degree is not a necessary requirement for their job. There exists a substantive

[7] For a discussion for Spain see Budria and Moro-Egido (2008) where the authors argue that overall the impact of the correction for sample selection has not proved to be of major importance in Spanish studies.

Table 1: Description of Variables in Quantile Regression and Selection Equation

Individual and Household	
Female	Dummy variable indicating the respondent's sex, Female=1, 0 otherwise.
Age	Respondent's age at the interview.
Son	Dummy variable indicating if the respondent has a son, Son=1 in the presence of a son, 0 otherwise.
South	Dummy variable indicating if the respondent is resident in the South of Italy, South=1, 0 otherwise.
Employed	Dummy variable indicating if the respondent is working at the interview, Employed=1, 0 otherwise.
Wage	Monthly wage of full time workers
Father education	Highest grade of years of school completed by respondent's father.
Mother education	Highest grade of years of school completed by respondent's mother.
Education	
Degree subject	A vector of 6 0-1 dummy variables indicating degree subjects: 1) Science=1 if mathematics, science, chemistry, pharmacy, geo-biology, agrarian; 2) Medicine=1 if medicine; 3) Engineering=1 if engineering, architecture; 4) Econ.&Law=1 if political science, economics, statistics, law; 5) Humanities=1 if humanities, linguistic, teaching, psychology; 6) Sport Science=1 if sport science.
Technical skill	A dummy variable for a group of High Schools: Technical Skill=1 if Accounting, Teacher training, Vocational; Technical Skill=0 if Liceo.
High school leaving grade	Final score by type of high school: H.Sch.Gr. Lyceum; H.Sch.Gr. Teaching; H.Sch.Gr. Accountancy; H.Sch.Gr. Vocational.
University leaving grade	Final score.
Degree on time	Dummy variable indicating if the degree is completed on time (adjusted for course duration), Degree on time=1, 0 otherwise.
Overeducation	Dummy variable for the answer to the question: "Is your degree a required qualification for your job?", Overeducation=1 if the answer is not, 0 otherwise.
Job	
Employed long-term	Dummy variable indicating if the respondent has a temporary or a permanent contract at the interview, Employed long-term=1, 0 otherwise.
Firm size	A three level dummy variable for firm size, <50 employees, >50 and <100 employees, >100 employees.
Industry	A dummy variable indicating if the individual is working in the industry sector or in the service sector. Industry=1, 0 otherwise.
Firm ownership	A dummy variable indicating if the firm ownership is public or private, Private=1, 0 otherwise.
University	
Education quality 1	Current revenue (from public funding and students' fees) per student.
Education quality 2	CENSIS-La Repubblica overall performance indicator.

literature comparing the outcomes deriving from subjective and objective measures of overeducation (obtained by professional job analysts). However, there is no consistent evidence that these different approaches give rise to systematic and significant bias of the incidence or wage effects of overeducation (McGuinness, 2006). Further, in our study it is essential to control for innate ability. This is extremely relevant in order to disentangle the effect of the individual's ability from the influence of university quality on earnings. The use of high school leaving grades in order to control for ability has been suggested in the literature (Dolton and Vignoles, 2000; McGuinness, 2003; Ordine and Rose, 2009) in order to alleviate the selection bias arising from the possible existence of a positive relationship between innate ability and university quality. In this specific case, we control for innate ability using pre-college grades variables, adjusted for the typology of high school. We also introduce in our estimated equations university leaving grades and the completion of the degree on time, although we know that these variables may obviously be influenced by the characteristics of the specific university attended. Differences in family background, possibly giving rise to disparities in schooling ability, are controlled by introducing the characteristics of parents' education. By representing social prestige as well as availability of various social resources, this is usually considered as a primary proxy for the cultural resources, other than education, provided to the child in the formative years. We also control for environmental features by including regional dummies among regressors. The results of the estimated wage equations are reported in Table 2, while selection equation's estimates are reported in Table 3.

Firstly, we investigate if the quality of qualification awarded by universities determines wages significantly. There exists some evidence that there are consistent positive links between research work in the university and students performance in the labor market in terms of job opportunities (Black and Smith, 2004). However, there is scarcity of evidence on the relationship between university quality and earnings. Interestingly, in Table 2 we notice that our quality indicators are both significant in our wage equations. This could imply that the information content conveyed by the specific institution attended is relevant for earnings. A complementary view is that the specific skills acquired by attending prestigious universities determine significantly the individual productivity.

Secondly, our empirical evidence points out that ability proxies expressed in terms of pre-college final marks are significant for all graduates. At the same time, father's education reveals to be statistically significant in both wage equations. Parents' status as represented by father's education is generally assumed to be linked to the financial situation of the family, but also to its general social standing, social network and power. The significance of this variable may be related to the fact that innate ability interacts with the household characteristics that determine schooling ability leading to different returns to human capital investment for individuals with similar educational attainment.

