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Will Robotics lead to changes in leadership and inequality ?

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Abstract

This paper presents a new framework for analysing robotics, AI and high-tech, which differs from the canonical model of technological progress by incorporating the higher education system. The main difference is that there is not just one type of skilled workers, but two types, and there is not one type of education but two - either elites universities or standard one. The signalling on the type of workers is revealed by a qualification exam to enter the elite universities.

The duality in the higher-education sector enables a separation of individuals by their abilities, and in consequence, human capital in both industries is different. We define inequality as the wage premium between workers in high-tech and low-tech industries. We show that robots and AI affect the "enhancement effect" of education in elite universities, and in consequence, inequality increases.

In other words, the wage and productivity gaps between high-tech and low-tech sectors are fueled by the duality in higher education, leading to heterogeneity in human capital. In consequence, while in regular models, robots might lead to convergence of workers productivity, and therefore to a reduction in wage inequality, in this model, inequality will increase.

This paper exposes a new **trade-off** in economics: a trade-off between inequality and leadership in technology. This paper shows that a country with high level of elitism has high level of inequality but will be also a country with leadership in science and engineering technology.

Keywords: ability, skills, productivity, duality, higher education, robots, wage premium, international leadership

JEL classification: I26, J24, O14, O4.

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I. Introduction

Robots are one of the main inputs in the production of goods, affecting the employment sector by assisting workers or even replacing them. Therefore, the literature on automation and robots has focused primarily on frameworks comprising the labor and the production sectors, without mentioning the education sector. Although these models mention the fact that skilled workers are part of the production, the education sector per se is absent, and the specificity of the education of these skilled workers is not mentioned at all.

The purpose of this paper is to incorporate the higher education sector in a model analyzing robots, and inequality. Why to do so? This paper will show that including how technical changes affect the education of the future workers allow us to present new insights on the relationship between robots and inequality. The focus on higher education allows us to analyze changes in technology and robotics in a framework in which skilled workers are nonhomogeneous.

Recall that in the literature on automation, the workers are divided into two categories: skilled and unskilled, but the skilled workers are seen as one single category of homogenous workers. In this paper, we depart from this assumption and in our model skilled workers are heterogenous.

Workers are heterogeneous in two aspects. First, individuals are heterogeneous in their abilities – some are abler than others. Second, and more important, skills are acquired through institutions which are different in their quality. Considering this double heterogeneity --in ability and in quality-- will affect the whole equilibrium of the economy.

Although in most research, higher education is seen as one single element, in fact, higher education institutions are different in their quality. Higher education is heterogeneous and consists of two channels: graduating from a prestigious and top university or graduating from a standard one.[1] This paper uncovers 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, and good labs and infrastructure. Second, recruitment for elite universities is highly selective.

First, this paper shows that the dichotomy 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 duality in higher education allows us to get a separating equilibrium, in which high ability students graduate from a top university, others from standard ones.

[1] Community colleges are included in the standard higher education. In some countries, recruitment can be different: in Israel, recruitment to the high-tech sector in Israel is through a very specific channel: having been a soldier at the special high-tech unit of the army - 8200.

Why is this dichotomy important for the economy and how is it linked to robotics and technical changes? The answer lies in the production sector. The economy is composed of high-tech and non-tech goods. The main differences between these two sectors stand in the intensity of capital but mainly that in the high-tech, the productivity of workers having graduated from an elite university and having received education at the frontier of knowledge is higher than if they would have graduated from a standard university.

Undeniably, the main difference between sectors is in the 'fit' 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. In other words, there is a better *match* between high-tech industry needs and the knowledge acquired in top schools, with better labs, top teachers, and knowledge at the frontier of technology. We term this the 'productivity enhancement' in the high-tech sector.

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, each sector will hire only one type of human capital, even if both types are perfect substitutes, and this separation of abilities affects the difference in labor productivity between sectors. In other words, 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.

