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Polarization in Higher Education and Technological Leadership

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Abstract

This paper highlights the role of polarization in higher education as a key factor to technological leadership as well as to labor market inequality.

Higher education polarization refers to the widening gap between elite and non-elite universities, primarily in two dimensions: institutional quality and the tightness of student recruitment. This paper introduces a model to analyze the impact of polarization and presents new indices that measure polarization within the higher education system.

The model emphasizes that disparities in university quality and recruitment tightness influence a country's technological leadership. Specifically, nations with a high "polarization gap" in higher education tend to lead in technology but also experience higher levels of inequality.

In the empirical analysis, we construct indices that measure the polarization gap both in quality and tightness of recruitment as well as an index for leadership in technology. These indices are a new contribution to the field of higher education. The findings reveal a positive correlation between the polarization gap, technological leadership, and inequality among OECD countries.

In consequence, this paper shows that a nation implementing a public education policy, which establishes a significant dichotomy between top-tier universities and standard ones, may stimulate progress and technological leadership, at the price of inequality.

Keywords: ability; polarization; skills; productivity; higher education; technological leadership; inequality.

JEL classification: I26, J24, O14, O4.

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I. Introduction

This paper emphasizes that polarization and heterogeneity in higher education are key factors in understanding both inequality and technological leadership. This paper presents a new framework, which incorporates polarization in the higher education system and shows that a heterogenous higher-education system leads to inequality but also to leadership in technology.

The essential element in this research is the polarization of the higher education system. While in the literature on inequality and economic growth, higher education is characterized as one homogeneous element, in fact, higher education institutions are heterogenous and consists of two channels: graduating from a prestigious and elite university or graduating from a standard one.

This paper uncovers theoretically and empirically two main differences between standard and elite universities. First, knowledge disseminated in elite universities is at the frontier of technology, since due to high budgets, they can afford top scholars, good labs and infrastructure. Second, recruitment for elite universities is highly selective.

We show that this double gap between universities, in quality and tightness of recruitment, explain the difference in leadership and inequality among countries.

The heterogeneity in higher education affects leadership in technology because workers are not similar in their ability. In this paper, we depart from the assumption of homogeneity of skilled workers: skilled workers are heterogenous.

In consequence, there is a double heterogeneity. First, individuals are heterogeneous in their abilities – some are abler than others. Second, and not less important, skills are acquired through institutions which are different in their quality. Considering this double heterogeneity --in ability of individuals and in quality of universities-- will affect the equilibrium of the economy and will affect leadership in technology and inequality among workers. The differences in quality between universities is the first polarization gap we describe and analyze in this paper.

The second polarization gap is about tightness of recruitment. We show that this difference between elite and non-elite universities enables the differentiation of individuals with high and low ability, so that only high ability students graduate from top universities. This is the first proposition of the paper, i.e., the polarization gap in higher education allows us to get a separating equilibrium, in which high ability students graduate from a top university, others from standard ones.

Why is this polarization important for the economy and how is it linked to inequality and leadership in technology? The answer lies in the production sector. The economy is composed of high-tech and non-tech goods, as in the literature, but in this model, the productivity of workers working in the high-tech sector and having graduated from an elite university is higher than if they would have graduated from a standard university, by having received education at the frontier of knowledge.

Indeed, the main difference between sectors is in the 'match' between the type of education, the ability of the worker and the good produced. Productivity of workers who graduated from an elite school is higher than if they would have graduated from a standard university.

Following our first proposition about abilities of workers, our second proposition stresses that skilled workers with a standard university education, which are with low-ability, are not working in the high-tech sector, while students graduating from an elite university, and who are with high-ability, are. In consequence, there exists a disparity in human capital between the two industries, allowing ex-post, to develop a 'tractable' model.

The logic of this model is that top universities are at the frontier of knowledge and disseminate this knowledge to the best, who can then use this knowledge in the sector which needs it most – the high-tech sector. This is the main message of this paper. It is the match between high ability, top education and high-tech sector, a sector which is a perfect match for the high-level of education, which is essential for analyzing leadership and inequality, as presented in the third proposition of this paper.

Indeed, the third proposition shows that the level of polarization of the higher education system affects inequality and leadership in technology: a greater polarization gap is related to higher inequality and higher leadership in technology, when inequality is the gap between skilled workers in elite and standard universities, and leadership is defined by the relative productivity of the leading sector.

In conclusion, this paper relates polarization in higher education to leadership in technology and to inequality. This paper shows that inequality is the price of having leadership in technology. A country which desires to be "at the frontier of knowledge", must have top universities, in which the entry is through meritocracy, leading to income inequality. There is a trade-off between inequality and leadership.

This paper is divided into two main parts: a theoretical model and an empirical section. The empirical section introduces new data and new indices in the field of higher education. This paper presents the two indices measuring the polarization gap for 17 OECD countries, based on the data of hundreds of universities. Our analysis shows positive correlations between the polarization gap, technological leadership, and inequality in OECD countries.

The paper is divided into five sections. In the next section, we review the literature. The model is presented in section III. Section IV presents the empirical analysis. Section V concludes.

II. Related Literature

2.1 Leadership in technology

Determining a country's leadership in technology involves considering various indicators and data points. In the literature, there is no single metric that definitively establishes technological leadership, and many indices are used as indicators to assess a country's strength in the technology sector. One strategy is to focus on Research and Development (R&D) spending. Some work focuses on total R&D spending, while others focus on main sectors (see Huang and Sharif, 2015 and Nelson and Wright, 1992). Another strategy is focusing on the number of patents granted since a high volume of patents suggests a strong focus on technological development (see Nelson, 1990).

An alternative approach is based on the contribution of technology-related industries to the country's business output, which reflects its economic reliance on leadership in the technology sector (see Fernando and Fabien, 2016). Moreover, there is another line of literature developing various global indices, such as the Global Innovation Index (GII) and the Global Competitiveness Index (GCI), which assess, and rank countries based on their innovation and technology capabilities. [1]

Some research, such as Jaunee (2016), focuses on venture capital (VC) activity and investment in startups which indicate a thriving technology ecosystem. Indeed, countries with a high level of VC funding often foster innovation and entrepreneurship. Similarly, the presence and growth of technology startups, particularly in sectors like artificial intelligence, biotechnology, and information technology, are key indicators of technological leadership. Similarly, the existence of innovation hubs, technology parks, and incubators that support the growth of technology companies and startups is a positive indicator.

An opposite view is to focus not on startup but on established and big companies and analyse the Global Tech Company Headquarters. The presence of global technology giants headquartered in a country is a sign of its influence in the tech sector. Another index of leadership could be to focus on Advanced information and communication technology (ICT) infrastructure since widespread connectivity contribute to a country's technological leadership, enabling the adoption of emerging technologies.

More indices that are common in the literature are "Exports of high-tech out of total exports", and "percent of scientists in the population" (Nelson and Wright, 1992 use both indices), "Human development index" (Kleinknecht et al, 2002) and "Ratio of researchers in R&D" (Nelson and Wright, 1992). Most indices are quite ad-hoc and new indicators may emerge as defining the notion of leadership and technology advances. It could be that AI may change the whole notion

[1] https://www.wipo.int/global_innovation_index/en/2023/ and https://databank.worldbank.org/metadataglossary/

of leadership. But as for today, the list we presented is a good description of the various indices which exist in the literature. Table A2 presents the various variables susceptible of being a good index for leadership in technology, and Table A3 shows the correlation between these various indices.

2.2 Heterogeneity in higher education and heterogeneity of ability of individuals

There is a vast empirical literature on education that casts doubt on the positive effect of an increase in human capital on economic growth (see Pritchett, 2001; Krueger and Lindhal, 2001; and Benhabib and Spiegel,1994). These results were due to the fact that human capital is defined as a homogenous factor and leads to a bias in the effects of education on economic growth. Research must take into consideration that education and human capital are heterogenous. For instance, Hanushek and Woessmann (2008, 2012) and Barro (2013) stressed the importance of school quality and cognitive skills rather than school quantity. Similarly, Altinok and Aydemir (2016) show that the effect of school quality on growth differs across regions and by the economic level of countries. Brezis and Crouzet (2006) show that differences of quality and recruitment among universities lead to the adoption of different types of new technologies, which affect the level of economic growth.

The polarization in higher education is based on the fact that Individuals are not equal in their inner ability, and there are indices, which tries to measure this heterogeneity. The heterogeneity of ability and skills can be measured in two different ways: either through SAT scores (or some similar measures which test the ability of students), or PIAAC.