Finally, we evaluate the wage penalization imposed by mismatch. Our parameters' estimates indicate that the wage impact of overeducation is extremely relevant meaning that mismatched graduates earn consistently less that their matched peers and this may influence the pattern of wage inequality within the

Table 2: Regression Models

Ind. Vars	Quality 1 Indicator	Quality 2 Indicator
Constant	5.452*** (0.000)	3.969*** (0.516)
Female	-0.103*** (0.087)	-0.099*** (0.009)
Age	0.011** (0.087)	0.015** (0.005)
Medicine	0.370*** (0.000)	-0.328*** (0.077)
Sport science	-0.105*** (0.025)	-0.111 (0.001)
Econ. & law	0.047*** (0.013)	0.022 (0.016)
Humanities	-0.110*** (0.014)	-0.130*** (0.016)
Mathematics	0.029** (0.014)	0.007 (0.018)
H.Sch.Gr. Lyceum	0.130*** (0.000)	0.137*** (0.029)
H.Sch.Gr. Vocational	0.122*** (0.000)	0.126*** (0.029)
H.Sch.Gr. Teaching	0.133*** (0.025)	0.141*** (0.029)
H.Sch.Gr. Accounting	0.124*** (0.025)	0.133*** (0.029)
University leaving Grade	0.223*** (0.063)	0.250*** (0.076)
Degree on time	-0.009 (0.010)	0.018 (0.135)
Father education	0.031*** (0.011)	-0.035*** (0.006)
Mother education	-0.006 (0.566)	-0.001 (0.012)
South	0.020 (0.015)	0.019 (0.277)
Industry	0.037*** (0.011)	0.026** (0.013)
Firm size	0.039*** (0.003)	0.038*** (0.003)
Employed long-term	0.112*** (0.010)	0.113*** (0.012)
Firm ownership	-0.082*** (0.009)	-0.074*** (0.011)
Education quality 1	0.126*** (0.007)	
Education quality 2		0.298*** (0.077)
Overeducation	-0.084*** (0.006)	-0.084*** (0.008)
Mills	-0.338*** (0.039)	0.303** (0.051)
Observations	15209	10785

Notes: i) The dependent variable is the log of monthly wage. ii) Standard Error in parenthesis; iii)*** 1% significant, ** 5% significant, * 10% significant. iv) "Mills" is the inverse Mills ratio from Probit regression reported in Table 3.

Table 3: Selection Models for Wage Equations

Ind. Vars	Quality 1 Indicator	Quality 2 Indicator
Constant	-6.064***	-5.589***
	(2.04)	(2.867)
Female	-0.159***	-0.099***
	(0.025)	(0.009)
Age	0.072***	0.073***
	(0.016)	(0.018)
Son	0.018	0.049
	(0.038)	(0.044)
Father education	-0.179***	-0.195***
	(0.029)	(0.034)
University leaving grade	0.145***	0.120***
	(0.041)	(0.050)
University leaving grade^2	-0.001***	-0.001***
	(0.000)	(0.000)
Degree on time	0.167***	0.149***
	(0.032)	(0.038)
Medicine	-2.200***	-2.191***
	(0.050)	(0.059)
Sport science	-0.119	-0.050
	(0.099)	(0.135)
Econ. & law	-0.507***	-0.478***
	(0.038)	(0.045)
Humanities	-0.299***	-0.280***
	(0.044)	(0.051)
Technical skill	0.149***	0.137***
	(0.026)	(0.030)
Education quality 1	0.468**	
	(0.211)	
Education quality 2		0.205
		(0.305)

Notes: i) Equation1 and Equation 2 use "Education Quality1" and "Education Quality 2" respectively ii) The dependent variable is a latent variable equal to 1 if the respondent is working at the interview; iii) Nineteen regional dummy variables included; iv) "University leaving grade^2" is the variable squared; v) Standard Error in parenthesis; v)*** 1% significant, ** 5% significant, * 10% significant.

group of graduates.

Our main results are consistent with a sort of polarization of the labor market even among graduate positions. As argued in Manning and Goos (2007) since the job distribution has become more polarized some educated workers are confined into the low-skill occupations at the bottom end of the wage distribution and this can explain the simultaneous increase in the returns to education and the extent of overeducation. In what follows we propose a possible explanation of this occurrence and we show a picture where workers in top wage occupations exploit a rent derived by the interaction of their innate and schooling ability with their educational choice in terms of university quality. At the same time, we show that *in equilibrium* there exists a pool of workers, possibly overeducated, that have limited access to these high rewarding positions, since their choices are constrained by insufficient innate or schooling ability.

3 The Theoretical Framework

In what follows we try to interpret the existing empirical evidence setting a model where we consider interactions between innate and schooling ability with educational choices in terms of quality. We argue that in the presence of asymmetric information on workers' ability the coexistence of high-pay and overeducated individuals may arise because firms extrapolate a signal from the quality of individuals' educational attainment. This leads to inefficient equilibria and inequality since individuals may be constrained to their choices by schooling ability, shaped by their family background.

