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RESEARCH ARTICLE

Productivity Gap between Sectors and Double Duality in Labor Markets

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Abstract Over the last decades, productivity in the tradable sector rose substantially, while in the non-tradable sector, output per worker has remained the same, despite a similar increase in human capital in both sectors. This paper shows that a *double duality* both in the production and the higher-education sectors as well as heterogeneous ability of individuals might explain the differences in labor productivity between tradable and non-tradable industries. The double duality in the economy enables a separation of individuals by their ability, and in consequence, human capital in both industries is different. The heterogeneity in human capital can explain that despite an increase in human capital in both sectors there is still a gap in productivity and in wage premium. In other words, the productivity gap between sectors is fueled by the double duality in labor markets, leading to heterogeneity in human capital. In consequence, there is a contrast between on one hand, more mobility across countries, and on the other hand, less mobility between sectors.

Keywords Ability · Skills · Productivity · Tradable goods · Services · Duality · Higher education · Human capital · Wage premium

JEL Classification F12 · F16 · F66 · I26 · J24 · O14

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1 Introduction

This paper relates the gap in labor productivity between the tradable and non-tradable sectors to a double duality in the labor markets, and to heterogeneity in ability of workers. More specifically, this paper focuses on the contribution of heterogeneity of human capital to the differences between these two sectors.

On this matter, there are few facts worth mentioning, which will be presented in greater length in the next section. The first is that there is a gap in labor productivity between the tradable and non-tradable industries observed in most of the OECD countries.

The second fact is that the wage premium for education is lower in non-tradable industries than in the tradable sector, and this gap has increased over the last two decades. The third fact is that over the decade, the level of education of workers has increased across all segments of the labor market, although slightly more rapidly in the tradable goods. All these three facts have been described in length in the literature.

A fourth empirical fact, less emphasized in the literature, is that ability and skills of workers in both sectors are different: High-ability workers tend to work in tradable industries, while low ability workers tend to work in the non-tradable sector. Moreover, the quality of education of workers in both sectors is different.

The purpose of this paper is to develop a framework which can assemble the various pieces of the puzzle together. This paper emphasizes that a *double duality* in the economy might explain the facts presented above: a duality in both the production sector and the higher-education sector.

The duality in the production sector is quite known: There are differences in the production functions between tradable goods which comprises mainly high tech and manufacturing industries, and the non-tradable sector which comprises mainly service goods.

But this is not the only duality in the economy: The economy displays a duality in higher education. There is not one channel of higher education, but two: graduating from a prestigious university, or graduating from a standard university or local college.[1]

Indeed, the higher education sector in many OECD countries displays two separate channels of education, due to separate entry exams in the various types of universities. While one needs a high grade on entry exams to enter elite universities, one needs only a high school diploma to enter a college.

This paper will show that the duality in the sector of higher education enables the differentiation of individuals with high and low ability, and this is part of the explanation of the strong division between the tradable and non-tradable sectors.

The second part of the puzzle lies in the production functions of tradable and non-tradable goods. It would be easy to assume that tradable use more capital, and therefore the wage premium is higher. But this is not clearly the case. So, we assume the production functions to be similar in the use of all factors of production, except for the "fit" between the type of education and the good produced. Indeed, in our model, the main difference between the two sectors is that in the production of tradables as high-tech, the productivity of workers having graduated from an elite university is higher 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

[1] The last decade, there was a huge increase in the intake of tertiary education in most countries, denoted as "the massification", but this was mainly due to rise in enrolment rates in local colleges (see Brezis and Hellier 2017).

and the knowledge acquired in top schools, and we term it as a 'productivity enhancement' in the tradable goods sector.

In light of these assumptions, our main proposition stresses that the double duality in the economy permits a separation of individuals by their ability. In other words, individuals with high ability work in the tradable sector, while individuals with low ability work in the non-tradable sector. Our model is quite simple, and draws on production functions very similar to the ones depicted in the literature, as in Autor and Dorn (2013). However, our model differs in the assumption that human capital is not homogenous, since we have in fact two different types of human capital. There are workers graduating from elite universities, and workers having a human capital by graduating from standard universities. The two types of human capital are perfect substitutes, and the producer can hire either workers graduating from elite universities or from standard universities. Moreover, the productivity of each human capital is a function of the average ability of the skilled workers having acquired this type of education. Since the duality in higher education permits to get a separating equilibrium, then each sector will hire only one type of human capital, even if both types are perfect substitutes. In consequence, this separation of abilities can explain the difference in labor productivity between sectors, which we test in the empirical part of the paper. Therefore this paper places the entire emphasis of the difference in productivity on the variance in ability of workers: High ability workers work in the traded sector, and therefore the productivity is higher than in the non-traded sector, in which individuals are with low ability.

The paper is divided into five sections. In the next section, we present a review of the literature, as well as empirical regularities. The model is presented in section III, and in section IV the empirical analysis is discussed. Section V concludes.

2 Related Literature and Empirical Regularities

This paper emphasizes the relationship between heterogeneity of sectors and of higher education. We therefore start describing the facts and literature regarding

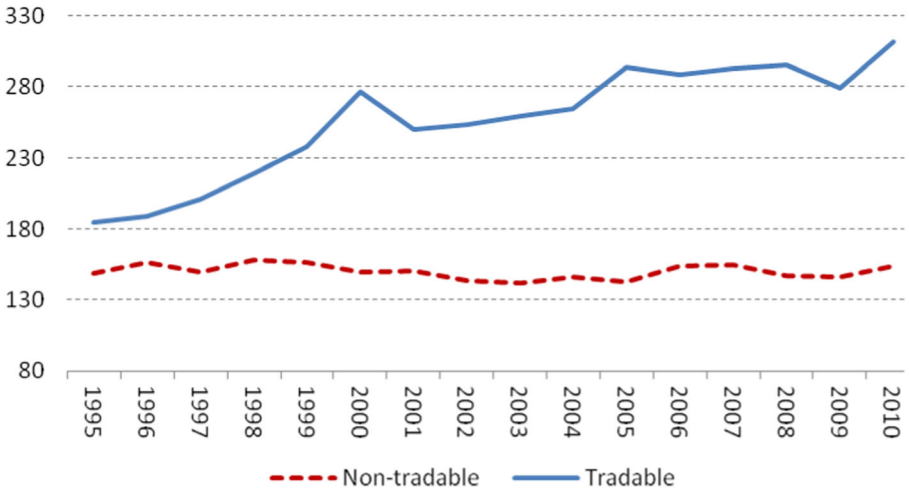

Fig. 1 Labor productivity in the tradable and non-tradable industries 1995-2010, NIS, constant prices, 2010