The "Published International Assessment of Adult Competencies" (PIAAC) is performed while the individual is already working, while SAT scores measure the ability of individuals prior to their academic studies. PIAAC enables to examine the distribution of workers' cognitive skills across the various segments of the labor market.

The polarization in higher education, i.e., elite vs. standard universities, has been mainly emphasized in relation to social mobility and inequality, and not to differences in technology. Brezis and Hellier (2018) show that a dual higher-education system characterised by the concomitance of both standard and elite universities generates permanent social stratification, high social immobility and self-reproduction of the elite. Moreover, Kerckhoff (1995) suggests that the effect of family backgrounds could be magnified when the education system is highly stratified and selective. This argument has been confirmed by several empirical works (Hanushek and Woessmann, 2006; Pfeffer, 2008; Dronkers et al., 2011).

The polarization in higher education is somewhat a new subject of research; we develop shortly the history of this polarization in the following section.

2.3 Polarization in Higher education

Since World War II, the development of education systems has followed rather diverse orientations in advanced economies. In what follows, we highlight some key facts on which our approach is based.

The first is the democratization of tertiary education, with admission procedures based on meritocracy. However, in many advanced countries, this democratization has come with the development of a two-tier system characterised by the concomitance of standard and elite universities. This differentiation between two types of universities has widened over time since the huge increase in the number of students has primarily concerned standard universities, the selection remaining narrow in elite establishments.

In the US, Su et al. (2012) note that, between 1959 and 2008, the non-elitist public post-secondary colleges have increased their enrolment by 525% against 250% in elite colleges. In France, elite universities are represented by the *Grandes écoles* that recruit less than 4% of a generation. Albouy and Wanecq (2003) have shown that there was almost no change in the recruitment of the top *Grandes écoles*, while at the same time the share of a generation completing tertiary education was multiplied by more than 3.5.[2] In contrast, Nordic countries do not exhibit such differences in the selection processes across universities.[3]

The second key fact is that standard and elite universities differ in their budgets, which to a large extent determine their quality. The expenditures per student are substantially higher in elite universities than in standard ones, and this gap has increased in the last decades in a number of advanced countries. In the US, expenditures per student in elite universities (Ivy League) are more than three times higher than in other universities. In addition, from 1999 to 2009, these expenditures increased by 20% in elite universities, and by less than 8% in standard ones (Desrochers and Wellman, 2011). In France in 2002, the spending per student is on average 3.5 times higher in the top GE than in standard universities.[4]

The third key fact is that the access to elite universities is mostly open to the elite's offspring. In the US, SAT scores are highly correlated with family education and wealth (Brezis and Temin, 2008; Carnavale and Strohl, 2010). Carnevale and Strohl (2010) show that the top socioeconomic quartile represents 70% of the students in the most selective colleges, against 14% for the bottom half of the population, this difference having significantly increased from 1982 to 2006.

[2] They define the '*Très Grandes écoles*' as the most prestigious schools leading to the highest top executive and public positions. They show that, for men, the share of a generation entering these top GE decreased from 0.8 for the generations born between 1929 and 1938, to 0.6% for those born between 1959 and 1968.

[3] The variance between elite and other universities is lower in Denmark, Finland and Norway (Brezis, 2012).

[4] Data from the *Observatoire Boivigny*.

For France, Albouy and Wanecq (2003) show that, since the end of World War II, the difference in the probability to enter a *Grande école* between students from the upper class and the 'popular classes' has followed a U-curve.[5]

These facts clearly indicate that that there is social stratification in the access to elite universities, and that the social segregation in the entry to elite establishments has increased in the last decades.

Finally, empirical regularities show that entering an elite university is the natural path to the highest private and public positions (Temin, 1999, for the US; Baverez, 1998, for France).

In the next section, we present a simple model, in which we can pinpoint the effects of the polarization gap in quality as well as in recruitment on the economy. We show that inequality as well as technological leadership are functions of these two elements of polarization. We present the main equations of the model in the text, and the proofs are presented in the appendices

III. The model

3.1 Introduction

This model introduces the higher education sector into the conventional models of technological progress, innovations and economic growth. This model draws on production functions similar to the ones depicted in the literature, as in Autor and Dorn, (2013). However, the model differs in the assumption that human capital is heterogenous. In order to understand the main mechanism of this model, we present a stylized economy with three key features related to the heterogeneity of workers.

(i) First, there is heterogeneity in the ability of individuals, i.e., individuals are not equal in their ability. (ii) There is polarization in the higher education market, i.e., all universities are not equal in their quality: There are elite and standard universities; and (iii) There are two goods, and the production functions of traditional non-tech goods and high-tech goods are not similar in the way they make use of human capital.

About the third feature, we assume that the economy produces two goods: High tech goods, which include digital economy, computers, electronic, and AI consumed by individuals, and the non-tech goods. The factor of productions of high-tech and non-tech goods are capital, unskilled as well as skilled labor, since workers can either acquire higher education, be 'skilled', with human capital H, or without university education, then they are 'unskilled workers' denoted L.

Higher education is not homogenous since there is polarization in the type of universities. Individuals can either receive education in a top university, (H_E for elite universities) or learn in

[5] The upper class offspring were 27 times more likely to enter a GE than those from the popular classes in the generations born in1929-1938 , 17 for the 1949-1958 generations, and 20 for the 1959-1968 generations.

a standard university (H_{NE} for non-elite). We assume that the type of education the individual acquires is common knowledge since it is acknowledged on his/her diploma.

The assumption of polarization in higher education is not commonly used in models of technological progress.[6] This is the specificity of this model. Indeed, as underlined in Brezis and Crouzet, 2006, during the last half of the twentieth century, a dramatic change took place in higher education: The number of universities and colleges in the West rose, and the number of students increased even more. Concurrently with this democratization of higher education, universities became heterogeneous not only in their specializations, but in their quality.

When higher education is provided only to very few, there is no need for selection, and universities do not differ in their quality and prestige. Yet, when higher education is democratized and nearly 40% of the population attends colleges or universities, uniformity in their quality is impossible. There is, therefore, a distinction between on the one hand, the elite universities, for which after World War II, selection became meritocratic, and on the other hand, the others.[7]

We start the presentation of the model by defining the effect of heterogeneity in the ability of individuals, and in the education market, then we turn to the utility and production sections.

3.2 Ability

We assume that individuals are born with different abilities. We could assume that personal ability is continuous and is randomly distributed across individuals. However, we can assume a simpler assumption, since in Brezis and Hellier (2018), we show that for all abilities lower than $\underline{a}$, students would be accepted in standard universities, and for ability higher than $\underline{a}$, they will be accepted in elite universities. Therefore, for sake of simplicity, we can regroup all the abilities lower than $\underline{a}$, and denote then by a^l (which could be the average of all abilities lower than $\underline{a}$). On the other hand, for abilities higher than $\underline{a}$, we regroup them and denote it by a^h (which could be the average of all abilities higher than $\underline{a}$). So, abilities are either high denoted a^h, or low denoted a^l. For sake of simplicity, we assume that:

$$a^h = \delta a^l \quad \text{where } \delta > 1. \qquad (1)$$

This difference in ability of individuals affects the economy through two channels. First, smarter people learn more rapidly, and therefore for getting the same grade or diploma, they

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[6] See for instance, Acemoglu and Autor (2011); Autor and Dorn (2013), and all seminal papers in this field by Acemoglu, Aghion, Autor, Dorn et al.

[7] There are several published rankings of universities, so that their ranking is public knowledge. This paper emphasizes that the large number of students and universities contributes to the divide in quality, creating a dichotomy between elite and standard institutions. (This phenomenon is not limited to higher education; it is also existing in the realm of academic journals. However, this paper focuses exclusively on the polarization within higher education).

have to invest less effort than an individual with low ability. Obviously, ability affects their results on entry exams to universities.

The second channel is through the labor market. Ability affects the productivity of individuals: individuals with high ability will have a higher productivity at work, which affects the efficiency of workers. These two channels are essential for understanding the effects of education on leadership in technology.

3.3 Acquiring skills -The Higher Education sector.

a. The recruitment process

There are elite universities, in which when graduating, the student acquires a human capital of type H_E; and there are standard universities, in which the student acquires human capital of type H_{NE}.

There are entry exams to the different universities, and the grades on the entry exam to the elite universities, are much higher than the grades to enter standard universities.[8] In consequence, we get the following polarization: Students with high grades on his entry exam will get access to elite universities and acquire human capital of type H_E. Students with lower grades (but with a high school diploma) register to a standard university and acquire human capital of type H_{NE}. Finally, individuals who did not graduate from high school will stay unskilled, and display a factor of production, L.