Consider the following setup where individuals and firms act strategically. We assume that there are two types of individuals with innate working ability θ_α (with $\alpha = h, l$ and $\theta_h > \theta_l$) who, before entering the job market, decide to acquire a level of education $e \geq 0$ involving direct and indirect costs.[8] Once in the job market, individuals can obtain a wage w. Firms set the production on the basis of technology T and employ individuals. Individuals' working ability is unobserved by firms. The share of high ability individuals, indicated by γ (with $0 < \gamma < 1$) is common knowledge. When individuals decide to acquire education, besides monetary costs they incur in costs that are related to personal attributes, including working ability, to their households' characteristics and to environmental and socioeconomic features. These elements determine the heterogeneity of schooling costs and imply that the cost of education may change across individuals with similar innate abilities. This line of reasoning is not far from that of Carneiro and Heckman (2002), who assume that schooling ability is enhanced by the family background and by the socioeconomic environment. To keep things simple, we parameterize with λ_β with $\beta = h, l$ and $\lambda_h > \lambda_l$, the individual components that shape schooling ability and influence

[8] The possibility of considering education as a continuous variable has been addressed in the literature (Gibbons, 1992). In line with the existing literature, we interpret different educational levels arising in *separating* equilibria as high school, graduate and possibly postgraduate qualifications.

the education costs that are uncorrelated with his innate ability. From now on, we refer to λ_β as the individual's schooling ability. Firms do not observe λ_β but just the share of individuals with high schooling ability λ_h, indicated by p (with $0 < p < 1$). We start by considering an interaction process where there are only firms and individuals and the education quality is exogenous. Using this setting, we demonstrate how the presence of individuals' with heterogeneous schooling ability imperfectly correlated with working ability, conditional on education quality, is crucial in deriving *pooling* equilibria. Moreover, we show that if individuals do not observe the cost that firms have to sustain to invest in technology, educational mismatch takes place affecting wage inequality within graduates.

3.1 The individuals

Consider a continuum of individuals ($i = 1, 2..$) that maximize an utility function, $u(\cdot)$, expressed in terms of wage $w(\cdot)$ and in terms of the costs of education $c(\cdot)$. Before entering the job market each individual can obtain a level of education e, involving monetary and non-monetary costs. The cost of acquiring education is a function $c(e, q, \theta_\alpha, \lambda_\beta)$ of the education level e, of the quality of education q, of the individual's innate ability θ and of individual's schooling ability λ. The wage depends on both the quality and the amount of education, on the firm's technology T, and on the individual's innate ability. Consider the following utility function:

$$u(w, e, q, \lambda|\theta, T) = w(e, q, \theta_\alpha, T) - c(e, q, \theta_\alpha, \lambda_\beta) \tag{2}$$

and assume that the cost function satisfies the following properties:

$$c_e(\cdot) > 0 \tag{3}$$

$$c_q(\cdot) > 0 \tag{4}$$

$$c_e(\cdot, \theta_l) > c_e(\cdot, \theta_h) \quad \forall \quad q \tag{5}$$

$$c_e(\cdot, \lambda_l) > c_e(\cdot, \lambda_h) \quad \forall \quad q. \tag{6}$$

First, notice that we define the quality of education as the set of scientific and technical skills provided by universities that raise the individuals' productivity. Consistently with our definition of education quality, we assume that the higher is the quality supplied by an institution, the higher is the cost (in terms of effort) that an individual has to sustain to obtain a given qualification (4). In this sense, the larger is the set of skills that an institution provides to students the more challenging is for the student body the achievement of a degree qualification. Equation (5) represents the so called single crossing property, which implies that the cost of an additional year of education is higher for individuals with low working ability than for those with high working ability. Equation (6) indicates that the cost of an additional year of education is higher for individuals with low schooling ability than for those with high schooling ability. This holds because individuals living in privileged social contexts may have relatively low costs of education since they may easily have tutorials, supplemental schools, or simply low opportunity costs of education. As recently pointed out by Carneiro and Heckman (2002) the fact that individuals are heterogeneous with respect to their family wealth, could generate differences in educational achievement not only because of liquidity constraint problems but mainly because high income families allow for better opportunities and social environment that determine the schooling success of their children. Here we model this issue explicitly with the intent of capturing the mechanisms that may lead individuals with different innate ability to achieve the same degree qualification. In fact, so far the possibility of *pooling* equilibria in the job market signaling game has been justified only by means of credit constraint arguments as in Hendel *et al.* (2005). These authors focus on credit market imperfections and on the mechanisms that may lead to an imperfect correlation between ability and educational attainment due to individuals' liquidity constraint. However, while their model predicts inequality trends *between* groups, *within* groups wage inequality does not arise in any of their signaling equilibria. Moreover, the authors question about the opportunity of spending public resources in order to have a more affordable higher education. In this respect our model, by considering not only the role of liquidity constraints, but by modeling a more wide concept of schooling ability is offering a more comprehensive view on what could be the possible determinant of *pooling* equilibria.