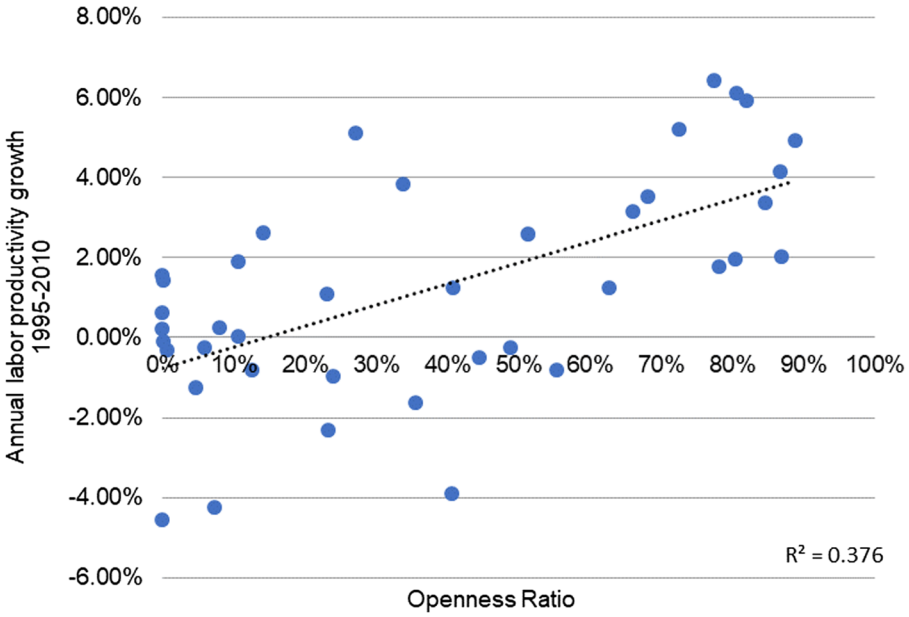

Fig. 2 Labor Productivity growth and the Openness Ratio for the various industries in Israel

the heterogeneity of sectors, and then the heterogeneity of individuals and of higher education.

2.1 Productivity Gap between Tradable and Non-tradable Industries

The two sectors display differences in the productivity of labor in most OECD countries. Figures 1 and 2 show that, in the last 10 years, there is a difference of some 100% in the

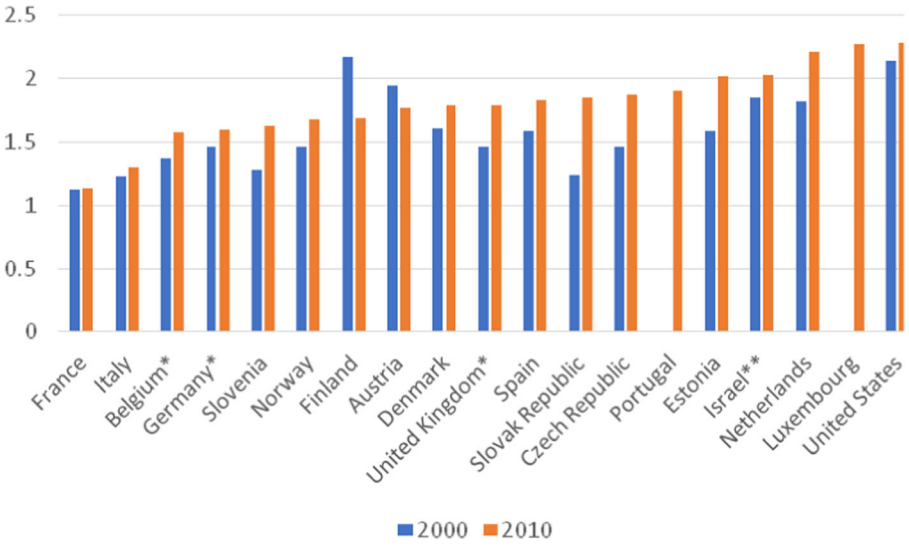

Fig. 3 Productivity differential between tradable and non-tradable industries in OECD countries

productivity of labor between the tradable and non-tradable industries in Israel. About most OECD countries, as shown in Fig. 3, the gap in productivity is also substantial.

The literature on the gap in productivity is diverse, and the vast body of work that emerged following the Melitz (2003) model has emphasized the importance of having heterogeneous firms in explaining productivity gap across sectors. Helpman et al. (2010) show that exposure to trade shock would result in the demise of the least productive firms, an expansion of the most productive firms, and a contraction of firms with intermediate productivity levels who serve only the domestic market. This mechanism could explain the gap in productivity between the tradable and non-tradable industries.

The empirical literature using micro data on a firm level emphasizes the heterogeneity in productivity exhibited by these two industry groups. (See Frias et al. 2012; and Greenaway and Kneller 2008 for a survey on this literature). They show that exporting firms tend to outperform the non-exporters even when controlling for firm-level characteristics such as industry and size. The underlying mechanism for explaining this gap is mainly related to exposure to fierce competition in international markets, termed as "learning by exporting effect". Indeed the literature shows that the 'exporting effect' leads to increasing efficiency and greater investments in capital and new technologies.

Using time series data, Spence and Hlatshwayo (2012) find that the incremental productivity growth in the US in the period 1990–2008 stems from the tradable sector, while virtually all employment is generated in the non-tradable industries. De Michelis et al. (2013) and Junankar (2013) find a negative relationship between labor force growth and productivity growth. Therefore the different trends in productivity growth between tradable and non-tradable industries may be tied to their opposite employment trends.[2]

This gap in productivity between tradable and non-tradable industries can also explain the convergence which occurs in the productivity of tradable sectors among OECD countries, and which is not present in the non-tradable sector (see Jones 2015). More specifically, Rodrik (2013, 2016) has shown that tradable (mainly manufacturing) industries exhibit unconditional convergence in labor productivity, while convergence in the economy as a whole (especially in the non-tradable sector) depends on policies, institutions, and other country-specific circumstances.