Individuals who have graduated from high school can register to classes which are helping them to improve their score on the entry exams. The cost for taking these exams, C, is the cost per hour of these classes, P, multiplied by the number of hours necessary for preparing for these exams. Individuals whose ability is low need plenty of time for the acquisition of the knowledge (i.e., he needs to invest high effort, e^l), whereas individuals whose ability is high need low investment (e^h). For matters of simplicity, we assume that efforts are inverse to the ability level, so that $e^h = 1/a^h$ and $e^l = 1/a^l$, and we get that:

$$C_l > C_h \qquad (2)$$

b. The externality effect of an elite university – world technology frontier in skills and tasks

What is the specificity of being in an elite university?

In an elite university, scholars teach at the frontier of knowledge, which will affect the new skills in the economy. Technological changes are a suite of changes, either by creative destruction, or by additive knowledge. Most of them are based on new knowledge taught at the top universities directly, but also indirectly through the peer effect. Indeed, the literature on peer

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8 In the various countries, the exam is slightly different. In the US, it is SAT, in France the "prep exams". See section 2.3 and Brezis and Crouzet (2006) for more details.

effect highlights that in top universities, since smart people meet other smart people, there is, on top of a better education, an externality of being in the elite school.

This knowledge will diffuse to the standard universities over the years, but for many years, only students at the top universities will get this knowledge which will permit to develop the new skills needed in the development of the high-tech sector.

In this paper, we focus on the science & engineering departments in elite universities, which based on new knowledge in robotic, and technology, give to their students a lead in these skills: the students get the newest knowledge, and they are on the frontier of world technology.

For sake of simplicity, we define this externality as $\lambda = \lambda(I)$, I being the investments in labs and scholars. Students from elite universities are therefore more productive in the high-tech sector, since budgets, I invested in elite universities are higher.

3.4 The two goods in the economy

There are two types of goods in the economy, high-tech goods, T and traditional, non-high tech goods, NT. Consumers want them both, (in different countries, the relative demand is different), and we assume an elasticity of substitution of 1 between these goods, so the utility function will take a Cobb-Douglas form such as:

$$U(T, NT) = T^{\frac{\pi}{1+\pi}} NT^{\frac{1}{1+\pi}} . \qquad (3)$$

π is the ratio of the demand of high-tech over non-tech goods.

3.5 The non-tech production function.

The tech sector as well as the non-tech one uses three factors of production: L, H and K. We assume a CES function between H and L, so that skilled and unskilled workers are substitute factors of production, and we assume that workers (skilled and unskilled), and capital K have a constant rate of substitution of 1. These assumptions are quite common and can be found in the literature on wage premium (see for instance Autor and Dorn, 2013).

Our model differs by assuming that H is not homogenous: we have in fact two different types of human capital, H_E and H_{NE} (workers graduating from elite and standard universities respectively). The two types of human capital are perfect substitute, and the producer can hire either workers graduating from elite universities or from standard universities.

The productivity of each human capital H is a function of the average ability of the skilled workers having acquired this type of education: a_1 and a_2 for non-elites and elite education respectively. So, if only high ability individuals graduate from an elite university, we get $a_2 = a^h$

, but if there are equal amount of low ability and high ability graduates from elite universities then $a_2 = (a^h + a^l)/2$.

So, the production function of the non-tech good takes the following form:

$$Y_{NT} = K^{1-\beta}[(a_1 H_{NE} + a_2 H_E)^{\alpha} + (a_u L)^{\alpha}]^{\frac{\beta}{\alpha}}. \tag{4}$$

where β, α are both between 0 and 1. The respective costs of the factor of productions of L, H_{NE}, H_E and K are: W_u, W_S^l, W_S^h, and *r*.

3.6 The high-tech production function.

The production function of the high-tech good is similar to the non-tech one. For sake of simplicity, we take a similar ratio in both goods (β is the same in both equations), but we assume a different substitution rate between skilled and unskilled labor, ρ (assumption which can be released. Later on we will also check the case where $\rho = \alpha$).

The main difference between these two sectors is in the 'match' between the type of education and the good produced. For producing high-tech, the productivity of the workers having graduated from an elite university and having received education at the frontier of knowledge has a higher effect than if they would have graduated from a standard university. In other words, there is a better match between the needs of the high-tech industry and the knowledge acquired in top schools. This is the 'productivity match' as λ (which is affected by the level of education in elite universities).

So the tech sector has the following production function

$$Y_T = K^{1-\beta}[(a_1 H_{NE} + \lambda a_2 H_E)^{\rho} + (a_u L)^{\rho}]^{\frac{\beta}{\rho}}. \tag{5}$$

where β, ρ are both between 0 and 1, and $\lambda > 1$.

3.7 The Equilibrium.

Let us find out, whether there is separation between types of ability, i.e., individuals with high ability work in tech industries while individuals with low ability work in the non- tech industries.

Proposition 1.

Under condition I, all individuals with low ability will acquire standard higher education of type H_{NE}, while individuals with high ability, will get access to elite universities and acquire human capital of type H_E.

Proof

The proof is presented in Appendix 1

We now check whether there is also polarization in the labor market.

Let us define Condition II:

Condition II: $$\frac{\lambda W_S^l}{a^l} > \frac{W_S^h}{a^h} > \frac{W_S^l}{a^l}$$

We then get the following Lemma.

Lemma 1

Individuals with human capital of type H_E (having graduated from an elite university) will all work in the high-tech sector, and the individuals with human capital of type H_{NE} (having graduated from a standard university) will work in the traditional, non-tech sector.

Proof - The proof is presented in Appendix 2

We now turn to Proposition 2.

Proposition 2

Under Conditions I and II, individuals with high ability, having graduated from a top university will work in the high-tech sector, and individuals with low ability will work in the low- tech *sector. Condition I is presented in the appendix.*

Proof

From Lemma 1, workers in the tech sectors are with education of type H_E. From Proposition 1, those with education type H_E are of high ability. In consequence, individuals with high ability work in the tech sector. Following the same reasoning, individuals with low ability will work in the non- tech sector.

Since the only skilled workers in the tech sector are of high ability and have acquired human capital of type H_E, we then get that $a_2 = a^h$, and the production function takes the following form:

$$Y_T = K^{1-\beta}[(\lambda a^h H_E)^\rho + (a_u L)^\rho]^{\frac{\beta}{\rho}}. \qquad (6)$$

Following the same reasoning, the production function of the non- tech sector is:

$$Y_{NT} = K^{1-\beta}[(a^l H_{NE})^\alpha + (a_u L)^\alpha]^{\frac{\beta}{\alpha}}. \tag{7}$$

3.8 The "tractable" model

Most models of innovations do not include heterogeneity of human capital, since equations (4) and (5) are not easily solvable. So, scholars prefer to assume homogenous human capital, and analyze skilled vs. unskilled workers. Out model permits to introduce heterogeneity in human capital and still have a tractable model, because we have proved that in fact there is a separating equilibrium in the economy.

This separating equilibrium enables us to simplify the "canonical model". Indeed, the equations of the production functions, (4) and (5) become (6) and (7), which can be analyzed easily. This equilibrium also allows us to analyze leadership in technology and inequality between the two types of skilled workers, which today characterizes the inequality between middle and top classes.

We can now check the assumptions under which we obtain that this separating solution is an equilibrium.

Lemma 2

With production functions presented in equations (6) and (7), Condition III is sufficient to obtain Conditions I and II.

Condition III $\delta(\tau-1) > \dfrac{P}{W_S^l a^l} > (\dfrac{\gamma}{\gamma-1})(\tau-1)$ where $\tau \equiv \lambda^\alpha \delta^\alpha \sigma^{\alpha-1} > 1$

Proof

The proof is presented in Appendix 3.

Proposition 2 allowed us to simplify equations (4) and (5), and define the world economy by equations (6) and (7). It allowed us to calculate changes in productivity and the wage inequality, when workers with different abilities work in different sectors.[9]

This model stresses that the equilibrium presented in the propositions holds under the assumption that costs of learning are neither too high (so that high ability individuals will invest in acquiring education in elite universities), nor too low (to avoid that low ability students will also invest in acquiring education in elite universities). Then, we obtain that indeed the separation equilibrium is stable and no individual has incentives to deviate from this solution.