Considering the utility function (2), the slope of the indifference curves between education and wage is given by:

$$mrs_{e,w} = c_e(e, q, \theta_\alpha, \lambda_\beta) - w_e(e, q, \theta_\alpha, T). \tag{7}$$

Given assumption (5) and (6) we know that individuals with high innate ability and high schooling ability have the lowest marginal cost of education. As a consequence, in Figure 1 the graphical statement is that these individuals have the less steep indifference curve (θ_h, λ_h). On the contrary, individuals with low working and low schooling ability have steeper indifference curves (θ_l, λ_l) than other individuals. Within these boundaries, we can draw the indifference curves for individuals with high working ability and low schooling ability (θ_h, λ_l) and those for individuals with low working ability and high schooling ability (θ_l, λ_h). The position of the curve (θ_l, λ_h) with respect to the curve (θ_h, λ_l) depends on which effect, schooling ability (6) or innate ability (5), dominates in reducing the marginal cost of education. We crucially assume that the dominant effect depends on the quality of the education. In particular, we assume that:

$$c_{eq}\left(\cdot, \theta_l\right) > c_{eq}\left(\cdot, \theta_h\right) > 0 \tag{8}$$

where c_{qe} is the cross partial derivative of the cost function with respect to the level and the quality of education. The implication of (8), which represents the core of our model, is that an increase in the quality of education raises the indifference curves of individuals with low working ability more than those of individual with high innate ability. The net effect of an increase in q, results in

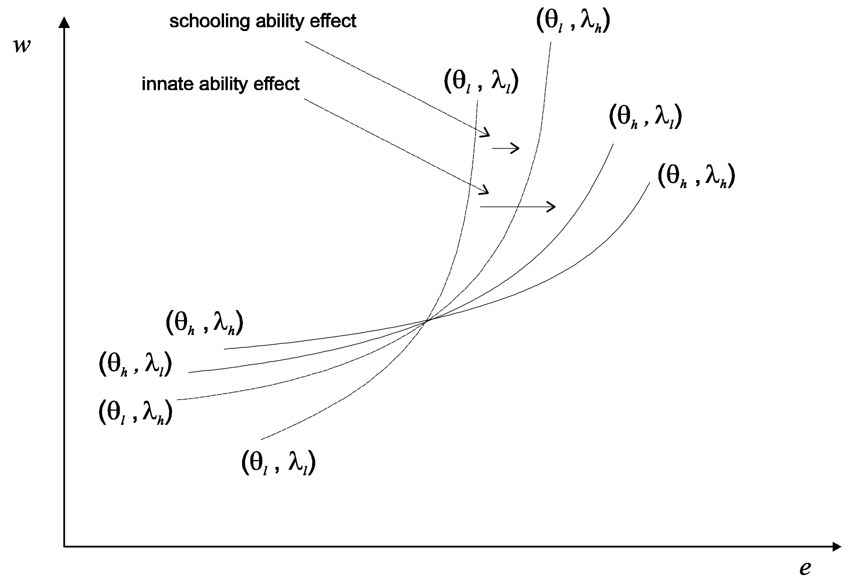

Figure 3: Individuals' indifference curves with working ability imperfectly correlated with schooling ability

the fact that *ceteris paribus* innate ability becomes more important than schooling ability in reducing the marginal cost of education and, as a consequence, it determines the relative position of the curves (θ_h, λ_l) and (θ_l, λ_h). This is so because we are assuming that schooling ability reflects all the elements that affect the marginal cost of education but that are uncorrelated with individual's innate ability. Hence, high quality of education magnifies the complementarity between innate ability and education by lowering the impact that all the other elements that influence the schooling costs may have. Indicate with q^* the threshold level of education quality for which innate ability is always more important than schooling ability.[9] Formally we have that:

$$|c_e(\cdot, \theta_h) - c_e(\cdot, \theta_l)| > |c_e(\cdot, \lambda_h) - c_e(\cdot, \lambda_l)| \quad iff \quad q \geq q^*. \tag{9}$$

As we discuss below, in our setting when the quality of education is $q < q^*$ individuals with different innate ability may have the same marginal cost of education, simply because schooling ability becomes more important. In this case, *partial pooling* equilibria where individuals with different abilities may acquire similar education may arise. As a consequence, in this model education quality acts in a twofold direction in determining individuals' productivity: on one side (as we discuss in the next subsection), it determines individuals' productivity directly as in standard human capital theory while, on the other side, it crucially

[9]See Epple *at al.* (2006) and Ordine and Rose (2008) for models where universities give rise to an heterogeneous supply of education quality in quasi-competitive settings.

determines the validity of the sorting condition (9) and hence it determines the type of signaling equilibrium arising in the job market.

3.2 The firms

Consider a continuum of firms ($f = 1, 2, ..$). Each firm f employs only one worker to produce the final output (y). Firms compete *à la* Bertrand to hire workers, hence *ex-post* wage reflects individual's expected productivity. Before hiring a worker, each firm makes a technological choice. In particular, it can choose between high or low technology. We indicate $T = \{HT, LT\}$ the firm's investment in high or low technology respectively. The cost of technology HT is given by $\delta_f > 0$ for all f. The cost of technology LT is normalized to zero.