2.2 Gap in Wages between Tradable and Non-tradable Industries

The tradable industries tend to pay higher wages than non-tradable industries. Figure 4 shows a strong correlation in Israel between the extent in which an industry is open to international trade and the annual average wage level. Higher wages are found also when controlling for workers' observable characteristics.

Accordingly, return on education was found to be higher in the tradable industries. Moreover, the results illustrated in Fig. 5 show that the college wage premium has remained relatively stable in the non-tradable industries while a steady increase was found in the premium on the tradable side in Israel. The data on OECD countries are presented in Fig. 6. They show a gap between wages in the tradable and non-tradable industries, in most countries.

Similarly to the literature on productivity, the literature on wage gap is based on heterogeneity of firms which lead to a wage gap between sectors open to trade and non-

[2] See also Jaumotte and Tytell 2007 and Mano and Castillo 2015.

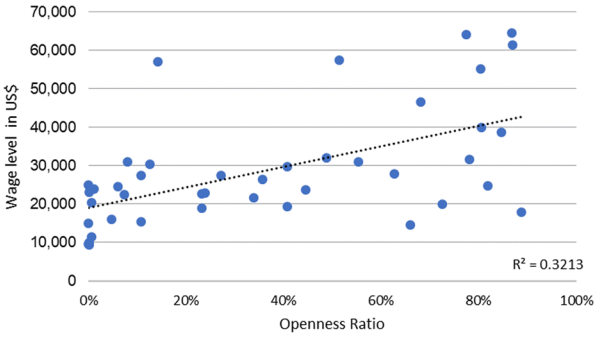

Fig. 4 Wage level and the Openness Ratio for the various industries in Israel

tradables (see Melitz 2003). In consequence, trade plays a crucial role in reallocation of skills to the exporting firms that tend to be more productive and pay higher wages (see also Helpman 2016). Helpman et al. (2010) show that employment in exporting firms induces a wage premium which can be explained by frictions in the labor market.

Our paper focuses on two other elements for explaining the gap in wages and productivity: heterogeneity of workers and higher-education duality. We therefore present the empirical regularities and the literature on this matter.

2.3 Heterogeneity of Ability and Skills of Workers between Tradable and Non-tradable

The level of human capital measured by years of schooling for the years 1995–2011 are presented in Fig. 7 for both tradable and non-tradable sectors in Israel. There has been a rise in the amount of human capital in both sectors; so,

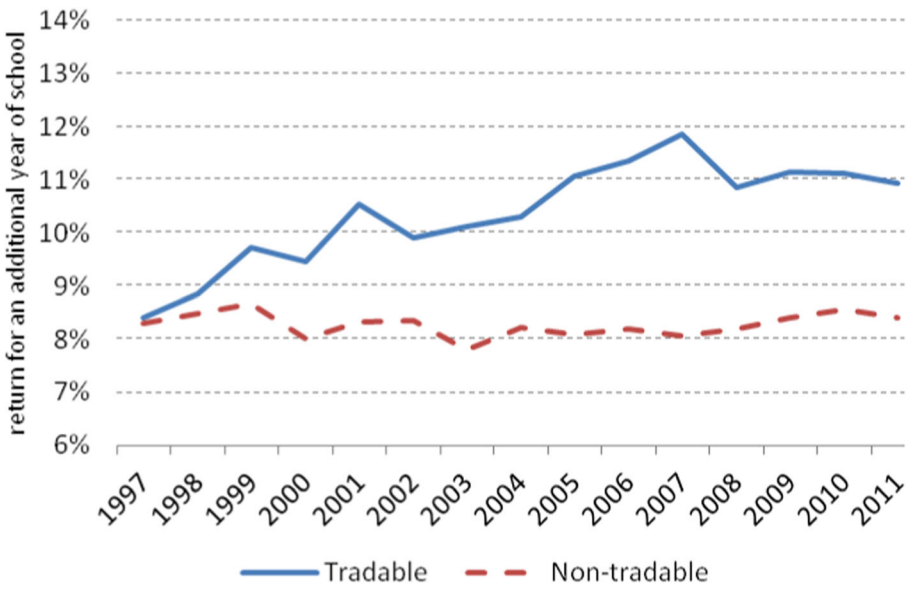

Fig. 5 The college wage premium in the tradable and non-tradable industries in Israel 1995-2011

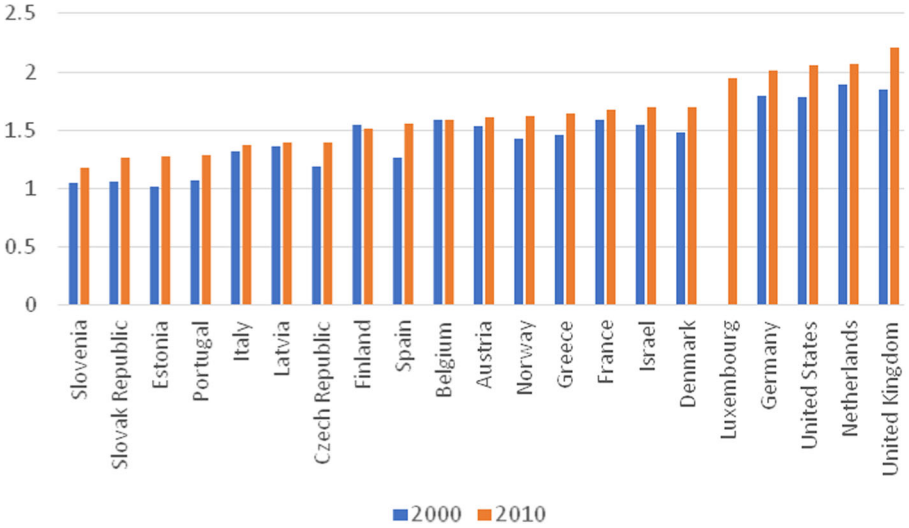

Fig. 6 Wage differential between tradable and non-tradable industries in OECD countries

productivity gap cannot be explained by a gap in human capital since it has increased in both sectors in the last 10 years (although with a slightly steeper one in the tradable industries).

If level of human capital cannot explain the gap, can the heterogeneity of skills and ability explain it? The heterogeneity of ability and skills can be measured in two different ways: either through SAT scores (or some similar measures which test the IQ of students), and PIAAC.

