THE PINHAS SAPIR CENTER FOR DEVELOPMENT
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Talent Utilization and Search for the Appropriate Technology

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Discussion Paper No. 6-2010

April, 2010

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Abstract

This paper analyzes a model of economic growth which is propagated by matching between technologies and the talents they require. It shows that differences in productivity across countries are amplified by three dimensions of talent utilizations: first, the variety of different talents utilized; second, the density of a specific talent utilized; third, the quality of match in the economy. Assuming set up costs, the equilibrium number of technologies increases with productivity. A larger number of technologies enables a better matching between individuals' talents and requirements of technologies. In addition, the number of technologies affects the incentives individuals face to search for the appropriate technology. Finally, we discuss the link between search and development.

Keywords: income level , total factor productivity, appropriate technology, talent utilization, search.

JEL Classifications: J21, L16, O11, O33, O47.

1 Introduction

Total factor productivity (TFP) is an important determinant of development. However, measured by the Solow residual, it is no more than "The Measure of Our Ignorance" (Abramovitz (1956)). This research provides a theoretical explanation of differences in TFP and, thus, income differences across countries. It harnesses Adam Smith's idea of the division of labor to explain how small differences in productivity across countries are amplified through search and matching. The premise of the paper is that each technology requires a different set of talents, which are distributed across individuals. When more individuals are properly matched to the appropriate technology, talent utilization increases, and with it output. The paper describes an economy in which exogenous productivity affects overall talent utilization through product variety and individuals' incentives to search for the appropriate technology.

The paper has the following results. Higher productivity yields a larger variety of technologies. A larger variety of technologies affects the effort individuals invest in search for the appropriate technology. A larger variety and higher search effort result in a smaller average mismatch between technologies and talents on the one hand, and in a higher number of individuals finding the appropriate technology on the other hand. Our main result shows that small differences in economies' productivity are amplified through higher talent utilizations and higher average match quality.

The idea of the paper is presented by a model of economic growth where the final output is produced by many intermediate goods. Each country produces a different variety of intermediate goods. Each intermediate good corresponds to a specific technology and produced by a continuum of entrepreneurs. To implement a particular technology a specific entrepreneurship talent is required. The extent to which entrepreneur's talent matches the technology requirements determines the efficiency units of labor that an entrepreneur supplies. Intermediate goods are then produced by entrepreneurs using their efficiency units of labor along with raw labor input.

With decreasing returns to accumulated factors, a fixed cost of importing each technology determines the number of intermediate varieties. Higher productivity increases entrepreneurial rent. As a result, a smaller continuum of entrepreneurs is needed to cover the fixed cost, yielding a higher average match. At the same time, lower labor resources are needed to produced each variety, leading to a larger number of varieties when labor market clears. The number of varieties affects individuals' incentives to search for their appropriate technology, given that search is required to overcome information frictions. We show under what conditions investment in search increases, which acts as another source of amplification that, ultimately, affects the extent to which talents are begin utilized.

This paper belongs to a strand in the literature that tries to deal with the repeated question: why are some countries so much richer than others? The answer that this literature provides lies between factors accumulation and the efficiency with which these factors are used.[1] On the one hand, Mankiw, Romer and Weil (1992), Parente, Rogerson and Wright (2000), Weil (2005) and Manuelli and Seshadri (2005) find that most of the cross-country differences in per capita output are induced by factors accumulation.[2] On the other hand, Chari, Kehoe and McGrattan (1996), Prescott (1998), Hall and Jones (1999), Parente and Prescott (2000), Klenow and Rodriguez-Clare (1997), Bils and Klenow (2000), Hendricks (2002) and Jeong and Townsend (2007) find that most of the cross-country differences in per capita output are induced by TFP.[3]

Given the importance of TFP in explaining large cross-country differences in income leaves us with the need to understand the underlying technological differences across countries. Zeira (1998), Basu and Weil (1998) and Acemoglu and Zilibotti (2001) are theoretical contributions that emphasize the role of appropriate technologies for explaining TFP differences. Zeira (1998) focuses on the range of technologies adopted due to differences in capital labor ratios. Basu and Weil (1998) addresses the role of learning-by doing that influences technological progress at the capital labor ratio.

[1] For an updated survey of such development accounting literature see Caselli (2005).

[2] Mankiw et al. (1992) addresses the role of human capital, Parente et al. (2000) emphasize the role of home production, Weil (2005) examines the role of health and Manuelli and Seshadri (2005) stresses the importance of controlling for the quality of education when examining this question.