Therefore, low ability workers graduate from standard universities and go to work in the non-tech sector. About high ability workers, they graduate from elite universities, and work in the high-tech sector. This separation equilibrium permits us to define leadership and define the

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[9] For simplicity matters, let us assume that $\sigma = \pi$, so that in a separating equilibrium, the demand for tech and non-tech goods is equal to the supply of these goods.

elements affecting the level of leadership. It also permits to calculate the various wages, as well as inequality between workers.

3.8 Heterogenous higher education, Leadership in technology, and Inequality

The two elements entering the definition of the polarization gap are the tightening of the recruitment, which is given by σ , when:

$$\sigma = \frac{H_E}{H_{NE}}$$

and the gap in quality λ, which is a function of the gap in budgets.

Based on the literature, we define leadership at the level of a country by the relative productivity of the leading sector, denoted as *Fd*.

$$Fd = \frac{Y_T}{Y_{NT}} = \beta\lambda^{\alpha}\delta^{\alpha}\sigma^{\alpha-1} \tag{8}$$

What about inequality? In appendix 3 we calculate the various wages, and we obtain the wage inequality, equation (9).

$$I_n = \frac{W_S^h}{W_S^l} = (\frac{\lambda a^h}{a^l})^{\alpha}(\frac{H_E}{H_{NE}})^{\alpha-1} = \lambda^{\alpha}\delta^{\alpha}\sigma^{\alpha-1} > 1 \tag{9}$$

From equations (8) and (9), we see that productivity gap, Fd and the wage inequality, I_n are a function of the two elements affecting the polarization gap: the gap in quality, λ and the gap in tightness of recruitment, σ (a lower σ means less openness of recruitment, i.e., higher tightness of recruitment). The third element affecting technological leadership and inequality is the gap in ability among individuals, δ .

A higher gap in quality due to a gap in budget, λ leads to higher wage inequality and to an increase in leadership. A lower openness of recruitment σ (which means an increase in tightness) leads to an increase in wage inequality and in leadership.

In conclusion, both elements of polarization (quality and tightness) lead to higher leadership. This effect increases over time since the development of innovations magnifies the "matching effect" of education in elite universities. In consequence, the 'productivity match' leads to an increase in the productivity of these workers, and to an increase in leadership in technology. So, we get the following proposition.

Proposition 3

An increase in the polarization gap (quality and tightness of selection) leads to an increase in leadership in technology and to an increase in inequality.

Proof

Focusing on equations (8) and (9), we see that wage inequality and the leadership index are a positive function of both elements of the polarization gap. (when λ increases, Fd and I_n increases, and when σ decreases, Fd and I_n increases).

We now turn to the empirical analysis. Since the two variables of the polarization gap have a main effect on the economy, as underlined in Proposition 3, we have invested much time and energy to develop indices of these two variables.

IV. Empirical Analysis

This paper relates polarization in higher education to leadership in technology and to inequality. The empirical analysis is divided into two main tasks. First, there is a need to develop variables on this matter, and then to perform econometric analysis. About the first task, there are no indices on polarization in the literature. In consequence we have developed an index of polarization. This paper also develops an index for leadership in technology. Next, we conduct empirical analysis, of the two main equations of this model, equations (8) and (9).

Our analysis begins with the development of a polarization index, for the two main differences between standard and elite universities. First, the gap in budgets, which influences the gap in quality. Second, recruitment for elite universities is highly selective, so we gather data on the gap in tightness of recruitment. We start with the polarization gap in quality.

4.1 Polarization gap in quality

There are main differences in the budget per student of elite universities vs. standard ones, and this budget difference leads to difference in quality of education, as emphasized in Desrochers, D. and J. Wellman, (2011).[10]

The index is presented in Table 1, column 1. For OECD countries, we identify the top universities based on the Shanghai ranking (ARWU) and calculate the budget per student for these top institutions. The polarization gap index is the ratio of the budget per student at top universities to the average budget per student (The indicator was standardized on a common scale, with the United States receiving a score of 100, and the scores of other countries were determined accordingly).

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[10] See Desrochers, D. and J. Wellman. 2011.

Here are some concrete examples. In England, the budget per student at the top three universities, including Cambridge, is \$80,400, which is 3.12 times the national average of \$25,770 per student (79.19 on the standard scale). In the United States, the top three universities, including Stanford, have a budget per student of \$111,500, while the national average is \$28,300—3.94 times the average budget (100 on the scale).[11]

The index presented in Table 1, col. 1 shows that countries with a high polarization index are the US, France, the UK, as well as Israel and Japan. (The index takes the value of 100 for the US; 30.46 for Sweden and 43.91 for Finland).

4.2 Polarization gap in tightness of recruitment

The second element included in the polarization gap is the tightness of recruitment. The aim of the index is to check the difference in the tightness of selection between the elite universities and the standard ones.

The way the index is calculated is the following: A priori, we should check the tightness of selection at the level of a university, but because of the absence of information on admission scores, at the level of the entire academic institution for most countries, we gather data on specific subjects of study. We focus on the most popular subjects of study in the countries of the sample, which are Economics, Psychology, Computer science and Law.[12]

In the next step, using the Shanghai ranking, we check the universities which are ranked high in those subjects of study and those which are ranked low. For all of these universities and subjects, we checked the required admission score.[13]

The polarization index is calculated as the ratio in the tightness of selection between the lowest ranked university and the highest ranked one.[14] In each country, and each university we focus on, we check the lowest grade needed to be accepted at the university. Given the distribution of students' grade on exams, we can calculate the percent of students who are accepted from the population of students. We denote this percent as the tightness of recruitment in this specific university (The indicator was standardized on a common scale, with the United States receiving a score of 100, and the scores of other countries were determined accordingly).

Let us present some examples. In the US, Harvard University is ranked first in the Shanghai ranking. The percent of applicants who are admitted is 5%, so the tightness of recruitment at

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11 For Sweden, Uppsala University has a budget per student of \$28,000 compared to \$23,300 for the average budget. So, it is only 1.2 times the average budget (30.46). And to give one more example, for Finland, University of Helsinki has a budget of \$30,960, compared to \$17.920 average budget, so that we have a polarization index of 1.73 (43.91).

12 However, for the US, there is more extensive information and therefore it was possible to perform a calculation at the level of the university. Information can be found on the government website https://nces.ed.gov.

13 See Appendix 4 for more details.

14 We could also compare a university that is not ranked to the highest ranked one, but this index will not have a similar comparison in the various countries.

Harvard is 5%. In average in the US higher education system, we get that 28 % of all applicants are accepted. The calculation of the polarization index for tightness of recruitment for the US is then 5.6 (28 divided by 5) and 100 on the standard scale. The data is presented in Appendix 4.[15]

Table 1, column 2 presents the polarization index of the gap in recruitment. In countries with a high level of inequality, such as US, Israel, and the UK, the polarization index is high (100 for US, 68.78 for Israel, and 79.19 for UK) and in countries with a low level of inequality the polarization index is also low, such as Denmark (19.64) and Sweden (25). This is the only research we know, which is presenting this index. Gathering data for elaborating this index was time consuming, and could not be done by AI, but is needed in order to check whether it is indeed related to technological leadership and inequality as developed in the theoretical model.

It is interesting to note that the index based on budgets (and quality), and the index based on tightness of selection are strongly correlated (R-squared= 0.5371, p-value= 0.002).

4.3 The Leadership Index

In the theoretical model, leadership in technology is defined as the relative productivity between sectors. What would be a good index to reflect this relative productivity? In the literature, many indices were presented (see section 2.1). A comprehensive index of national technological leadership should ideally incorporate multiple dimensions of leadership. Furthermore, the index should be relatively simple to implement and rely on readily available, high-quality data. Two particularly significant indicators of technological leadership are research and development (R&D) expenditure as a percentage of GDP and patents per capita. R&D expenditure directly measures a nation's investment in innovation, while patents provide a tangible metric for productivity of the leading sectors. By combining these two indicators into a composite index, we can gain a more nuanced understanding of a nation's technological leadership. This is the leadership index we have chosen.

To construct the index, we obtained raw data on R&D expenditure as a percentage of GDP and the number of patent applications per capita. These two parameters were then normalized to a common scale, with the United States serving as the benchmark (assigned a score of 100), and other countries receiving scores relative to the US. The final index was calculated as the average of these two normalized indices.

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[15] In the UK, the top university is Cambridge. The average score of acceptance is such that only 13.8% of applicants are admitted. In the median-ranked University of Fribourg, the university admits 49.2% of applicants. In consequence, the index of the recruitment gap in the UK is 3.6. (49.2/13.8), 79.19 on the standard scale. In Denmark, the applicant at the University of Copenhagen (ranked first) has a 56% chance of admission compared to a 61% chance for the median-ranked university, Aalborg University. Thus, Denmark's index is 1.1 (61/56), 19.64 on standard scale, significantly lower than the US or UK.