The production function is given by:

$$y = y\left(e, q, \theta_\alpha, T\right) = \frac{1}{\eta} e^{\eta} q [\varepsilon]^{1\{T=HT \text{ and } \theta=\theta_h\}} [1]^{1\{T=LT \text{ or } \theta=\theta_l\}} \quad (10)$$

with

$$0 < \eta < 1 \text{ and } \varepsilon > 1.$$

Equation (10) assumes a scenario where, the effect of education on worker's productivity is positive, as in standard human capital theory, with decreasing returns to education.[10] At the same time, the marginal effect of education on individual's productivity depends on the quality of education and on the match between high ability individuals and high technology firms. From relation (10) it appears that high technology is complementary only to high ability workers.[11] The marginal returns to education are given by the following relations conditional to the ability-technology match:

$$\begin{aligned} y_e &= \frac{q}{e^{1-\eta}} \varepsilon \quad iff \quad T = HT \text{ and } \theta = \theta_h \\ y_e &= \frac{q}{e^{1-\eta}} \quad if \quad T = LT \text{ or } \theta = \theta_l \end{aligned}$$

The Bertrand competition among firms ensures that the wage schedule reflects the expected workers' productivity.[12] Because of the strategic complementarity between ability-signaling and technology we need to model the firms' technological choice. Since the high technology is costly and it is complementary only to high ability workers, firms need a credible on ability in order to invest

[10] $y_{ee} = -(1-\eta)\frac{q}{e^{2-\eta}}[\varepsilon]^{1\{T=HT,\theta=\theta_h\}}[1]^{1\{T=LT \text{ or } \theta=\theta_l\}} < 0.$

[11] Notice that the presence of a neutral technology in the production fuction would not affect our results. Alternatively it is possible to think to each worker as an efficient unit of labor. Galor and Moav (2000) assume exogenous complementarity between the rate of technological change and ability of workers.

[12] The wage schedule is actually the firms' willingness to pay. Since firms compete for workers, their willingness to pay is uniquely defined by the break even point of offering a wage equal to the expected productivity.

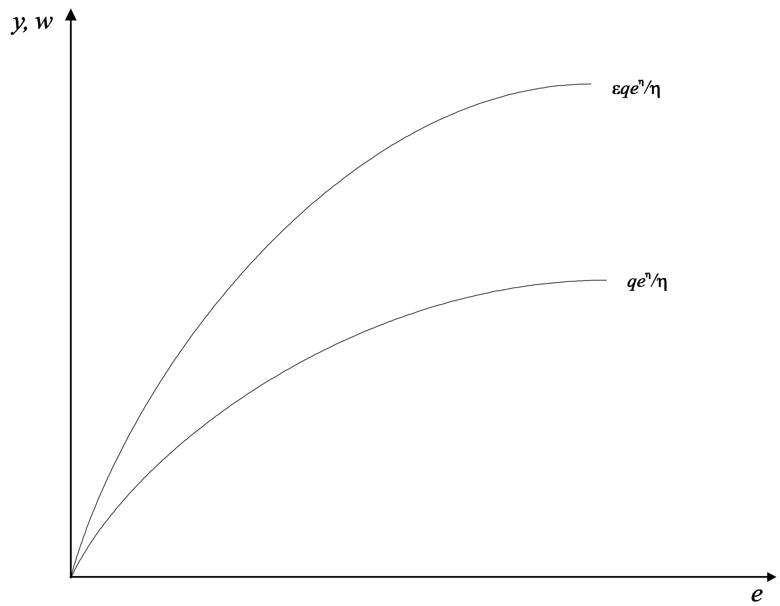

Figure 4: Individual's productivity conditional to ability-technology match

in HT, otherwise they would incur in a loss equal to δ_f. The wage-productivity curves, conditional on ability-technology match are graphically illustrated in Figure 2. As stated above, the effect of *ability biased* technologies is captured by the parameter $\varepsilon > 1$. This conjecture about the centrality of the positive interaction between technologies and ability for the comprehension of the observed *within* wage inequality is largely consistent with empirical evidence. Bartel and Sicherman (1999) find that the education premium in the US over the period 1979-1993 is the result of an increase in demand for innate ability or other unobserved characteristics of more educated workers. Murnane *et al.* (1995) argue that the return to cognitive skills have risen during the 1980s. Juhn *et al.* (1993) provide evidence regarding observed and unobserved components of skills. The authors show that the premium to unobserved components precede the increase in the return to education. Moreover, Galor and Moav (2000) focus on *within* groups inequality considering an endogenous growth model with exogenous ability biased technological transitions.