We then introduce the effects of robots in the economy. We define inequality as the wage premium between workers in high-tech and low-tech industries. We show that inequality increases when the introduction of robots and AI magnify the "enhancement effect" of education in elite universities. In consequence, the enhancement effect leads to an increase in the productivity of these workers, and to an increase in inequality.

The paper is divided into four sections. In the next section, we review the literature. The model is presented in section III. Section IV concludes.

II. Related Literature

1. Heterogeneity in higher education

The empirical literature on education has cast 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). The main path/excuse to explain these weird results is that human capital which is computed as a homogenous factor will bias 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 duality 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 (2017) 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 model presented in the next section is introducing the heterogeneity in higher education in the basic models of technological changes.

2. Robotics

There is a vast literature on the effects of automation on employment and on wages. Over time, the empirical literature starts to be more homogenous in their conclusions, that at the micro-level, automation may lead to a displacement of workers, but at the macro level, employment and wages are not affected.

On the micro level, the literature has followed mainly the methodology of Acemoglu and Restrepo (2018, 2020) showing that each robot could displace between four to ten workers.[2] The Acemoglu-Restrepo methodology has been applied to several other countries. Chiacchio et al. (2018) finds a displacement effect between three and four workers per robot in six European countries, but do not point to robust and significant results for wage growth.

Aghion et al. (2019, 2020) find a displacement effect of ten workers per robot on French administrative data. However, using German data, Dauth et al. (2021) report a null effect of exposure to robots on aggregate employment. For low and mid skilled workers, they report lower wages, while at the aggregate level the use of industrial robots contributes to the fall in the labor share.

[2] Indeed, Acemoglu and Restrepo (2020) stresses that the job destruction effect of automation at the micro level dominates. They analyze the effect of the increase in industrial robot usage between 1990 and 2007 on US labor markets. Using within-country variation in robot adoption they estimate the local labor market effects of robots by regressing the change in employment and wages on the exposure to robots. They find that one more robot per thousand workers reduces the employment to population ratio by about 0.2 percentage points and wage growth by 0.42 %, while productivity increases, and labor share decreases. According to their estimates, each robot installed in the US replaces six workers.

It should be noted that there are some empirical works who do not find displacement at the micro-level. For instance, Mann et Püttmann (2017), who measure automation using patent data, paint a different picture. Moreover, Krueger, 1993, Autor et al., 1998 and Bresnahan et al., 2002 who use the measure of computers or IT as a proxy do not find displacement.[3]

On the macro-level, most papers stress that an increase in productivity due to automation does not reduce employment through spillover effects. Indeed, automating firms become more productive, which enables them to lower their prices and therefore to increase the demand for their products; the resulting increase in market size translates into higher employment in the economy. The decline in manufacturing employment is thus offset by positive employment spillovers on other local industries in the service sector (Dauth et al., 2021; Mann and Püttmann, 2017; Gregory et al., 2016).

In other words, this literature shows that robot densification is associated with increases in both total factor productivity and wages, and with decreasing output prices. Using the same measure on a panel of fourteen European countries, Klenert et al. (2020) find that robot use is correlated with an increase in total employment.

The intuition underlying the reverse effect between micro and macro-economics is that the productivity effect may contribute to the crowding-out of non-automating firms by automating firms. Since the productivity effect inside the automating firm causes an increase in product demand, the market share of the firm goes up at the expense of its non-automating competitors.

In conclusion, automation is not an enemy of employment. By modernizing the production process, automation makes firms more competitive, which enables them to win new markets and therefore to hire more employees in a globalized world. Firms that automate more become more productive, and they obtain larger market shares than their competitors. The resulting gain in market share prompts those firms that automate to produce at a larger scale, and therefore to hire more employees.