Table A1 in the appendix presents the two components of the calculated index (R&D and patents) as well as the final composite index, which is the average of the two. The leadership index is presented in column 3 of Table A1 and in Table 1, column 4.

In section 2.1 of the related literature, we have shown that there are other possible indices. These alternative indices are presented in Table A2. We investigated the correlation between all these indices. Table A3 presents the correlations among these various indices, as well as their correlations with the polarization indices and the Gini index.

4.4 Econometric Analysis

The model and equations (8) and (9) have shown that both the productivity gap (Fd) and wage inequality (I_n) are a function of two factors affecting the polarization gap: quality of education and tightness of recruitment.

We will begin the analysis by examining the correlation between the leadership index and the polarization gap of higher education (quality gap and recruitment gap). Subsequently, we will also investigate the correlation between the polarization indices and the Gini index of social inequality.

A. Leadership and polarization in higher education

We first start by analyzing the relationship between polarization of the higher education system (as measured by the gap in quality and gap in recruitment) and the Leadership index.

A.1 Leadership and Gap in quality

Let us now consider the following econometric equation:

$$\text{Leadership\_index}_j = \alpha + \delta\text{quality\_index}_j + u_{jt}$$

when:

- $\text{Leadership\_index}_j$ represents the leadership Index for country j.
- quality_index_j represents the gap in quality for country j.
- u_j is the term for random error between countries.

Figure 1 presents the relationship between leadership and gap in quality. The regression analyses are presented in Table B1, revealing a statistically significant positive relationship between the polarization gap in quality and the Leadership Index.[16]

A.2 Leadership and Gap in recruitment

We examine the following equation:

[16] We have also performed panel data analysis on this section, since we collected data on 'quality gap' for three years. The analysis confirms a significant relationship between gap in quality and leadership as well as with the Gini index.

$$\text{Leadership\_index}_j = \alpha + \delta \text{recruitment\_index}_j + u_j$$

Figure 2 presents the relationship between leadership and gap in recruitment. The regression analyses are presented in Table B1 revealing a statistically significant positive relationship between the polarization gap in recruitment and the Leadership Index.

B. Inequality and polarization in higher education

The results of both analyses (with gap in recruitment, and gap in quality) are presented in Table B2. For both polarization indexes, the quality gap and recruitment gap, we found a statistically significant correlation with the Gini index.

4.5 Conclusion of the empirical part

The aim of our empirical work is to establish that polarization and heterogeneity in higher education are related to both inequality and leadership. The regressions have shown that both the gap in quality and in recruitment affect leadership and inequality. In Figures 1 and 2, we show the relationship between the two polarization indices and the leadership index.

Since these polarization indices affect positively inequality as well as the leadership index, we are not surprised that in Figure 3, we find a correlation between these two endogenous variables. Indeed, countries with high leadership are countries with high inequality.

Countries at the forefront of technology require a polarized higher education system, which inevitably leads to wage inequality among skilled workers. There is no 'free lunch' in building leadership in high-tech.

V. Conclusion

This paper unveils the effects of higher education policy on leadership in technology and inequality. This paper shows that a nation implementing a public education policy, which establishes polarization between top-tier universities and standard ones, may stimulate progress and leadership, at the price of inequality. Specifically, countries characterized by a high polarization gap attain leadership in science and engineering technologies, where the 'polarization gap' measures the distinctions between elite and non-elite universities.

The initial finding of this paper is that the polarization gap contributes to higher productivity and inequality by directing top workers toward sectors where high ability significantly influences productivity. In countries with a high polarization gap, a distinction arises among students, resulting in a separating equilibrium. This means that only students with high abilities graduate from top universities, while skilled workers with lower abilities are admitted to standard universities. Conversely, in countries with low polarization, there is no separating equilibrium, and no alignment occurs between students' abilities and the universities they attend.

In this paper, the primary distinction between high-tech and low-tech sectors lies in the match between education type, worker ability, and the nature of goods produced. In the high-tech sector, the productivity of workers educated at the forefront of knowledge is higher than if they had graduated from a standard university.

Top universities, being at the forefront of knowledge, play a crucial role. Having the best students directed towards sectors utilizing this knowledge more efficiently leads to technological progress. In countries with a high polarization gap, there is differentiation among students, ensuring that the best universities impart this knowledge to more capable students who can then apply it in sectors with rapid technological progress, such as the high-tech sector.

In essence, polarization leads to higher worker productivity, by channelling the top workers to the sectors where high ability affects productivity very much. In consequence, countries choosing to develop dual quality education tracks can reach the frontier of leadership in technology but at the price of higher inequality, while countries without this polarization in higher education will not develop high tech sectors and sectors where productivity is high. The choice of the high education policy affects productivity growth.

Another aspect developed in this model is the inequality among workers. This paper posits that inequality is the cost associated with achieving technological leadership and experiencing productivity growth. Inequality is the consequence of being at the frontier of technology. Moreover, Brezis and Hellier (2018) have shown that these two elements of polarization (quality and recruitment) also affect negatively social mobility and stratification.

In the empirical section, we compile data on both the leadership index and the polarization gap index, which consists of two components: a quality gap and a recruitment selectivity gap. We show that, in OECD countries, there is a clear correlation between technological leadership, inequality, and the polarization gap.

A country that primarily adopts existing technologies without pushing the technological frontier may avoid significant heterogeneity in its higher education system and, consequently, wage inequality. However, a nation aiming to lead in knowledge and innovation must establish elite universities where admission is based on meritocratic exams, which inevitably leads to increased inequality.

An interesting case for future research could be China, which is not an OECD country and is not included in our sample. In China, much of the inequality does not stem from the capital-labor divide, as most capital is state-owned. Nonetheless, inequality is high and continues to rise, largely due to inequality among skilled workers, which is precisely the focus of this paper.

Indeed, China's higher education system is strongly shaped by its entrance exam to universities, the *gaokao*, suggesting a high polarization index. Moreover, the type of inequality discussed in this research has sharply increased in China over the past decade.

In recent years, China has also made significant technological advancements, with a large number of highly cited research papers and substantial investments in high-tech industries. Therefore, the relationship this paper highlights between inequality, leadership, and polarization in higher education is not only relevant to OECD countries but also to any nation aspiring to lead in fields that drive economic growth.

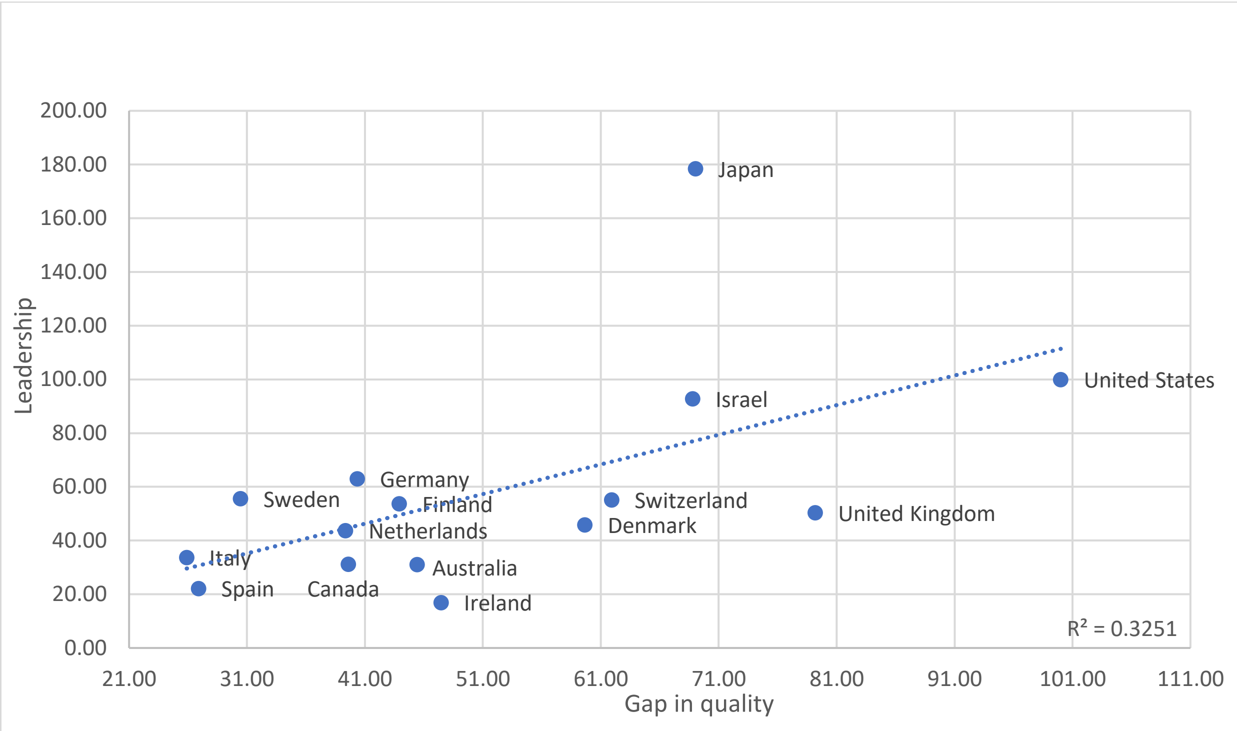
Table 1: Indices on the polarization Gap, Inequality, and Leadership in Technology.