[3] While Chari et al. (1996), Prescott (1998) and Parente and Prescott (2000) allow for differences in physical and intangible capital, Klenow and Rodriguez-Clare (1997), Bils and Klenow (2000) and Hendricks (2002) allow for differences in the quality of education across countries and Jeong and Townsend (2007) stresses the importance of occupational shifts and financial deepening. Interestingly, Hall and Jones (1999) addresses the importance of exogenous variables captured by social infrastructure in explaining cross-country differences in TFP, an evidence that support our approach.

Acemoglu and Zilibotti (2001) emphasizes skill supply for utilizing advanced technologies. In these papers, differences in factor distribution across countries drive the adoption or invention of the appropriate technology. In our model, appropriateness is at the micro level.[4] Each individual can be appropriately matched to a technology, or not. Thus, countries may have the same input distribution, yet differ in the appropriateness of technology.

The interplay between TFP and division of labor is augmented by a search mechanism. With higher TFP and hence more varieties, workers have a higher probability of finding a better match for their talents, and thus search might be more intense. The information friction and search decision provides an endogenous margin which amplifies initial differences in TFP. The inefficiency of matching between heterogenous workers and heterogenous firms in the presence of information frictions has been put forth by Shimer (2005). Decreuse's (2008) setup of the search and matching process is most similar to ours, as it allows workers to have heterogenous sector specific skills and make a choice about the number of market segments to search.[5] While this literature is concerned with the matching friction underlying unemployment (see also Mortensen and Pissarides, Shimer, and Ebrahimy and Shimer), we focus, rather, on the informational friction underlying talent utilization. Workers do not have direct information on the best match for their talent, and hence have to search. Most importantly, our search mechanism is embedded in a larger model which also specifies the production side of the economy, and solves for the number of varieties.

The rest of the paper is organized as follows. Section 2 formalizes the arguments, section 3 provides a comparative statics exercise, section 4 presents some concluding remarks and part of the proofs appears in the appendix.

[4]Our research is motivated by evidence provided by Baumgardner ((1988a), (1988b)) and Garicano and Hubbard (2009) that find that individuals' specialization differs across regions.

[5]See also Gautier and Teulings (2004)

2 The Model

Consider a small open economy in a world with one final good, which is used for consumption only. This final good is produced using a continuum of intermediate goods. For simplicity the model assumes no physical capital and, therefore, intermediate goods are produced using labor only. All markets are assumed to be perfectly competitive. The final good as well as each intermediate good is assumed to be perfectly tradable, but labor is not tradable, and its market is domestic. For simplicity there is no population growth and population size is normalized to one.

2.1 Production

2.1.1 Production of the final good

The final good is produced by the following continuous log-linear production function

$$\log Y = \int_0^1 \log x(j)\, dj \tag{1}$$

where Y is the total output produced in an economy, $x(j)$ is the input of intermediate good j.

2.1.2 Production of intermediate goods

Each country produces a discrete variety of intermediate goods out of a potential continuum, which is the interval $[0, 1]$. Each point on this unit segment represents a different type of intermediate good which requires a specific talent to operate the technology by which it is produced. This specific talent will be henceforth called the "job requirements".

Individuals are indexed on the unit segment with uniform density. The index of each individual represents her talent.[6] As job requirements represent the location

[6] A different location on the unit segment reflects a different type of talent. More specifically, the location of a specific individual: $(i = 1)$ does not indicate a maximum level of talent; rather, it represents a different talent from any $(i \neq 1)$.

of an entrepreneur whose talent accurately matches these requirements, individuals and intermediate goods are both indexed on the same unit segment without any ambiguity.

Each intermediate good is produced by a continuum of entrepreneurs, each endowed with a specific talent which matches to some extent, the job requirements of the technology used. The extent to which an entrepreneur's talent matches the job requirements determines the number of efficiency units of labor this entrepreneur supplies, according to the following function.

$$h(j,i) = h_0 - bd(j,i) \tag{2}$$

where $h(j,i)$ is the ex-post efficiency units of labor that entrepreneur i supplies for producing intermediate good j, h_0 is the maximum efficiency units of labor that an entrepreneur can have and $d(j,i)$ is the distance between the location of intermediate good j, which reflects its job requirements, and that of entrepreneur i, which reflects her entrepreneurship talent. This distance expresses the level of mismatch between the two. The larger the distance is, the greater the mismatch.