3. Heterogeneity of workers, tasks and skills

Related, but separate from the debate about the nature of direct and indirect effects of automation on employment, there is a debate about the types of jobs that are created or destroyed and the distribution effects of automation. The economic literature has long considered technological change to be labor augmenting and favorable to skilled workers, but a substitute for low-skill workers. This literature puts an emphasis on parameters such as tasks, skills, occupation, and industrial composition as main elements affecting distribution effects.

[3] The local exposure to robots is an indirect measure of robot penetration at the local level, which is based on the rise in the number of robots per worker in each national industry on the one hand, and on the local distribution of labor between different industries on the other hand. Linking automation patents to industries and labor markets, they find a positive effect of automation on employment.

In the wake of the IT and computer revolution in the 1990s, the emphasis was given to the skill-biased technological change hypothesis. This hypothesis indeed supported the idea of complementarity between technology and skilled workers (see Acemoglu and Autor, 2011, for an overview). Technological change would result in the polarization of the job market, i.e., the slower increase in mid-wage occupations compared to both high-wage and low-wage occupations.

In the 2000s, following the critic of Card and DiNardo (2002), and the seminal paper of Autor et al. (2003), the academic consensus shifted to a labor-replacing view of automation in routine tasks. According to this idea, “traditional” automation replaces routine jobs, and creates more demand for non-routine jobs that cannot be performed by machines. Several studies have documented the disappearance of manufacturing and routine jobs (Autor et al., 2003; Jaimovich and Siu, 2012; Autor and Dorn, 2013; Charnoz and Orand, 2017; Blanas et al., 2019).

It is interesting to note that using Canadian data, Dixon et al. (2019) document a polarization effect: investments in robotics are associated with shrinking employment for mid-skilled workers, but with increasing employment for low-skilled and high-skilled workers, notably managerial activities. This shift from low-skilled to high-skilled workers may also contribute to boosting productivity (Humlum, 2019; Acemoglu et al., 2020).

A new approach is to focus on the effects of technological changes on the dynamic changes in the type of occupations and tasks (with new job titles), instead of focusing on substitution or complementarity. [4] Robots and automation is then modelled as the (endogenous) expansion of the set of tasks that can be performed by capital, replacing labor in tasks that it previously performed. This takes the form of the introduction of new, more complex versions of existing tasks, and it is assumed that labor has a comparative advantage in these new tasks.

In the following model, we take this perspective on automation, and we focus on the innovation process itself which takes place at the level of universities.

III. The model

3.1 Introduction

My model is compact and 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 nonhomogeneous. In order to understand the main mechanism of this model, I present a stylized economy with three key features related to the heterogeneity of workers.

(i) Firstly, there is heterogeneity in the ability of individuals, i.e., individuals are not equal in their ability. (ii) There is duality 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

[4] See Acemoglu and Restrepo, 2020.

production functions of traditional non-tech goods and high-tech goods are not similar in the way they make use of human capital.

This paper stresses a specific aspect of the effects of robots on inequality. While most research focus on the robots as a factor of production, this paper put the emphasis on two other features of robots-AI-IT. One is about the final good, and the other is related to higher education.

About the final good, we assume that the economy produces two goods: High tech goods, which include also robots and AI consumed by individuals, and 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 duality in the type of universities. Individuals can either receive education in a top university, (H_E for elite universities) or learn in a standard university (H_{NE} for non-elite).[5] We assume that the type of education the individual acquires is common knowledge since it is acknowledged on his diploma. The assumption on a duality in higher education is not commonly used in models of technological progress.[6] This is the specificity of this model.

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 section.

3.2 Ability

We assume that individuals are born with different abilities, either high denoted a^h, or low denoted a^l. For sake of simplicity, we assume that $a^h = \delta a^l$ where $\delta > 1$. We also assume that the ratio of high ability workers over low ability workers is σ.

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 have to invest less effort than an individual with low ability. Obviously. the 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 robotics on inequality.

3.3 Acquiring skills -The Higher Education sector.

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[5] In Israel, the duality is coming from the recruitment in the army.