	Index of gap in quality (1)	Index of gap in recruitment (2)	Gini index (3)	Leadership Index (4)
Australia	45.43	50.00	48.93	31.05
Canada	39.59	50.00	49.35	31.21
Denmark	59.64	19.64	43.40	45.81
Finland	43.91	28.57	43.33	53.71
France	-	57.14*	45.11	55.94
Germany	40.36	46.43	46.94	62.97
Ireland	47.46	53.57*	48.62	16.94
Israel	68.78	69.64	59.66	92.83
Italy	25.89	33.93*	50.39	33.70
Japan	69.04	89.29	53.77	178.46
Netherlands	39.34	35.71	42.48	43.77
Norway	-	28.57	40.17	35.94
Spain	26.90	28.57	46.01	22.22
Sweden	30.46	25.00	40.68	55.59
Switzerland	61.93	25.00	42.21	55.18
UK	79.19	64.29	46.94	50.37
United States	100.0	100.0	58.31	100.0

Sources: World Bank, World Forum, and own calculations.

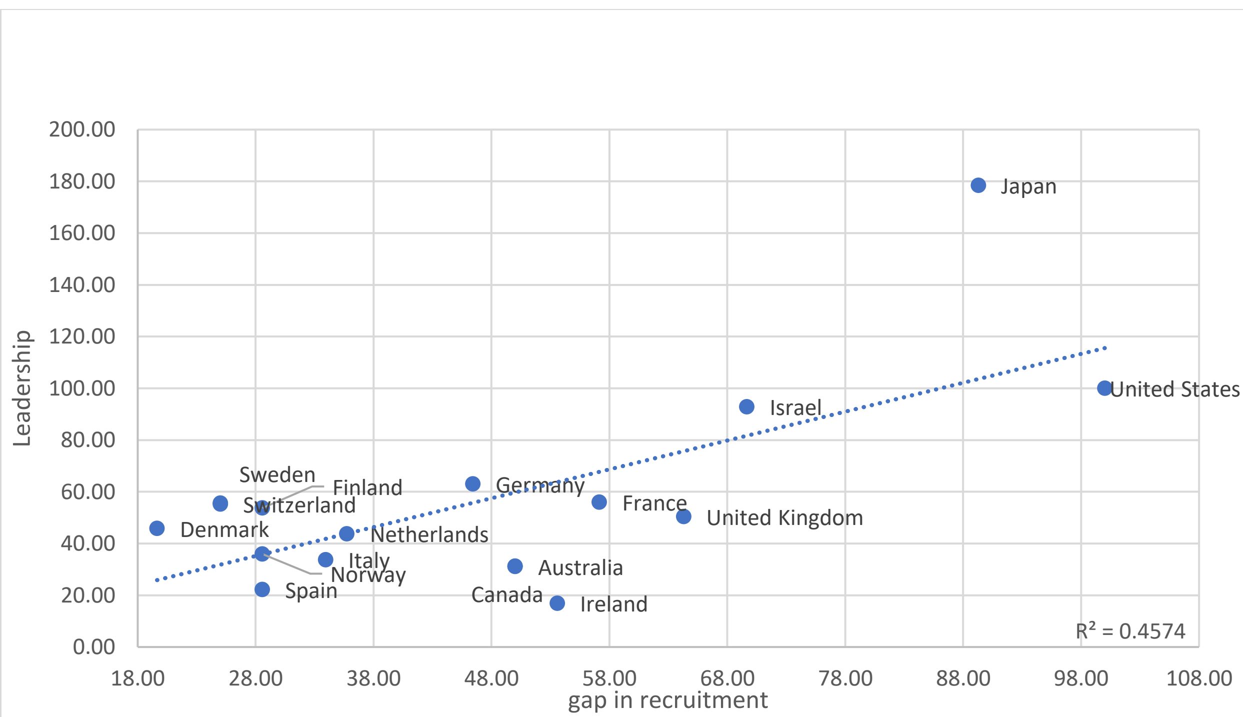
Notes: column (1) is the index of polarization gap in quality as explained in section 4.1; column (2) is the index of polarization gap in recruitment as explained in section 4.2 and elaborated in appendix 4; Column (3) is the Gini index of disposable income before taxes; Column (4) is the index of leadership, as presented in the appendix Table A1, column (3).

Figure 1: The technological leadership index and gap in Quality



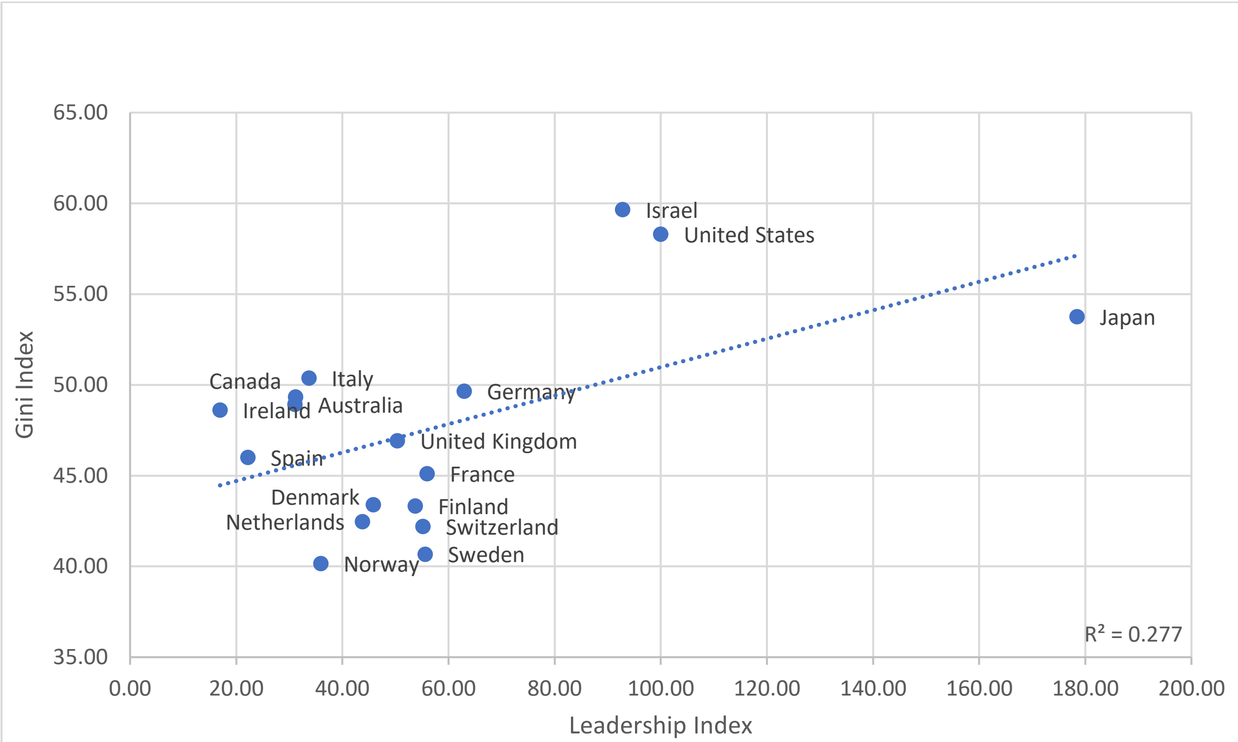
Source: own calculation

Figure 2: The technological leadership index and gap in tightness of recruitment



Source: own calculation

Figure 3: The leadership index in technology and the Gini Index



Source: own calculation and The World Bank.