3.3 The interaction process

The interaction process consists in the following stages. Firstly, individuals conditional on their schooling and working ability choose the level of education e they want to acquire. Secondly, firms observe the education acquired by the individual and decide the technology T to adopt. Then, production takes place and payoffs realize. The strategic interaction of this model considers explicitly the externalities generated by individuals with low working ability that want to signal an ability that they do not have in order to achieve a higher utility. In a Spence setting (corrected for human capital theory i.e., with education that increases productivity) the only equilibrium of a similar interaction process would be an efficient *separating* equilibrium where the signal is credible and no *pooling* equilibria may arise.[13] In our setting, we are considering the presence of an element (schooling ability) that represents an unobserved attribute that influences the cost of acquiring human capital but that is uncorrelated to the individual's productivity. Quoting Spence "..it is possible that attributes that lower the cost of acquiring education might not be those that enhance productivity....".[14] Here, we model this issue explicitly. As we discuss in the next Section, the dimension of the "working ability effect" with respect to the "schooling ability effect" is crucial in (partially) re-establishing *pooling* equilibria consistently with *forward induction*.

4 The Equilibria

Assume that firms are heterogeneous with respect to the cost that they have to sustain in order to acquire the HT technology. In fact, there is no reason why firms should have the same cost to obtain the same technology since, for instance these costs may be related to the actual technological endowment of each firm, to the structural characteristic of the specific environment, to spillover effects, etc.[15] Assume that there are two types of firms parameterized by δ_f with $f = h, l$ and $\delta_h > \delta_l$. Indicate with ξ $(0 < \xi < 1)$ the probability that a firm is a low cost type, i.e. $\xi = prob(\delta_f = \delta_l)$. Individuals know the value of ξ but they do not observe the type of firm (δ_f) that will hire them.

Proposition 1 *If the quality of education is such that working ability is more important than schooling ability* ($q \geq q^*$) *any equilibrium of the interaction process must be a separating equilibrium where wages reflect individuals' productivity.*

Proof. Since we are assuming that relation (9) holds ($q \geq q^*$), this implies that the marginal cost of education is larger for individuals with low working ability than for individuals with high working ability, independently on their schooling

[13] See Gibbons (1992) pp. 239-244 for a recall of this result. The result is due to Cho and Kreps (1987) and to the signaling requirement known as *intuitive criterion* applied to the perfect Bayesian equilibrium solution concept. The application of the *intuitive criterion* is equivalent to the application of the *forward induction* reasoning due to Kohlberg and Mertens (1986).

[14] See Spence (2002) p. 449.

[15] In the growth theory literature, the cost of advanced technology has been considered typically related to the actual firm's technological endowment. The closer is a firm to the technological frontier the lower is the cost that it needs to sustain in order to update its technology. The concept of technological frontier has been introduced by Nelson and Phelps (1966). Acemoglu *et al.* (2006) study empirically the relation between R&D expenditure and the distance from the technological frontier and build up a model where firms differ in terms of costs to adopt new technologies.

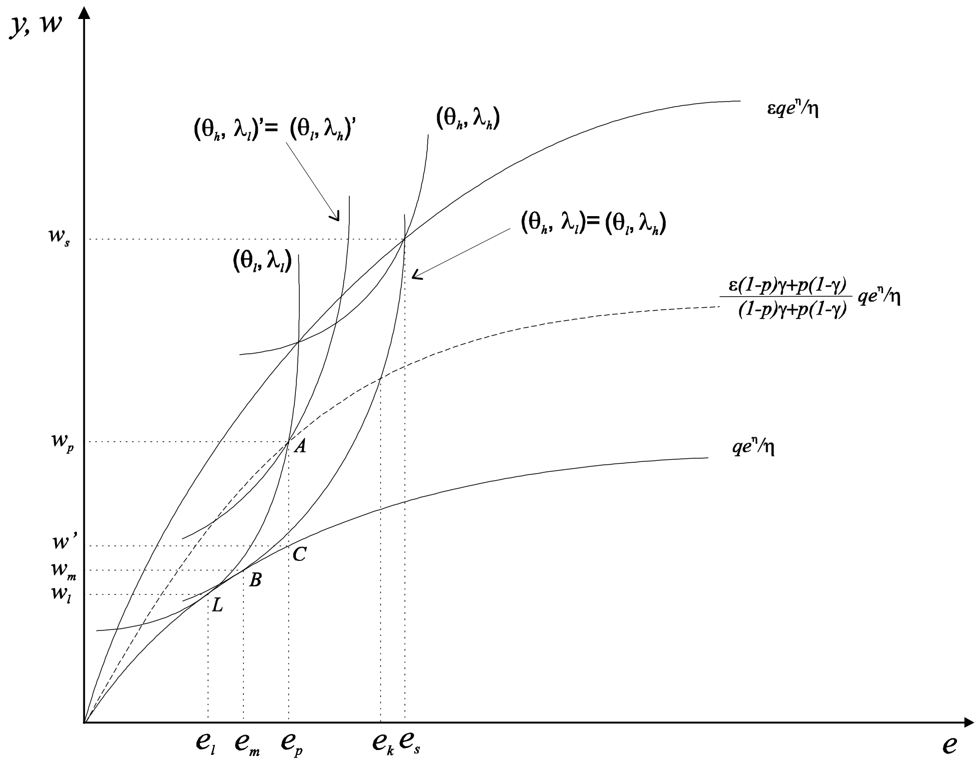

Figure 5: A partial pooling equlilibrium in the job market signaling game

ability. This implies that only a *separating* equilibrium can be consistent with *forward induction* as in Cho and Kreps (1987). When individuals come from high quality institution the signaling mechanism is working as in the classical Spence' model and this generates perfect separation between individuals with different productivity. ■