[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.

a. The selection/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 exams for entry to the different universities, and the grades on the entry exam to gain access to the elite universities, are much higher than the grades to enter standard universities.[7] In consequence, we get the following partition: 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) will register to a standard university and will 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 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 $e^l = 1/a^l$.

So the costs for each individual for entering elite universities are:

$$C_h = P.e^h = \frac{P}{a^h} \qquad \text{for individuals with high ability} \tag{1}$$

$$C_l = P.e^l = \frac{P}{a^l} \qquad \text{for individuals with low ability} \tag{2}$$

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: $c = P/\gamma a^l$ with $\gamma > 1$ and $\delta > \gamma/(\gamma - 1) > 1$.

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

[7] In the various countries, the exam is slightly different. In the US, it is SAT, in France the “prep exams”. See Brezis and Crouzet (2006) for more details. But in Israel, the most important signaling effect for entering the high-tech sector is having worked in the 8200 unit of the IDF as a soldier.

directly, but also indirectly through the peer effect. Indeed, the literature on peer 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.[8]

This knowledge will diffuse to the standard universities over the years, but for some 5-10 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 robotics, AI and IT 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, I define this externality as $\lambda = \lambda(R)$, R being the new development in the research of technology in AI and robots, which enhances the level of productivity of the top students at the top universities by the "enhancement effect, λ. Students from elite universities are therefore more productive in the high-tech sector.

3.4 The two goods in the economy

There are two sorts of goods in the economy, high-tech goods, T and traditional, non-high tech 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:

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

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.

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[8] The same effect takes place in the 8200 unit in Israel.

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 ‘fit' 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 enhancement' as λ (which is affected by the level of robotics).

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.

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

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

Proposition 1.

Under conditions Ia and Ib, 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 duality 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 tech *sector, and individuals with low ability will work in the non-* tech *sector.*

Proof

From Lemma 1, workers in the tech sectors are with education of type H_E. From Proposition 1 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:

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

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

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

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

This separating equilibrium enables us to simplify the “canonical model”. This equilibrium also allows us to analyze inequality between the two types of skilled workers which characterize today the inequality between middle and top classes. The inequality is within skilled workers – workers with very good education, and workers with education in colleges, which do not permit them to work in the high-tech sector.

I have no doubts, that the discrepancy between wages of unskilled and skilled workers is also very important. But this is not the main story of generations y-z even if this inequality has also increased.

This separating equilibrium leaves us with equations (6) and (7) which allow us to calculate inequality, as in the following corollary.

Corollary

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

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

In consequence, inequality in wages is:

$$\omega_3 = \frac{W_S^h}{W_S^l} = (\frac{\lambda a^h}{a^l})^\alpha (\frac{H_E}{H_{NE}})^{\alpha-1} = \lambda^\alpha \delta^\alpha \sigma^{\alpha-1} > 1 \tag{8}$$

Proof

The proof is presented in Appendix 3.

Proposition II allowed us to simplify equations 2 and 3, and define the world economy by equations (6) and (7). It allowed us to calculate the wage premium, when workers with different abilities work in different sectors.[9] In appendix 3 we calculate the various wages, and we obtain that:

$$\omega_3 = \frac{W_S^h}{W_S^l} = (\frac{\lambda a^h}{a^l})^{\alpha} (\frac{H_E}{H_{NE}})^{\alpha-1} = \lambda^{\alpha} \delta^{\alpha} \sigma^{\alpha-1} > 1 \qquad (8)$$

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 will go to work in the non-tech sector. For high ability workers, they will graduate from elite universities, and work in the high-tech sector. This separation equilibrium permits us to calculate the wage premium, when workers with different abilities work in different sectors as presented in equation (8).

Two essential variables affect the wage-premium equation, and both are related to gap in productivity. The first element is the gap in abilities, δ; the higher the gap, the higher the wage premium. The second element is the productivity enhancement in the tech sector, λ influenced by change in robotics and AI.