Each individual is a potential entrepreneur, who can produce an intermediate good j according to the following production function

$$x(j,i) = A\,[l(j,i)]^{\alpha}\,[h(j,i)]^{(1-\alpha)} \tag{3}$$

where $\alpha \in (0,1)$, $x(j,i)$ is the output of intermediate good j produced by entrepreneur i, $l(j,i)$ is the number of workers employed by her and A is a productivity parameter, which is country specific. This coefficient may reflect geography: land quality, climate and access to sea, resource endowments: land abundance and natural resources or even infrastructure, and should therefore differ across countries.

Each intermediate good is produced by a continuum of entrepreneurs taking prices as given. Namely, each entrepreneur i takes the equilibrium wage, w, the cost $r(j)$ of technology j's blueprint, and the price $P(j)$ of a unit of intermediate good j and maximizes:

$$\pi(j,i) = P(j)\,[l(j,i)]^{\alpha}\,[h(j,i)]^{(1-\alpha)} - w[l(j,i)] - r(j) \tag{4}$$

2.1.3 The monopolistic market for technologies

The final good is produced by many intermediate goods, where each one requires knowledge of a specific technology. This knowledge is owned by a monopoly. Since intermediate goods are substitutes in the production of the final good, competition arises among monopolies.

The market for technologies operates as follows. A monopolistic owner of a technology incurs a setup cost, C. This cost, which is measured in terms of the final good, can be interpreted as the cost of importing on the shelf technology for producing intermediate good j. Her revenues are $R(j)$, which consist of total payments collected from all entrepreneurs using technology j. Assuming an owner does not observe entrepreneurs' talents, she cannot discriminate and thus charges a uniform price, $r(j)$. Therefore, profit generated by monopolistic owner j is

$$\pi(j) = R(j) - C \tag{5}$$

Where $R(j) = \int\limits_{i\in E(j)} r(j)\,di$ and $E(j)$ is the set of entrepreneurs using technology j.

2.2 Individuals

Each individual derives utility from consuming the final good and, thus, individuals' maximization problem collapses to income maximization problem. An Individual can either work as an entrepreneur, utilizing her talent and earning some profits or be employed as a simple worker, earning the equilibrium wage, w.

For a non trivial number of technologies to arise in equilibrium, an entrepreneur must earn at least as much as a simple worker. However, to be an entrepreneur, an individual must search and find an appropriate technology. The information friction is such, that each individual does not know how well her talent matches with the existing technologies. This could either be because she does not know her own talent or she does not know the technological requirements of j.

Assumption 1 *The probability that entrepreneur i finds the closest technology j is independent of her distance from technology j.*

This assumptions captures the symmetry in individuals' ignorance regarding technological requirements. Individuals are as likely to find the most appropriate technology for their talents whether they are very close to it or further away.[7] This assumption implies that investment in search is equal across individuals.

An individual invests s in search, incurs a cost $g(s)$ and finds the closest technology with probability $q(s)$. Accordingly, individuals choose search effort to maximize,

$$I = [1 - q(s)]w + q(s)I_{Informed} - g(s) \tag{6}$$

Where $I_{Informed}$ is the average income of the set of individuals who find the location of the closest technology j, thus:

$$I_{Informed} = [E(\pi(j,i)|_{\pi(j,i)>w})]\rho + w(1-\rho) \tag{7}$$

Such that ρ is the probability that labor market clearing conditions enable an informed individual to operate as an entrepreneur, that is, $\pi(j,i) > w$.

2.3 Labor market

Labor market consists of entrepreneurs producing using different technologies and employing workers. let J denotes the equilibrium number of technologies and $\phi(j,i)$

[7] As will be seen later, the average distance is shorter in more developed countries. Thus, relaxing this assumption and allowing for higher success probability for shorter distances will add another dimension of amplification.

is the density of entrepreneurs i who buy technology j. Each entrepreneur i producing with technology j demands $l(j,i)$ workers. Let $\{j_1,\ldots,j_J\}$ be the set of technologies arising in equilibrium. Aggregate demand for labor is

$$\sum_{j\in\{j_1,\ldots,j_J\}} \int_{i\in E(j)} \phi(j,i) l(j,i) \;\; d\,i$$

and aggregate supply of labor is

$$1-\sum_{j\in\{j_1,\ldots,j_J\}} \int_{i\in E(j)} \phi(j,i) \;\; d\,i$$

2.4 Equilibrium

An equilibrium is a vector $\{s, r(j), E(j), P(j), l(j,i), w, J\}$ which is a solution to (i) individuals' maximization of income; (ii) the monopolistic market for technologies: profit maximization and (iii) zero profits condition; (iv) the final good maximization problem; (v) the intermediate goods maximization problems; (vi) a threshold condition on individual's choice of employment; and (vii) labor market clearing condition.