Proposition 2 *If the quality of education is such that schooling ability is at least important as working ability in reducing the marginal cost of education* ($q < q^*$) *and* ξ *is larger than a given value* $\bar{\xi}$, *the only (perfect bayesian) equilibrium of the interaction process is a partial pooling equilibrium where a share of individuals with high and low working ability acquire the same level of education and they are employed in HT or LT firms, following a stochastic process.*

Proof. First notice that we refer to *partial pooling* as an equilibrium where only a share of individuals with different working ability are pooled together. Consider Figure 5 where, in order to simplify the illustration, we consider the case in which relation (9) is satisfied as an equality i.e., we consider the case where individuals with high working ability and low schooling ability (θ_h, λ_l)

and individuals with low working ability and high schooling ability (θ_l, λ_h) have the same marginal cost of education and, as a consequence, they have the same map of indifference curves (θ_h, λ_l)=(θ_l, λ_h).[16] Here, we refer to these individuals as pooled individuals. In the figure, first notice that individuals (θ_h, λ_h) i.e., individuals with high working ability and high schooling ability, always separate themselves from others by acquiring education e_s. When e_s is observed, firms always invest in HT. This individuals would obtain a wage that is at the top of wages' distribution because of their working and schooling ability and of firm's technology. Now, consider pooled individuals (θ_h, λ_l)=(θ_l, λ_h). These individuals in order to separate from types with low working and schooling ability (θ_l, λ_l), must acquire an education $e \geq e_p$. Here, for simplicity, assume that if they do not separate, firms always invest in LT. Pooled individuals acquire education $e \geq e_p$ only if firms invest in HT when such e is observed. In fact, when $T = HT$, by acquiring e_p pooled individuals reach a higher indifference curve (point A) than the one they would reach if they acquired education $e_m < e_p$ (point B). On the contrary, if $T = LT$, when $e = e_p$ they would reach a lower curve (point C). More precisely, pooled individuals prefer to acquire an educational level $e \in [e_p, e_k]$ only if firms invest in HT. Because of Bertrand competition, firms invest in HT when $e \in [e_p, e_k]$ is observed only if:

$$E[y(e, q, \theta_\alpha, HT)] - \delta_f > y(e, q, \theta_\alpha, LT) \tag{11}$$

or, equivalently only if:

$$[\varepsilon(1-p)\gamma + p(1-\gamma)]\, q\frac{e^\eta}{\eta} - \delta_f > q\frac{e^\eta}{\eta} \tag{12}$$

where the LHS of (12) represents the expected productivity of firms investing in HT when $e \in [e_p, e_k]$ is observed. Assume that when $e \in [e_p, e_k]$ a firm invests in HT only if $\delta_f = \delta_l$ i.e., relation (11) holds only if $\delta = \delta_l$ and it does not hold for any $e \in [e_p, e_k]$ when $\delta = \delta_h$. In this case, we know that pooled individuals have to choose between education e_m and education $e = e_p$. Individuals choose the educational level e_p only if:

$$E[w(\cdot)|e_p] - w_m \geq c(\cdot, e_p) - c(\cdot, e_m) \tag{13}$$

where

$$E[w(\cdot)|e_p] = \xi w_p + (1-\xi)w' \tag{14}$$

with w_m representing the wage paid to pooled individuals with education e_m and w_p and w' representing respectively the wage paid by HT and LT firms to pooled individuals with education e_p. Notice that if condition (13) is satisfied, all pooled individuals decide to acquire an educational level e_p, but once in the labor market, they have only a probability ξ of being employed in a HT firm. In this setup, individuals with the same educational level can be employed in

[16] Ordine and Rose (2009) show that, generally, this result is valid even when schooling ability is more important that working ability.

firms that differ in terms of technology and pay different wages to individuals having the same educational level. ■

The result contained in proposition 2 is completely consistent with the phenomenon of job mismatch/overeducation. In particular, individuals with education e_p (we may think to these individuals as college graduates) would be characterized by *within* wage inequality not only due to possibly differentials in the quality of education/returns to education (as a reminder, q determines the position of the wage schedule), but also reflecting heterogeneity in the signaling mechanism of education. Their wage would not necessary reflect their working ability, since high ability individuals could be employed in LT firms.