About the first measure, i.e., 'SAT" scores, the distribution of the workers cognitive scores on the Israeli SAT is displayed in Fig. 8. As is shown, while

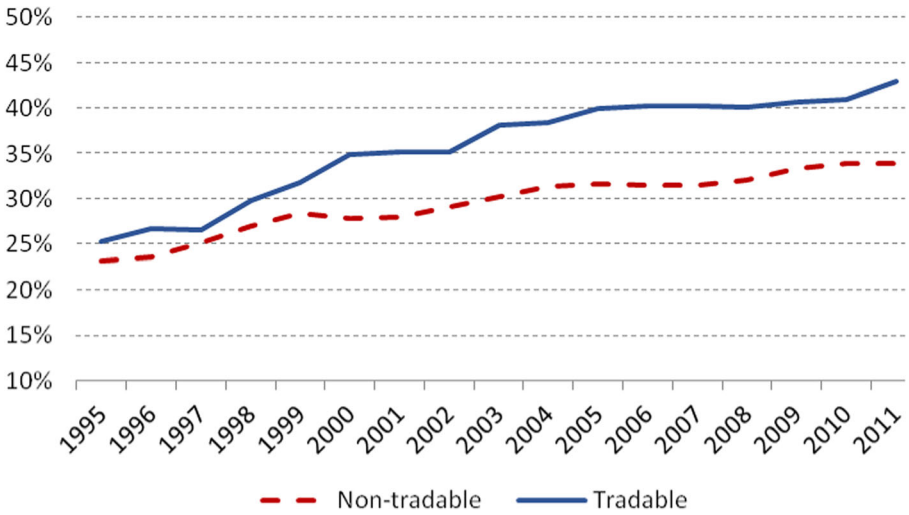

Fig. 7 Share of adults (25–64 year-olds) with higher education in the tradable and non-tradable industries, 1995–2011. Source: ICBS

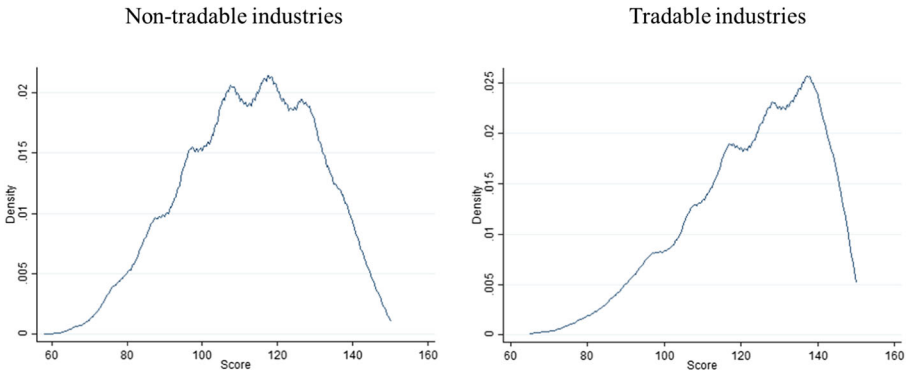

Fig. 8 The distribution of the workers cognitive scores in the tradable and non-tradable industries. Source: ICBS

workers' ability in the non-tradable sector is normally distributed, ability among workers in the tradable sector is strongly skewed to the right, further strengthening the assumption that substantial differences exist in workers' ability in each industry group.[3]

The second method of assessing skills, i.e., the 'PIAAC' is different since it is performed while the individual is already working, contrarily to the SAT scores which has measured the ability of workers while being a student. Indeed, the "Published International Assessment of Adult Competencies" (PIAAC) measures skills of workers at work.[4] It enables to examine the distribution of workers' cognitive skills across the various segments of the labor market.

Figure 9 presents the distribution of skills in an average of 23 OECD countries for workers with tertiary education. On average, college graduates with higher abilities tend to find employment in the tradable industries in higher rates.[5] These facts strongly suggest that ability and skills of workers are different between tradable and non-tradable industries.

There is also heterogeneity in the type of education acquired by workers. Whereas 68% of workers in the tradable industries in Israel (in the age group 27–32) have obtained their education from a elite university, this number drops to only 51% among the non-tradable industries. [6]

[3] This conclusion is supported by a simple Kolmogorov–Smirnov test ($p < 0.01$). The data are for the year 2011 for workers in the age group 27–32 (n = 68,664) for the quantitative section of the exam. The data was restricted to workers who completed at least an undergraduate degree and were employed at the time of the survey on a full time basis.

[4] The "Programme for the International Assessment of Adult Competencies" (PIAAC) measures adults' proficiency in key information-processing skills - literacy, numeracy and problem solving in technology-rich environments. The survey was conducted during the year 2012–2014. The results shown are an average score of the literacy and numeracy parts of the exam.

[5] Although results can vary significantly between countries. In Figure 9, we present average Z-score of 23 OECD countries: Czech Republic, Belgium, Chile, Denmark, Germany, Greece, Ireland, Israel, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Poland, Slovakia, Slovenia, Spain, Sweden, Turkey, UK, USA and France.

[6] We could not find comparable data for OECD countries.

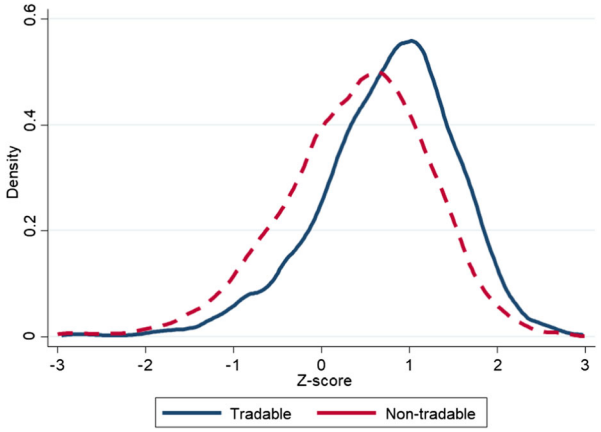

Fig. 9 The distribution of the workers cognitive scores (PIAAC exam) for workers with tertiary education in OECD countries

The literature on the heterogeneity of workers between tradable and non-tradable industries is not vast. Lately, Macis and Schivardi (2016) have shown that exporting firms also tend to employ workers with both observable and unobservable higher skills.