2.4.1 Final good market

Let the final good serves as a numeraire. Profit maximization by firms, which produce the final good, leads to the following first-order condition

$$P(j)=\frac{\partial Y}{\partial x(j)}=\frac{Y}{x(j)} \tag{8}$$

Substituting equation (8) into equation (1) we get that the condition $\left(\int_0^1 \log P(j)\, dj = 0\right)$ must hold at the optimum. Due to symmetry and to the world competition in markets for intermediate goods all prices must be equal. Hence $P(j)=P=1$.

2.4.2 Intermediate goods market

Profit maximization by entrepreneur i who produces intermediate good j leads to the following demand for labor

$$l(j,i) = \left(\frac{\alpha A}{w}\right)^{\frac{1}{1-\alpha}} [h_0 - bd(j,i)] \tag{9}$$

The process of establishing new firms by new entrepreneurs takes place until it becomes unprofitable to set up a new firm for producing the same intermediate good j. This is generated by a threshold condition that applies to the marginal entrepreneur in sector j, who is indifferent between being an entrepreneur in sector j or working as an employee in any firm. Formally, the threshold condition is:

$$\pi(j \pm \bar{d}(j)) = (1-\alpha)A\left[\bar{l}(j)\right]^{\alpha}\left[\bar{h}(j)\right]^{(1-\alpha)} - r(j) = w \tag{10}$$

where $\bar{h}(j)$ is the number of efficiency units of labor that the marginal entrepreneur has and $\bar{l}(j)$ is the number of workers employed by her. Recall from equation (2) that $\bar{h}(j) = h_0 - b\bar{d}(j)$, where $\bar{d}(j)$ is the maximal distance between the requirements of sector j and the talent of the marginal entrepreneur.

2.4.3 The monopolistic market for technologies

Entrepreneurs join sector j from both sides, the size of sector j is represented by the width of that sector which is the interval $[j - \bar{d}(j), j + \bar{d}(j)]$. Thus, the size of each sector, which is $2\bar{d}(j)$, represents the continuum of firms that produces the same intermediate good j. The density of entrepreneur i working in sector j is known by the following two results:

Lemma 1 *At the macro level, density of potential entrepreneurs in an economy is* $\phi(j,i) = q(s_{ij})$.

Proof. Follows directly from corollary (1). ■

Corollary 1 *Density of entrepreneur i is independent of her distance from her closest technology j, i.e. $\forall i, j$ s.t. $i \in E(j)$, $\phi(j,i) = q(s)$.*

Proof. Follows directly from assumption (1) and lemma (1) ■

Thus, the density of entrepreneurs for a given skill-technology match is the probability that an entrepreneur matches with her closest technology. This probability depends on search effort s which is the same for all individuals. Since density does not depend on i, it is now convenient to integrate using the distance t defined by: $t = |j - i|$. Then (5) becomes:

$$\pi(j) = r(j) \cdot 2 \left[\int_0^{\bar{d}(j)} q(s) \quad dt \right] - C \tag{11}$$

Where $q(s)$ is the density of entrepreneurs at any given location. This density is a function of search effort, s, and it is independent of distance, t. From equation (10) it follows that the price that owner j charges for selling her technology to other entrepreneurs, $r(j)$, affects entrepreneurs' surpluses and therefore affects the size of sector j. First order condition with respect to the monopolistic rent yields:

$$\frac{\partial d(\bar{j})}{\partial r(j)} r(j) + \bar{d}(j) = 0 \tag{12}$$

Applying the implicit function theorem on equation (10) implies that:

$$\frac{\partial \bar{d}(j)}{\partial r(j)} = \frac{-w^{\frac{\alpha}{1-\alpha}}}{\alpha^{\frac{\alpha}{1-\alpha}}(1-\alpha) b A^{\frac{1}{1-\alpha}}} \tag{13}$$

substituting equation (13) into equation (12), isolating w,

$$w = \alpha(1-\alpha)^{\frac{1-\alpha}{\alpha}} b^{\frac{1-\alpha}{\alpha}} A^{\frac{1}{\alpha}} \left(\frac{\bar{d}(j)}{r(j)} \right)^{\frac{1-\alpha}{\alpha}} \tag{14}$$

substituting equation (14) and (9) into (10) and isolating $r(j)$ yields:

$$r_j = \gamma \frac{b\bar{d}(j)}{(h_0 - 2b\bar{d}(j))^{\alpha}} A \tag{15}$$

where $\gamma = \alpha^{\alpha}(1-\alpha)^{(1-\alpha)}$.