It is important to note that, while in this analysis we are considering only one exogenous level of education quality, the main result would hold in the presence of a finite number of institutions fixing different quality levels to maximize their objective functions.[17] Here, we show that the quality of education may interact with wage inequalities in two stages: a) it determines the returns to education directly, hence the same qualification may generate different returns; b) it determines the allocation of an individual in the job place by determining the credibility of the signal arising in the job market. When the quality of education is below a threshold value, graduates individuals would not be able to collocate at the top of the wage distribution, even if they have high working ability since they cannot signal in the job market. Interestingly, in this framework we may explain the *ceteris paribus* effect of an increase in the intensity of ability biased technology when $q < q^*$.[18] In Figure 6 the implications of an increase in ε for wages are straightforward. We can summarize them as follows:

1. An increase in *between* wage inequality (roughly captured by $\overline{w_l w_p'} - \overline{w_l w_p}$). A rise in the intensity of ability-complementary technology affects expected productivity and wage of graduates (e_p' in the Figure 6). The overall wage of graduates increases while wages of low educated individuals remain unaffected and this raises *between* groups inequality.

2. An increase in *within* wage inequality (roughly captured by $\overline{w'' w_p'} - \overline{w' w_p}$). A rise in ε increases productivity of graduates only in the case of a good match in the job market. This implies that wage inequality *within* graduates increases since the wage differential due to educational mismatch becomes larger.

In our model a rise in the intensity of ability complementary technology is fully able to predict both a rise in *between* and *within* groups wage inequality using a simple demand-supply setting in the presence of *ability biased* technology and asymmetric information on workers productivity. At the same time we point

[17] The results can be extended in a setup where there are heterogeneous universities fixing different quality standards. See Ordine and Rose (2009) for a paper that considers this issue explicitly.

[18] When the quality of education allows for full separation, the effect of a rise in ε would only be an increase in the wage of graduates workers with a consequent rise in *between* groups wage inequality.

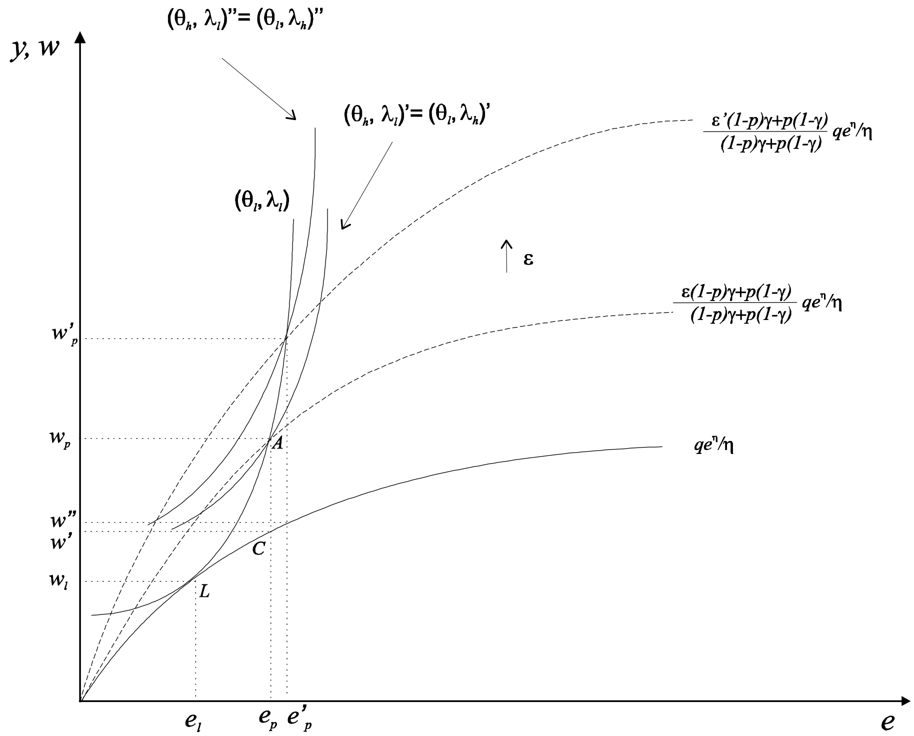

Figure 6: Effects of a rise in the intensity of ability-complementary technology on wage inequality

out the importance of considering the role of education quality in determining both different returns to education and different signaling mechanisms.

5 Concluding Remarks

In this study we undertake a theoretical and empirical analysis aimed at evaluating possible determinants of wage inequality among graduates. We show some empirical findings that highlight that university quality, innate ability, schooling ability proxied by parental background, and educational mismatch strongly affect earnings of graduates. Our findings are consistent with a polarized view of the labor market where some workers earn a wage premium deriving from their specific educational choices while others are confined into low-pay occupations since their choices are constrained by insufficient schooling ability. We provide a theoretical framework where we stress the importance of considering interactions between innate and schooling ability with the educational choices in terms of quality and we show that in the presence of asymmetric information on workers' ability the coexistence of high-pay and overeducated individuals may arise because firms extrapolate a signal from the quality of individuals' educational attainment.

In terms of policy, our findings enter the debate on the role of schooling in determining inequalities. Our model predicts that public expenditure on education may reduce wage inequality *within* graduates as far as it is addressed to reduce disparities arising from schooling ability. Indeed, the chance of reaching the top tail of the wage distribution may just be constrained by insufficient schooling ability. In this sense, removing this constraint may increase the allocative efficiency in the job market. It is crucial that government programs are directed toward individuals with high innate ability rendering more affordable the access to high quality universities.

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