Going back to the premises by Balassa (1964) and Samuelson (1964) about the effects of productivity on mobility of workers, empirical works have shown that there is heterogeneity of workers. Indeed, Friedman and Lavi (2007) find that Balassa and Samuelson statements do not seem to hold in the Israeli economy and attribute this to a segmented labor market. They suggest that workers' characteristics in the tradable industries differ greatly from those on the non-tradable side, resulting in low mobility between the sectors. In consequence, a rise in productivity in the tradable industries does not lead to reallocation of labor, and wages in each industry group will develop independently. Under this segmented labor market hypothesis, the tradable industries will employ the better skilled workers, yield a higher return to skills and demonstrate much faster growth rates. This paper will show evidence of these assertions.

2.4 Heterogeneity in Higher Education

The duality in higher education has been mainly emphasized in relation to social mobility and inequality. Indeed, 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). Moreover, in the recent economic literature on education and human capital, there has been a growing interest into the

analysis of stratification of educational systems (see Brezis and Crouzet 1999, and Brezis and Temin 2008).

The impact of education on economic growth has been a major topic in economic research. From the early studies by Becker (1962), Mincer (1974) and Schultz (1971) to the literature which followed Romer's (1990) endogenous growth theory, human capital accumulation has been regarded as a key determinant of long-term economic growth. Yet there is an emergence of an empirical literature which casts doubt on the positive effect of an increase in human capital on economic growth. The results of Pritchett (2001), Krueger and Lindahl (2001) and Benhabib and Spiegel (1994) show that human capital, depicted by the average years of education, does not increase economic growth. So, human capital in the form of a homogenous education does not seem to affect economic growth in the data.

With the use of scores on internationally comparable examinations, 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.

To conclude, while education rates have increased across all segments of the labor market, productivity has taken a much less uniform course. On the tradable side, productivity has risen sharply, but on the non-tradable side productivity has reached a near standstill. Moreover, the gap in the wage premium has increased, and skills and education of workers in both sectors are different. The model presented in the next section will try to give an explanation to these facts.

3 The Model

3.1 Introduction

Our framework is based on three main assumptions. (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 is duality in the labor market, i.e., the production functions of tradable and non-tradable industries are not similar in the way they make use of human capital.

The factor of productions of tradable and non-tradable goods are capital, unskilled as well as skilled labor. Indeed, we assume that workers can either acquire higher education, be 'skilled workers', and have human capital H, or if they did not enter a university, then they are 'unskilled workers' denoted L. Moreover, higher education is not homogenous, and there is duality in the type of universities. Individuals can either learn in a top university, (H_E for elite

universities) or learn in a standard university (H_{NE} for non-elite).[7] The type of education the individual acquires is common knowledge, since it is acknowledged on his diploma.

We start the presentation of the model with defining the effect of heterogeneity in the ability of individuals, then to the utility function, and we then turn to the production section, and to the educational market.

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 much less effort than an individual with low ability. It is well known that in the same class, there are students who glance for few minutes at a math book, and will solve almost all exercises. Some others will have to redo 10 times the same exercise to know solving it.

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.

3.3 The Utility

There are two sorts of goods in the economy, tradable, T and non-tradable, NT. Consumers want them both, and we assume an elasticity of substitution of 1 between these goods, so the utility function will take a Cobb-Douglas form such as:

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

π is the ratio of the demand of tradable over non-tradable. In the next section, we present the production functions.

3.4 The Tradable and Non-tradable Production Functions

The tradable sector as well as the non-tradable 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).

[7] In this paper, the duality in higher education can take two quite equivalent forms. Either one wants to focus on the duality in the type of faculties (science versus humanities), or one prefers to focus on the duality between elite universities vs. standard universities. For both dualities, the reasoning is the same. In this paper, we focus on the second type of duality, i.e., elite vs standard universities. The assumption on a duality in higher education is usually not included in models related to productivity and wage premium. See Acemoglu and Autor (2011) and Autor and Dorn (2013).

Our model differs in the assumption 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 elites 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-tradable good takes the following form:

$$Y_{NT} = K^{1-\beta}[(a_1 H_{NE} + a_2 H_E)^{\alpha} + (a_u L)^{\alpha}]^{\frac{\beta}{\alpha}}. \quad (2)$$

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.

The production function of the tradable-good is similar to the non-tradable one. There is in the literature a debate whether the capital-labor ratio is higher in the tradable sector than in the non-tradable. 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 (assumption which can be released. Later on we will indeed check the case in which substitution rates are equal: $\rho = \alpha$).

The main difference between these two sectors is in the 'fit' between the type of education and the good produced: For producing high-tech (a tradable good), the productivity of the workers having graduated from an elite university 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. We denote this 'productivity enhancement' as λ.

So the tradable sector has the following production function

$$Y_T = K^{1-\beta}[(a_1 H_{NE} + \lambda a_2 H_E)^{\rho} + (a_u L)^{\rho}]^{\frac{\beta}{\rho}}. \quad (3)$$

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

3.5 The Higher Education Sector

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. The grades on the entry exam (SAT) to gain access to the elite universities, are much higher than the grades to enter standard universities.[8] In consequence, we get the following partition: Students with a

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

high grades on his SAT 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.

The individuals who have graduated from high school can register to classes which are helping them to improve their score on the SAT exams. The costs for taking these exams is the price 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:

$$C_h = P.e^h = \frac{P}{a^h} \qquad \text{for individuals with high ability} \tag{4}$$

$$C_l = P.e^l = \frac{P}{a^l} \qquad \text{for individuals with low ability} \tag{5}$$

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 $\delta > \gamma/(\gamma - 1) > 1$.

3.6 The Equilibrium

Let us find out, whether there is separation between types of ability, i.e., individuals with high ability work in tradable industries while individuals with low ability work in the non-tradable industries. In order to do so, we verify three lemmas, so that we find the conditions under which we get the separating equilibrium.

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

Condition Ia

$$\frac{P}{a^l}\left(\frac{\gamma-1}{\gamma}\right) > W_S^h - W_S^l > \frac{P}{\delta a^l}$$

Condition Ib

$$W_S^l - c > W_u$$

Lemma 1 Under condition 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 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:

$$W_S^h - C_h > W_S^l$$

The 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}.

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

Proof (i) Let us first analyze the tradable sector. From the production function displayed in Eq. (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^hat 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:

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

(ii) About the non-tradable sector, from Eq. (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:

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

QED.