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APPENDICES

Appendix 1

Before proving Proposition 1, let us calculate the costs of studying at elite and standard universities.

The costs for each individual for entering elite universities are:

$$C_h = P.e^h = \frac{P}{a^h} \quad \text{for individuals with high ability} \tag{A1}$$

$$C_l = P.e^l = \frac{P}{a^l} \quad \text{for individuals with low ability} \tag{A2}$$

and we get that $C_l > C_h$

We assume that the costs for entering standard universities are 0 for high-ability individuals while the costs for low-ability is low but not zero, and we assume it is c, when c is:

$$c = P / \gamma a^l \text{ with } \gamma > 1 \text{ and } \delta > \gamma/(\gamma-1) > 1. \tag{A3}$$

Proof of Proposition 1.

Let us first define conditions Ia and Ib, and then present the proof for Proposition 1.

Condition I: Condition Ia: $\frac{P}{a^l}(\frac{\gamma-1}{\gamma}) > W_S^h - W_S^l > \frac{P}{\delta a^l}$ **Condition Ib**: $W_S^l - c > W_u$

Let us assume that indeed all individuals of high ability acquire H_E, and individuals with low ability go to learn in standard universities. We show that this is an equilibrium, i.e., no individual wants to diverge from this equilibrium.

a).

For a high ability person, from the right-hand side of Condition Ia, it is easy to show that we get the following inequality:

$W_S^h - C_h > W_S^l$

This inequality means that high ability individuals get a higher income from investing in education in elite university than from getting a degree in standard university (remember that costs for high ability individual to learn in standard university are 0). In consequence we have shown that indeed high ability individuals prefer to learn at elite universities.

b).

For a low ability person, from the left-hand side of condition Ia, we get the following inequality (remember that for low-ability individual, cost of learning in standard university is c):

$W_S^l - c > W_S^h - C_l$

which means that a low ability person is better off going to a standard university than to an elite university.

Moreover, from condition Ib, i.e., $W_S^l - c > W_u$, we get that a low ability individual having a high school diploma prefers to enter a standard university than not to get higher education. In consequence low ability individuals enter a standard university.

This lemma states that under Conditions Ia and Ib, we get that the polarization in higher education leads to a separating equilibrium: individuals with high ability acquire H_E and individuals with low quality acquire H_{NE} .

Appendix 2

Proof of Lemma 1

(i) Let us first analyze the tech sector. From the production function displayed in equation (5), human capital of types H_E and H_{NE} are perfect substitute. In consequence the producer will employ the type which is the cheapest for him for producing the same amount of output.

One worker of type H_E (which we know from lemma 1 that he is of high ability) is producing λa^h at cost W_S^h, while the worker of type H_{NE} is producing a^l at cost W_S^l .

It is less expensive to hire workers having graduated from elite universities if:

$\frac{W_S^l}{a^l} > \frac{W_S^h}{\lambda a^h}$ which is equivalent to the left hand side of condition II.

(ii) About the non- tech sector, from equation (4), a worker of type H_E (being of high ability) is producing a^h at costs W_S^h, while the worker of type H_{NE} is producing a^l at cost W_S^l .

It is less expensive to hire workers having graduated from standard universities if:

$\frac{W_S^h}{a^h} > \frac{W_S^l}{a^l}$ which is equivalent to the right hand side of condition II.

Appendix 3

Proof of Lemma 2

In order to prove the Lemma, let us find out the wages: W_u , W_S^l , W_S^h .

The marginal products of H_E and L are equal to their wages, so:

$$W_u = \frac{\partial Y_T}{\partial L} = \beta K^{1-\beta} L^{\beta-1} a_u{}^{\rho} [(\lambda a^h \frac{H_E}{L})^{\rho} + (a_u)^{\rho}]^{\frac{\beta-\rho}{\rho}} . \tag{A4}$$

and:

$$W_S^h = \frac{\partial Y_T}{\partial H_E} = \beta K^{1-\beta} H_E^{\ \beta-1} (\lambda a^h)^\rho [(\lambda a_h)^\rho + (a_u \frac{L}{H_E})^\rho]^{\frac{\beta-\rho}{\rho}} . \qquad \text{(A5)}$$

So that the wage premium of education of type H_E is:

$$\omega_1 = \frac{W_S^h}{W_u} = (\frac{\lambda a^h}{a_u})^\rho (\frac{H_E}{L})^{\rho-1} . \qquad \text{(A6)}$$

From the non-tech function of production, the marginal products of H_{NE} and L are equal to their wages, so:

$$W_u = \frac{\partial Y_{NT}}{\partial L} = \beta K^{1-\beta} L^{\beta-1} a_u^{\ \alpha} [(a^l \frac{H_{NE}}{L})^\alpha + (a_u)^\alpha]^{\frac{\beta-\alpha}{\alpha}} . \qquad \text{(A7)}$$

$$W_S^l = \frac{\partial Y_{NT}}{\partial H_{NE}} = \beta K^{1-\beta} H_{NE}^{\ \beta-1} a^{l\,\alpha} [(a^l)^\alpha + (a_u \frac{L}{H_{NE}})^\alpha]^{\frac{\beta-\alpha}{\alpha}} . \qquad \text{(A8)}$$

And the wage premium of education of type H_{NE} (solving as in the case of high-tech) is:

$$\omega_2 = \frac{W_S^l}{W_u} = (\frac{a^l}{a_u})^\alpha (\frac{L}{H_{NE}})^{1-\alpha} \qquad \text{(A9)}$$

From (A6) and (A9), we get that the wage premium of education of type H_E vs. type H_{NE} is:

$$\omega_3 = \frac{W_S^h}{W_S^l} = (\frac{a^l}{a_u})^{-\alpha} (\frac{H_{NE}}{L})^{1-\alpha} (\frac{\lambda a^h}{a_u})^\rho (\frac{H_E}{L})^{\rho-1} \qquad \text{(A10)}$$

If we make the simplifying assumption that $\rho = \alpha$, then:

$$\omega_3 = \frac{W_S^h}{W_S^l} = (\frac{\lambda a^h}{a^l})^\alpha (\frac{H_E}{H_{NE}})^{\alpha-1} \qquad \text{(A11)}$$

Remembering that the ratio of high ability individuals vs. low ability is σ , then we get:

$$I_n = \omega_3 = \frac{W_S^h}{W_S^l} = (\frac{\lambda a^h}{a^l})^\alpha (\frac{H_E}{H_{NE}})^{\alpha-1} = \lambda^\alpha \delta^\alpha \sigma^{\alpha-1} > 1 \qquad (9)$$

Two conditions to check:

a).

Remember that condition II is : $\frac{\lambda W_S^l}{a^l} > \frac{W_S^h}{a^h} > \frac{W_S^l}{a^l}$

which given equation (9) is equivalent to:

$$\lambda\delta > \lambda^{\alpha}\delta^{\alpha}\sigma^{\alpha-1} \qquad \text{and} \qquad (10)$$

$$\lambda^{\alpha}\sigma^{\alpha-1} > \delta^{1-\alpha}$$

And since we have that $\lambda, \delta, \gamma, > 1$ and $\alpha < 1$, then equation (10) holds, when we assume that: $\lambda^{\alpha}\sigma^{\alpha-1} > \delta^{1-\alpha}$. (For instance, if $\alpha = .5$, and $\sigma = 1$, this condition is equivalent to $\lambda > \delta$).

b).

Regarding condition Ia: $\frac{P}{a^l}(\frac{\gamma-1}{\gamma}) > W_S^h - W_S^l > \frac{P}{\delta a^l}$

Since $\tau = \lambda^{\alpha}\delta^{\alpha}\sigma^{\alpha-1} > 1$, then Condition Ia is equivalent to Condition III.