3.8 Progress in robotics, IT and AI.

Let us assume, as it indeed happens in recent years, we witness a shift in the types of technological progress. New technologies (embedded into robots, IT and AI) enter the classroom in elite universities and affect the knowledge of students in elite universities vs. standard ones. This happens mainly in sciences.

This paper focuses on higher education in science and engineering. In social and human sciences, the teacher in a top university might have better knowledge (hopefully) than is standard ones, but the class will not be very different. In a classroom in computer science or chemistry; it will be very different.[10] The classes will be equipped with the top IT, AI and robotics. In consequence, the training of high ability students will have an enhancement effect on the high-tech sector. What will be the effect of progress in robotics on inequality?

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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.

[10] In Israel, it is slightly different. If you enter (don't worry, you will not) an office in 8200, it will be equipped with the top IT, AI and robotics. In consequence, the training very specific to 8200 which is linked to AI and robotics permit to the best soldiers with high ability to have higher productivity in the high-tech sector. This is the story of the high tech in Israel.

Proposition 3

The introduction of new robots and AI will lead to an increase in the enhancement factor λ *. In consequence wage inequality increases.*

Proof

We have shown that in the production function of high-tech, the enhancement effect takes the form of $\lambda = \lambda(R)$, R being the new development in AI and robots technology, which increases the level of productivity of the top students at the top universities by the "enhancement effect. From equation (8), when λ increases, then wage inequality increases.

This proposition stresses that the higher this productivity enhancement, the higher the wage premium. This result relates automation to education since elite education leads through better labs and equipment, to an enhancement of the ability of the smart people, due to a better match between the needs of the high-tech industry and the knowledge acquired in top schools.

IV. Conclusion

There is a huge and new literature on robots, employment and wages, which explains us that firms using robots are more efficient and are therefore crowding out firms with no robots. In consequence, total productivity increases, wages increase, and since the firms using robots grow, they don't have to throw people out, even if robots for sure displace workers.

This paper goes in a completely different line of conclusions. The companies which use robotics and particularly AI grow and crowd out the other firms, because they use people with higher ability, and who got their knowledge from the best universities, with the top scholars in their field.

In other words, the narrative with robots is not about robotics but about the intelligence of human beings. This is the reason why wage inequality increases. The new economy makes the differences in talent more acute. Robotics enhance human capital --the select one.

The first result of this paper is that inequality in wages between sectors increases when robots and AI affect the 'enhancement effect" of education in elite university on the productivity of these workers. Some of the literature put the focus on the inequality between low-skilled and high skilled workers, this paper focuses on middle class vs. the top, i.e., between skilled and high-quality vs. skilled and low-quality workers. This changes the results of the impact of robotics and AI in the economy. This model stresses that to have leadership necessitate an increase in inequality, because of the dichotomy between elite and standard universities.

Indeed, this paper exposes a new **trade-off** in economics: a trade-off between inequality and leadership in technology. This paper shows that a country with high level of elitism has high level of inequality but will be also the countries with leadership in science and engineering technology. Why?

Recall that we define elitism as the gap between elites and non-elite universities. In countries with high elitism there is a differentiation between students of high and low ability, so that only high ability students graduate from top universities.

Top universities are at the frontier of knowledge and disseminate this knowledge to the abler students, who can then use this knowledge in the sectors with high pace of technological changes as the high-tech sector. Indeed, elitism leads to higher worker productivity, by channelling the top workers to the sectors where high ability affects productivity very much. Recall that the main difference between sectors is in the 'fit' between the type of education, the ability of the worker and the goods produced. In the high-tech sector, the productivity of the workers having received education at the frontier of knowledge has a higher effect than if they would have graduated from a standard university.

Countries choosing to develop dual quality education tracks permits to be at the frontier of leadership in technology at the price of higher inequality. Inequality is the price of being at the top in technology. A country which only adopts technology and is not at the technology frontier may avoid having duality in the higher education and having inequality. But a country which wants to be "at the frontier of knowledge", must have top universities, in which the entry is through meritocracy and exams, leading to inequality.