We now turn to the Proposition.

Proposition Under Conditions I and II, individuals with high ability will work in the tradable sector, and individuals with low ability will work in the non-tradable sector.

Proof From Lemma 2, workers in the tradable sectors are with education of type H_E. From Lemma 1, those with education type H_E are of high ability. In consequence, individuals with high ability work in the tradable sector. Following the same reasoning, individuals with low ability will work in the non-tradable sector.

Since the only skilled workers in the tradable 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:

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

Following the same reasoning, the equation of the non-tradable sector is:

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

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

Lemma 3 With production functions as presented in Eqs. (6) and (7), Conditions I and II holds when the costs of education are such that:

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

Proof The proposition permits us to simplify the equations presented in a general way (Eqs. 2 and 3) to Eqs. (6) and (7), and to calculate wages and wage premium, when

workers with different abilities work in different sectors.[9] In the appendix we calculate the various wages, and therefore we get that:

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

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 Eq. (8) is equivalent to:

$$\begin{array}{ll} \lambda\delta > \lambda^{\alpha}\delta^{\alpha}\sigma^{\alpha-1} & \text{and} \\ \lambda^{\alpha}\sigma^{\alpha-1} > \delta^{1-\alpha} & \end{array} \tag{9}$$

And since we have that λ, δ, $\gamma > 1$ and $\alpha < 1$, then Eq. (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 since $\tau = \lambda^{\alpha}\delta^{\alpha}\sigma^{\alpha-1} > 1$, then:

$$\text{Condition Ia is then equivalent to Condition III : } \delta(\tau-1) > \frac{P}{W_S^l a^l} > \left(\frac{\gamma}{\gamma-1}\right)(\tau-1)$$

QED.

These three lemmas have permitted to show that the equilibrium presented in the proposition 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 get that indeed the separation equilibrium is stable and no individual has a reason to deviate from this solution.

Therefore, low ability workers indeed graduate from standard universities and will go to work in the non-tradable sector. For high ability workers, they will graduate from elite universities, and work in the tradable sector.

This separation equilibrium permits us to calculate the wage premium, when workers with different abilities work in different sectors as presented in Eq. (8). Two interesting elements enter 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 tradable sector, λ. The higher this productivity enhancement, the higher the wage premium. This result is quite intuitive since elite education leads

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

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.

3.7 Conclusion of the Model

The model has permitted to explain the following facts.

(i) Our Proposition states that people with high ability (i.e., high grade on SAT) are the ones working in the tradable sector and the ones with low ability are working in the non-tradable sector. This is what has been emphasized in section 2.3.
(ii) Productivity of workers in the tradable sector is higher than in the non-tradable sector (since it is a function of λa^h and a^l respectively); This is what has been emphasized in section 2.1.
(iii) From Eq. 8, we see that the relative wage is higher than 1, so wages of skilled workers in the tradable sector are higher than in the non-tradable sector. This is what has been emphasized in section 2.2.

Recall that the wage premium in our model is given by the following equation:

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

In other words, the gap in wages between tradable and non-tradable is a function of the gap in ability, δ, the enhancement gap, λ as well as the relative size of the elite universities, σ.

In the next section, we check empirically Eq. (8).

4 Empirical Results

4.1 The Sample and Data

The first step in the analysis is to define the two sets of tradable and non-tradable industries for all OECD countries in our sample. We do so by following the approach introduced in Mano and Castillo (2015) which classifies an industry as tradable if the average export to value added ratio across all countries is greater than 10%.[10] Two assumptions underline this approach: The tradability of an industry is not country specific, i.e. a unified definition fits all countries in the sample. Secondly, tradability does not change over time. We introduce slight adjustments to this classification[11] and

[10] In this part we use a unified classification for all OECD countries. In the charts and data that relate only to Israel we use a country specific division which defines industries as treatable if the share of imports and exports to value added (the openness ratio) exceeds 40% (see Appendix Table 2).
[11] We exclude the Agriculture and Mining industries since they tend to be either country specific or highly government regulated. We also exclude some of the Information and communication activities where their tradability varies significantly across countries.

focus only on industries in the business sector. In addition, Appendix Table 3 shows in detail the industry classification we use in this section.

Our main data base in this section is the recently 'Published International Assessment of Adult Competencies' (PIAAC) which enables the examination of the distribution of workers cognitive skills across the various segments of the labor market.

We will examine two assertions in this part:

1. Workers with higher ability will find employment in the tradable industries.
2. The tradable industries will yield a higher return for ability and skills.

4.2 Empirical Analysis

We begin by examining the difference in the ability and skills of workers by estimating the following regression:

$$skills_{ij} = \alpha_1 + \alpha_2 \overline{X}_{ij} + \alpha_3 tradable + \delta_j + \varepsilon_{ij} \tag{10a}$$

Where *skills* represents the z-score on the PIAAC survey for individual i in occupation group j. δ is the fixed effect component for 53 occupation groups. $\overline{X}$ is a vector of individual characteristics including dummy variables for age, age^2, gender, tertiary education and non-natives. Our focus in this analysis is the coefficient of the dummy variable *tradable* which reveals the average difference in ability and skills between the two industry groups for workers which share similar observable characteristics and are employed in similar occupations. The regression is estimated separately for each country.

The results are presented in Table 1, column 1. We see that, indeed the coefficient of 'tradable' is significant for many OECD countries.

We then go to our second assertion examining the return for skills. We do so by running the following Mincer regression:

$$\begin{aligned} wage_{ij} = {} & \alpha_1 + \alpha_2 \overline{X}_{ij} + \alpha_3 tradable_i + \alpha_4 tradable{\cdot}\overline{X}_{iji} + \alpha_5 skills_{ij} \\ & + \alpha_6 tradable{\cdot}skills_{ij} + \delta_j + \varepsilon_{ij} \end{aligned} \tag{10b}$$

where 'wage' represents the log hourly wages of employees, 'skills' represents the score on the PIAAC survey and several additional individual characteristics are included in vector $\overline{X}$. Our main focus is the coefficient for the interaction of the dummy variable 'tradable' with the variable 'skills'.

The results of this regression are presented in Table 1, columns (2)–(4). The results are in line with our second assertion: employment in the tradable industries yields a higher return for skills. This result is significant and robust for adding the controls specified in Eq. 11 in six OECD countries.