Another potential entrepreneur, $j\prime$ far from j finds it profitable to initiate a new sector that produces a different intermediate good. She incurs the set up cost, C, and through the above described market for technologies she sells the blueprint to other entrepreneurs close to her. Ultimately, many sectors are being established, where each sector produces a unique intermediate good by a continuum of firms. The larger the variety of intermediate goods, the smaller the surplus for each owner. This conclusion is driven by the assumption of substitution of the intermediates in producing the final good. As a result, at equilibrium, the variety of intermediate goods in an economy is determined by applying the zero profit condition for all owners, which yields:

$$\gamma \frac{b\bar{d}(j)}{(h_0 - 2b\bar{d}(j))^{\alpha}} A \cdot 2 \left[\int_0^{\bar{d}(j)} q(s)\ d\,t \right] = C \tag{16}$$

By corollary (1), equation (16) collapses to

$$2q(s)\gamma \frac{b\left[\bar{d}(j)\right]^2}{\left[h_0 - 2b\bar{d}(j)\right]^{\alpha}} A = C \tag{17}$$

Corollary 2 *All sectors are symmetric, i.e., each sector has the same size and, therefore, charges the same price for selling technology.*
(i) $\forall j, r(j) = r$
(ii) $\forall j, \bar{d}(j) = \bar{d}$

Proof. Follows directly from equation (17) and (15). ■

Using corollary (2) and substituting (15) into (14) yields

$$w = \gamma(h_0 - 2b\bar{d})^{1-\alpha} A \tag{18}$$

2.4.4 Structure of the market

Recall that t is the distance between an entrepreneur and her technology. Given that J is the equilibrium number of sectors, and by corolary xxxxx ??? labor market clearing implies that

$$2J\left[\int_0^{\bar{d}} q(s)l(t)\ dt\right] = 1 - 2J\left[\int_0^{\bar{d}} q(s)\ dt\right] \tag{19}$$

The term $2\int_0^{\bar{d}} q(s)dt$ represents the size (measure) of entrepreneurs out of a normalized population. Therefore, the left hand side of (19) represents the demand for labor and the right hand side of (19) represents the supply for labor.

Using corollary (2) and substituting equation (18) into (9), equation (9) can be rewritten as a function of distance from technological requirements solely.

$$l(t) = \frac{\alpha}{1-\alpha}\frac{h_0 - bt}{h_0 - 2b\bar{d}} \tag{20}$$

Proposition 1 *Firm's size positively affected by the matching.*

Proof. Follows directly from equation (20). ■

Using assumption (1) and substituting equations (20) into (19), yields:

$$J = \frac{1}{q(s)\bar{d}\left(\frac{\alpha}{1-\alpha}\frac{2h_0 - b\bar{d}}{h_0 - 2b\bar{d}} + 2\right)} \tag{21}$$

2.4.5 Individuals' Optimization:

Corollary (2) yields that $\rho = 2\bar{d}J$. Along with (7), (6) could be rewritten as

$$I = [1 - q(s)]w + q(s)\{2\bar{d}JE(\pi) + (1 - 2\bar{d}J)w\} - g(s) \tag{22}$$

where $E[\pi]$ is the expected rents from being an entrepreneur, which can be described by

$$E(\pi) = \int_0^{\bar{d}} \left\{(1-\alpha)A[l(t)]^{\alpha}[h(t)]^{1-\alpha} - r\right\} f(t)\, dt \tag{23}$$

Where $f(t)$ is the density function of talent with distance t. Given that t is uniformly distributed on $[0, \bar{d}]$, $f(t) = \big(1/\bar{d}\big)$.

Substituting equation (20) and (15) into (23) yields

$$E(\pi) = \gamma \frac{h_0 - \frac{3}{2} b\bar{d}}{(h_0 - 2b\bar{d})^{\alpha}} A \tag{24}$$

Maximizing equation (22) yields the following first order condition

$$q'(s) 2\bar{d} J \{E(\pi) - w\} = g'(s) \tag{25}$$

The intuition behind equation (25) is straightforward. Left hand side of (25) is the marginal gain from a marginal increase in s and left hand side is its marginal cost.