Appendix 4. The polarization gap index in student recruitment

We present data for all the four most relevant fields we examined. We checked the required admission score. [17] In Table 1, we present the average index.

country	Local Rank	Law	Computer Science	Psychology	Economics	Average
Australia	First- The University of Melbourne	8	14	12	10	11
	Median- Deakin University	26	46	29	23	31
	First vs median	**3.2**	**3.3**	**2.4**	**2.3**	**2.8**
Canada	First- University of Toronto	10	8	15	7	10
	Median- Carleton University	20	15	40	40	29
	First vs median	**2**	**1.9**	**2.7**	**5.7**	**2.9**
Denmark	First- University of Copenhagen	31	90	14	88	56
	Median- Aalborg University	49	90	17	88	61
	First vs median	**1.6**	**1.0**	**1.2**	**1.0**	**1.1**
Finland	First- University of Helsinki	5	10	13	5	8
	Median- University of Turku	15	10	15	13	13
	First vs median	**3**	**1**	**1.2**	**2.6**	**1.6**
Germany	First- Heidelberg University	4	4	4	5	4.3
	Median-Martin Luther University Halle-Wittenberg	8	14	9	14	11.3
	First vs median	**2**	**3.5**	**2.2**	**2.8**	**2.6**
Israel	First- The Hebrew University of Jerusalem	3	2	6	11	5.5
	Median- Ariel University. For law: Reichman University	6	10	38	32	21.5
	First vs median	**2**	**5**	**6.3**	**2.9**	**3.9**
Japan	First- The University of Tokyo	1	5	13	5	6
	Median- Miyazaki University For law: Ehime University, for psychology: Ochanomizu University *	30	30	20	40	30
	First vs median	**30**	**6**	**1.5**	**8**	**5**
Netherlands	First- University of Amsterdam	10	10	8	5	8.3
	Median- University of Groningen	20	15	10	20	16.3
	First vs median	**2**	**1.5**	**1.25**	**4**	**2.0**
Norway	First- University of Oslo	1	5	1	9	11.5
	Median- University of Stavanger. for CS and psychology: OsloMet - the metropolitan university	11	15	15	35	19.0
	First vs median	**11**	**3.0**	**15**	**3.9**	**1.6**
Spain	First- University of Barcelona*	45	45	40	60	48
	Median- University of La Laguna. for CS: first- Complutense University of	75	90	50	90	76

[17] There are differences between countries in the admission methods and grades required. Some countries require "normalized" external tests (such as the SAT or ACT in the US), other countries require external tests in selected subjects (such as the "A level" in the UK). There are countries where the average grades in high school are enough (such as Sweden) and there are countries that combine different indicators (such as Israel which combines the "Psychometric" test with scores from the matriculation exams) In order to be able to compare the countries and the different admission methods, the scores were converted into a uniform bar, in percentages.

country	Local Rank	Law	Computer Science	Psychology	Economics	Average
	Madrid, median- University of Las Palmas de Gran Canaria.					
	First vs median	**1.7**	**2**	**1.2**	**1.5**	**1.6**
Sweden	First- Lund University	4	8	4	20	9
	Median- University of Gothenburg	7	20	4	20	12.7
	First vs median	**1.7**	**2.5**	**1**	**1**	**1.4**
Switzerland	First- University of Zurich	8	8	13	13	10.5
	Median- University of Fribourg	15	15	15	15	15.0
	First vs median	**1.9**	**1.9**	**1.2**	**1.2**	**1.4**
UK	First- University of Cambridge	15	10	20	10	13.8
	Median- University of Fribourg	56	47	47	47	49.2
	First vs median	**3.7**	**4.7**	**2.4**	**4.7**	**3.6**
US	First- Harvard University					5
	average					28
	First vs average					**5.6**

Appendix 5. The Leadership Index- Tables A1-A3

Table A1: The Construction of the Leadership Index

Country Name	R&D/GDP (1)	Patents/population (2)	Leadership Index (3)
Australia	52.9	9.2	31.05
Canada	49.1	13.3	31.21
Denmark	81.4	10.3	45.81
Finland	86.5	21.0	53.71
France	64.2	47.7	55.94
Germany	90.9	35.0	62.97
Ireland	32.7	1.2	16.94
Israel	160.7	24.9	92.83
Italy	42.1	25.4	33.7
Japan	95.3	261.6	178.46
Netherlands	66.8	20.8	43.77
Norway	56.1	15.8	35.94
Portugal	48.6	4.0	26.29
Spain	41.3	3.1	22.22
Sweden	98.9	12.3	55.59
Switzerland	97.2	13.2	55.18
United Kingdom	84.3	16.4	50.37
United States	100	100.0	100.0

Source: Data from the World Bank website was standardized to an index, where the US was assigned a score of 100 and the scores of the other countries were adjusted accordingly.
Note: Column (3) = (column (1) + column (2))/2.

Table A2: The various indices of technological leadership in the literature

Country Name	Leadership Index (1)	High-tech exports/ total exports (%) (2)	Ratio of Researchers in R&D / population (per million) (3)	Human Development Index (HDI) (4)	Tertiary graduates (%) (5)	patent/ pop. (6)	R&D / GDP (%) (7)	The Global Innovation Index (8)	high R&D industries/"Business economy" (%) (9)
Australia	31.05	40.690	4532.40	0.951	20	4	1.829	55.22	
Canada	31.21	17.850	4516.30	0.936	26	6	1.697	55.73	1.99
Switzerland	55.18	28.841	5551.97	0.962	24	6	3.359	68.30	11.54
Germany	62.97	26.523	5393.15	0.942	35	15	3.142	57.05	3.59
Denmark	45.81	25.608	7691.89	0.948	20	5	2.813	57.70	4.43
Spain	22.22	23.609	3109.24	0.905	20	1	1.429	49.07	1.95
Finland	53.71	21.834	7527.36	0.940	28	9	2.989	59.97	3.82
France	55.94	20.756	4926.19	0.903	20	21	2.219	53.59	4.67
UK	50.37	20.554	4683.77	0.929	25	7	2.915	62.42	2.78
Ireland	16.94	16.830	4769.14	0.945	28	1	1.131	59.13	8.25
Israel	92.83	15.991	-	0.919	23	11	5.557	53.54	7.92
Italy	33.7	15.805	2671.83	0.895	21	11	1.454	46.40	2.48
Japan	178.46	13.670	5454.68	0.925	18	115	3.296	53.97	3.17
Netherlands	43.77	13.370	5911.68	0.941	17	9	2.309	61.58	3.85
Norway	35.94	12.415	6698.84	0.961	16	7	1.938	53.80	1.49
Sweden	55.59	8.770	7930.81	0.947	19	5	3.417	62.40	4.43
United States	100.0	8.132	4821.23	0.921	24	44	3.457	60.10	4.08

Source: OECD, United Nations, World bank and own calculations.
Notes: Column (1) is the leadership index presented in Table A1, column III. See section 2.2 for the sources of the indices.

Table A3: Pearson correlation coefficient between the various indices

	Gini Index	high R&D industries/ total "Business economy"	global innovation index	Gap in quality	Gap in recruitment	High-tech exports/ total exports (%)	Ratio of Researchers in R&D / population (per million)	Human Development Index (HDI)	Tertiary graduates (%)	patent/population (per 100 k)	R&D/GDP (%)	leadership index
Gini Index	1											
high R&D industries/ total "Business economy"	0.07	1										
global innovation index	-0.32	0.53	1									
Gap in quality	0.54	0.24	0.37	1								
Gap in recruitment	0.82	-0.01	-0.06	0.73	1							
High-tech exports/ total exports (%)	-0.17	0.28	0.02	-0.17	-0.28	1						
Ratio of Researchers in R&D / population (per million)	-0.55	0.13	0.53	0.09	-0.32	-0.15	1					
Human Development Index (HDI)	-0.49	0.31	0.65	0.05	-0.35	0.23	0.65	1				
Tertiary graduates (%)	0.18	0.22	0.23	0.05	0.12	0.23	-0.09	0.07	1			
patent/population (per 100 k)	0.45	-0.14	-0.13	0.43	0.67	-0.30	-0.02	-0.23	-0.18	1		
R&D/GDP (%)	0.39	0.39	0.32	0.54	0.33	-0.18	0.56	0.05	0.11	0.26	1	
leadership index	0.52	0.04	0.03	0.57	0.68	-0.32	0.15	-0.16	-0.10	0.92	0.62	1

Source: own calculations.

Appendix 6. The Econometric Analysis- Tables B1-B2

Table B1: Regression Results- Leadership

Dependent Variable - Leadership Index		
	(1)	(2)
Constant	1.018 (24.54)**	3.942 (16.46)**
gap in quality	1.104 (0.44)*	-------------
gap in recruitment	-------------	1.116 (0.31)*
R^2	0.182	0.457
Obs	15	17

Notes: Std. err. are in parenthesis.
*   p < 5%
** not statistically significant

Table B2: Regression Results- Inequality

Dependent Variable - GINI Index		
	(1)	(2)
Constant	40.83 (3.56)*	38.05 (1.91)*
gap in quality	0.14 (0.06)*	-------------
gap in recruitment	-------------	0.20 (0.36)*
R^2	0.28	0.67
Obs	15	17

Notes: Std. err. are in parenthesis.
*   p < 5%