Table 1 The Skill premium in the tradable and non-tradable industries

Country	(1) Skills differential	(2) Skills premium in Non-traded	(3) Skills premium in Traded	(4) Skills premium differential
Lithuania	0.087	0.087	0.054	−0.032
Czech Republic	0.05	0.040	0.013	−0.028
Norway	0.161***	0.064	0.042	−0.022
Greece	0.165**	−0.003	−0.005	−0.002
Denmark	0.101**	0.053	0.055	0.003
Japan	0.117***	0.082	0.088	0.006
Italy	0.121***	0.058	0.078	0.02
France	0.158***	0.052	0.077	0.025
Belgium	0.126	0.052	0.077	0.025
Slovakia	0.059	0.085	0.118	0.033
Spain	0.07*	0.026	0.059	0.034
Slovenia	−0.014	0.054	0.096	0.043*
Korea	0.008	0.040	0.085	0.045
Netherlands	0.106**	0.051	0.103	0.051***
Poland	0.064	0.068	0.120	0.052**
UK	0.161***	0.075	0.129	0.054**
Ireland	0.234***	0.056	0.135	0.079***
Israel	0.123***	0.087	0.177	0.091**
Chile	0.101*	0.021	0.125	0.104**

* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$

(i) The skills differential is the coefficient of α_3 in Eq. 10a which represents the gap in skills between the tradable and non-tradable measured in standard deviation units

(ii) The skill premium in the Non-traded is the coefficient of α_5 in Eq. 10b representing the increase in the hourly wage (in %) as a result of an increase of one standard deviation in skills (measured by the PIAAC survey). The Skills premium differential is the coefficient of α_6

The conclusion that can be drawn from this analysis is that in many OECD countries, workers with higher ability and skills tend to find employment in the tradable industries which rewards a higher return for their human capital. These facts match the results of lemmas 1 and 2, and our proposition presented in the previous section.

5 Conclusion

This paper relates the differences which exist between the tradable and non-tradable sectors to a duality in the higher education sector, and to heterogeneity in ability of workers. There are three main differences between these two sectors. The first one is the difference in productivity; the second one is related

to the differences in the wage premium to education. The third difference is the ability and skills of individuals working in these two sectors, since the data show that the average ability is higher in the tradable sector than in the non-tradable one. Therefore this paper focuses on the heterogeneity of human capital as a main factor explaining these facts.

It is interesting to note that the role of higher education and human capital has evolved over the decades. In the past, human capital was described as the factor of production which represented the skills of workers. It was analyzed as a homogenous factor. Today, human capital takes different forms and human capital is not anymore portrayed as a homogenous factor of production.

In consequence, in this paper, we differentiate between types of education and abilities of individuals. On the one hand, individuals can be either with low or high ability. On the other hand, individuals can graduate either from prestigious universities or from standard ones. Our model has shown that there is a relationship between abilities and types of education: Individuals with low ability are more prone to graduate from standard universities, while high ability students will graduate from elite and prestigious schools. It is this disparity which explains all the various differences between the service and the manufacturing sectors.

In conclusion, globalization has led to global labor markets. But, globalization led also to more separated markets: the tradable and the non-tradable sectors are not similar. They are hiring different types of human capital, and this is possible because there is heterogeneity in higher education.

The duality existing in the labor market between tradable and non-tradable sectors is fueled by the duality in higher education leading to heterogeneity in human capital. In consequence, there is a contrast between on one hand, more mobility across countries, and on the other hand, less mobility between sectors.

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Appendix–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:

$$W_u = \frac{\partial Y_T}{\partial L} = \beta K^{1-\beta} L^{\beta-1} {a_u}^{\rho} \left[\left(\lambda a^h \frac{H_E}{L} \right)^{\rho} + (a_u)^{\rho} \right]^{\frac{\beta-\rho}{\rho}}. \tag{11}$$

and:

$$W_S^h = \frac{\partial Y_T}{\partial H_E} = \beta K^{1-\beta} {H_E}^{\beta-1} \left(\lambda a^h\right)^{\rho} \left[(\lambda a_h)^{\rho} + \left(a_u \frac{L}{H_E} \right)^{\rho} \right]^{\frac{\beta-\rho}{\rho}}. \tag{12}$$

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

$$\omega_1 = \frac{W_S^h}{W_u} = \left(\frac{\lambda a^h}{a_u}\right)^{\rho} \left(\frac{H_E}{L}\right)^{\rho-1}. \tag{13}$$

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

$$W_u = \frac{\partial Y_{NT}}{\partial L} = \beta K^{1-\beta} L^{\beta-1} {a_u}^{\alpha} \left[\left(a^l \frac{H_{NE}}{L}\right)^{\alpha} + (a_u)^{\alpha}\right]^{\frac{\beta-\alpha}{\alpha}}. \tag{14}$$

$$W_S^l = \frac{\partial Y_{NT}}{\partial H_{NE}} = \beta K^{1-\beta} {H_{NE}}^{\beta-1} a^{l\alpha} \left[\left(a^l\right)^{\alpha} + \left(a_u \frac{L}{H_{NE}}\right)^{\alpha}\right]^{\frac{\beta-\alpha}{\alpha}}. \tag{15}$$

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

$$\omega_2 = \frac{W_S^l}{W_u} = \left(\frac{a^l}{a_u}\right)^{\alpha} \left(\frac{L}{H_{NE}}\right)^{1-\alpha} \tag{16}$$

From (13) and (16), we get that the wage premium of education of type H_E vs. type H_{NE} is:

$$\omega_3 = \frac{W_S^h}{W_S^l} = \left(\frac{a^l}{a_u}\right)^{-\alpha} \left(\frac{H_{NE}}{L}\right)^{1-\alpha} \left(\frac{\lambda a^h}{a_u}\right)^{\rho} \left(\frac{H_E}{L}\right)^{\rho-1} \tag{17}$$

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

$$\omega_3 = \frac{W_S^h}{W_S^l} = \left(\frac{\lambda a^h}{a^l}\right)^{\alpha} \left(\frac{H_E}{H_{NE}}\right)^{\alpha-1} \tag{18}$$

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

$$\omega_3 = \frac{W_S^h}{W_S^l} = \left(\frac{\lambda a^h}{a^l}\right)^{\alpha} \left(\frac{H_E}{H_{NE}}\right)^{\alpha-1} = \lambda^{\alpha} \delta^{\alpha} \sigma^{\alpha-1} \tag{19}$$