This is the case of Israel, where recruitment of the best is allowed through entering the military 8200 academy unit. This selection is explaining the success of the high-tech sector in Israel. It is also explaining the increase in inequality this last decade.

This paper is theoretical. In the next paper, I will show that an index of educational elitism is negatively correlated with inequality and positively correlated to an index of "frontier of technology".[11]

[11] In Brezis (2018), I have presented a first version of the elitism index for higher education for some OECD countries. In the next research, the elitism index will incorporate also the index for recruitment tightness.

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Appendix 1

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 duality 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

(i) Let us first analyze the tech sector. From the production function displayed in equation (3), 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 (2), one 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 -Wages and wage premium

Let us now 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:

$$W_u = \frac{\partial Y_T}{\partial L} = \beta K^{1-\beta} L^{\beta-1} a_u{}^{\rho} [(\lambda a^h \frac{H_E}{L})^{\rho} + (a_u)^{\rho}]^{\frac{\beta-\rho}{\rho}} . \tag{A1}$$

and:

$$W_S^h = \frac{\partial Y_T}{\partial H_E} = \beta K^{1-\beta} H_E{}^{\beta-1} (\lambda a^h)^{\rho} [(\lambda a_h)^{\rho} + (a_u \frac{L}{H_E})^{\rho}]^{\frac{\beta-\rho}{\rho}} . \tag{A2}$$

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

$$\omega_1 = \frac{W_S^h}{W_u} = (\frac{\lambda a^h}{a_u})^{\rho} (\frac{H_E}{L})^{\rho-1} . \tag{A3}$$

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

$$W_u = \frac{\partial Y_{NT}}{\partial L} = \beta K^{1-\beta} L^{\beta-1} a_u{}^{\alpha} [(a^l \frac{H_{NE}}{L})^{\alpha} + (a_u)^{\alpha}]^{\frac{\beta-\alpha}{\alpha}} . \tag{A4}$$

$$W_S^l = \frac{\partial Y_{NT}}{\partial H_{NE}} = \beta K^{1-\beta} H_{NE}{}^{\beta-1} a^{l\alpha} [(a^l)^{\alpha} + (a_u \frac{L}{H_{NE}})^{\alpha}]^{\frac{\beta-\alpha}{\alpha}} . \tag{A5}$$

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

$$\omega_2 = \frac{W_S^l}{W_u} = (\frac{a^l}{a_u})^{\alpha} (\frac{L}{H_{NE}})^{1-\alpha} \tag{A6}$$

From (A3) and (A6), we get that the wage premium of education of type H_E vs. type H_{NE} is:

$$\omega_3 = \frac{W_S^h}{W_S^l} = (\frac{a^l}{a_u})^{-\alpha}(\frac{H_{NE}}{L})^{1-\alpha}(\frac{\lambda a^h}{a_u})^{\rho}(\frac{H_E}{L})^{\rho-1} \qquad \text{(A7)}$$

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

$$\omega_3 = \frac{W_S^h}{W_S^l} = (\frac{\lambda a^h}{a^l})^{\alpha}(\frac{H_E}{H_{NE}})^{\alpha-1} \qquad \text{(A8)}$$

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

$$\omega_3 = \frac{W_S^h}{W_S^l} = (\frac{\lambda a^h}{a^l})^{\alpha}(\frac{H_E}{H_{NE}})^{\alpha-1} = \lambda^{\alpha}\delta^{\alpha}\sigma^{\alpha-1} \qquad (8)$$

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 (8) is equivalent to:

$$\lambda\delta > \lambda^{\alpha}\delta^{\alpha}\sigma^{\alpha-1} \quad \text{and} \qquad (9)$$

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

And since we have that $\lambda, \delta, \gamma, > 1$ and $\alpha < 1$, then equation (9) 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.