Appendix

Table 2 Israeli industry characteristics in 2010

Branch	GDP per hour worked	Average years of school	Employees (In thousands)	Openness ratio	Tradability
Storage, parking lots and freight terminals	85.86	12.25	5.4	0.00%	Non-Tradable
Hairdressing and beauty parlours	39.99	12.52	109.14	0.00%	Non-Tradable
Restaurants and dining services	29.12	12.29	137.77	0.00%	Non-Tradable
Postal and courier activities	75.17	12.98	13.28	0.00%	Non-Tradable
Labour recruitment and provision of personnel	26.04	14.93	92.77	0.10%	Non-Tradable
Security and cleaning activities	30.01	12.22	118.12	0.10%	Non-Tradable
Health services	49.02	15.11	161.45	0.60%	Non-Tradable
Motor vehicles, motorcycles and bicycles - sale, maintenance and repair and retail trade of fuel	77.06	12.2	64.45	0.70%	Non-Tradable
Education	84.82	15.53	40.68	1.00%	Non-Tradable
Recreational, cultural and sporting activities	75.37	14.3	56.66	4.60%	Non-Tradable
Land transport	68.77	11.6	78.49	6.00%	Non-Tradable
Publishing and printing	60.39	13.66	23.1	7.30%	Non-Tradable
Telecommunications	218.98	14.01	41.97	8.00%	Non-Tradable
Wholesale trade (excl. Motor vehicles and motorcycles)	85.33	13.36	153.61	10.70%	Non-Tradable
Retail sale (excl. Sales, maintenance and repair of motor vehicles)	53.79	12.59	226.86	10.70%	Non-Tradable
Insurance and social insurance funds	143.27	14.24	37.2	12.60%	Non-Tradable
Banking and other financial institutions	252.71	15.27	75	14.10%	Non-Tradable
Hotels and accommodation services	69.79	12.07	31.99	23.10%	Non-Tradable
Manufacture of food products	78.63	12.09	56.78	23.20%	Non-Tradable
Business activities n.e.c.	82.56	15.69	206	23.90%	Non-Tradable
Manufacture of soft and alcoholic beverages and tobacco products	131.29	13.45	4.43	27.10%	Non-Tradable
Manufacture of wood and wood products	58.22	11.41	4.94	33.80%	Non-Tradable
Manufacture of paper and paper products	84.99	12.06	9.65	35.60%	Non-Tradable
Manufacture of furniture	45.23	11.82	16.8	40.70%	Tradable
Manufacture of non-metallic mineral products	113.36	12.62	9.55	40.80%	Tradable
Manufacture of metal products (excl. Machinery and equipment)	75.07	12.68	44.49	44.40%	Tradable
Manufacture of basic metal	81.28	12.33	6.07	48.80%	Tradable
Computer and related services	146.85	15.96	121.05	51.40%	Tradable
Auxiliary transport activities	113.6	13.82	35.94	55.40%	Tradable
Manufacture of plastic and rubber products	85.33	13.2	23.35	62.70%	Tradable

Table 2 (continued)

Branch	GDP per hour worked	Average years of school	Employees (In thousands)	Openness ratio	Tradability
Manufacture of wearing apparel (except knitted)	50.2	12.78	4.34	66.00%	Tradable
Manufacture of refined petroleum and its products	319.87	13.9	31.27	68.20%	Tradable
Manufacturing n.e.c.	81.02	12.9	4.87	72.60%	Tradable
Manufacture of industrial equipment, medical and scientific equipment	166.46	15.4	33.58	77.40%	Tradable
Manufacture of electric motors and electric distribution apparatus	96.93	13.48	7.82	78.10%	Tradable
Air transport	233.24	14.78	8.8	80.40%	Tradable
Manufacture of electronic components	221.75	14.81	19.69	80.60%	Tradable
Manufacture of textiles	68.32	12.8	7.72	82.00%	Tradable
Manufacture of machinery and equipment	89.2	14.08	20.76	84.70%	Tradable
Manufacture of electronic communication equipment	124.34	15.21	15.93	86.70%	Tradable
Manufacture of transport equipment	138.43	13.6	20.11	86.90%	Tradable
Manufacture of footwear and leather products	68.73	11.62	1.77	88.80%	Tradable

Note: Tradable industries are defined as industries in which their openness ratio exceeds 40%. The index measures the share of exports and competitive imports within the total supply of the industry at the year 2006

Table 3 Industry classification for OECD countries

ISIC code	Industry description	Tradability classification
D01T03	Agriculture, forestry and fishing	Excluded
D05T09	Mining and quarrying	Excluded
D10T12	Food products, beverages and tobacco	Tradable
D13T15	Textiles, wearing apparel, leather and related products	Tradable
D16T18	Wood and paper products, and printing	Non-tradable
D19T23	Chemical, rubber, plastics, fuel products and other products	Tradable
D24T25	Basic metals and fabricated metal products	Tradable
D26T28	Machinery and equipment	Tradable
D29T30	Transport equipment	Tradable
D31T33	Furniture and other manufacturing	Tradable
D35T39	Electricity, gas and water supply	Excluded
D41T43	Construction	Non-tradable
D45T47	Wholesale and retail trade, repair of motor vehicles and motorcycles	Non-tradable
D49T53	Transportation and storage	Tradable
D55T56	Accommodation and food service activities	Non-tradable

Table 3 (continued)

ISIC code	Industry description	Tradability classification
D58T60	Publishing, audio visual and broadcasting activities	Excluded
D61	Telecommunications	Non-tradable
D62	Computer programming, consultancy and related activities	Tradable
D63	Information service activities	Tradable
D64T66	Financial and insurance activities	Tradable
D68	Real estate activities	Non-tradable
D69T75	Professional, scientific and technical activities	Tradable
D77T82	Administrative and support service activities	Non-tradable
D84T88	Public administration and defence	Excluded
D90T92	Creative, arts and entertainment activities	Non-tradable
D93	Sports activities and amusement and recreation activities	Non-tradable
D94T96	Other service activities	Non-tradable
D97T98	Activities of households as employers	Non-tradable
D99	Activities of extraterritorial organizations and bodies	Excluded

Source: Mano and Castillo (2015)

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