Using lemma (1) and substituting (18), (21) and (24) into (25) yields

$$\frac{q'(s)}{q(s)} \frac{\gamma b\bar{d}}{\left(\frac{\alpha}{1-\alpha}\frac{2h_0 - b\bar{d}}{h_0 - 2b\bar{d}} + 2\right)(h_0 - 2b\bar{d})^{\alpha}} A = g'(s) \tag{26}$$

Using corollary (2) along with substituting equations (17) into (26) yields

$$\frac{q'(s)}{q(s)^2 g'(s)} \frac{C}{2\bar{d}\left(\frac{\alpha}{1-\alpha}\frac{2h_0 - b\bar{d}}{h_0 - 2b\bar{d}} + 2\right)} = 1 \tag{27}$$

Ultimately, (17) and (27) solve for the equilibrium values of s and $\bar{d}$ and (21), in turn, solves for J.

3 Comparative Statics

This section examines how economies vary in their optimal structure, an environment that induces individuals to invest in search for the suitable technology. More specifically, it analyzes how differences in productivity across countries explain differences in the number and size of sectors and in investment in search.

3.1 Exogenous search

In this subsection we would like to understand the role of search vs diversification in explaining differences in per-capita income and in economies' structure. To this end, we examine the equilibrium holding s and thus q constant.

In this scenario individuals have no active role in determining the equilibrium of the economy. Moreover, holding q constant, in this model, reveals one aspect of the amplification effect stemming from talent utilization. This aspect reflects differences in talents diversity employed within different economies, the extensive margin.

3.1.1 Economy

Proposition 2 *With exogenous s, higher level of development is associated with:*
(i) a smaller continuum of talents employed at the sectorial level. Formally, $\frac{\partial \bar{d}}{\partial A} < 0$.
(ii) a higher number of intermediate goods. Formally, $\frac{\partial J}{\partial A} > 0$.
(iii) a larger continuum of talents employed at the macro level. Formally, $\frac{\partial B}{\partial A} > 0$, where $B = 2J\bar{d}$.
(iv) a higher monopolistic price for selling the right for using her technology. Formally, $\frac{\partial r}{\partial A} > 0$.

Proof.
(i) Follows directly from applying the implicit function theorem on (17).

$$\frac{\partial \bar{d}}{\partial A} = -\frac{\bar{d}}{2A\left(1 + \frac{\alpha b \bar{d}}{h_0 - 2b\bar{d}}\right)} < 0 \tag{28}$$

(ii) Follows directly from (i) and (21).
(iii) Follows directly from (i) and (21).
(iv) Follows directly from differentiating (15) with respect to A and substituting (28).

$$\frac{\partial r}{\partial A} = \frac{\gamma b \bar{d}}{(h_0 - 2b\bar{d})^{\alpha}} \left(1 - \frac{1 + \frac{2\alpha b \bar{d}}{h_0 - 2b\bar{d}}}{2 + \frac{2\alpha b \bar{d}}{h_0 - 2b\bar{d}}}\right) > 0 \tag{29}$$

■

Thus, higher basic productivity increases the share of entrepreneurs out of the population. Since in this model talents play a role only through entrepreneurship activities, it turns out that in more developed countries population talents are better utilized, albeit the same ex-ante distribution of talents in all countries. Notice that although the continuum of entrepreneurs is larger in more developed countries, the size of each sector is smaller. As a result, the average matching between entrepreneurs' talents and job requirements is higher. put it differently, differences in basic productivity across countries are amplified through talents utilization. This talents utilization takes two forms: first, more people use their talents, and second, average matching at the sectorial level is higher.

3.2 Edogenous search

3.2.1 Individuals

Lemma 2 *For a given level of investment in search, s, the term $[E(\pi) - w]$ in (25) is increasing in A*

Proof. See Appendix. ■

Since for a given s, (28) shows that $\frac{\partial \bar{d}}{\partial A} < 0$, the right hand side of (27) increases with A, which leads us to the following proposition

Proposition 3 *For probability and cost functions that satisfy:*
(i) $\partial \left(\frac{q'(s)}{q(s)^2 g'(s)} \right) / \partial s < 0$*, investment in search, s, increases with development.*
(ii) $\partial \left(\frac{q'(s)}{q(s)^2 g'(s)} \right) / \partial s > 0$*, investment in search, s, decreases with development.*

Proof. Follows directly from proposition $(2(i))$ and equation (27). ■

To elaborate the results of our model at the macro level, we next assume specific probability and cost functions. To simplify we assume that both function are linear with respect to search, i.e., $q(s) = s$ and $g(s) = s$.[8] Consequently, (26) collapses to

$$s = \frac{\gamma b\bar{d}}{\left(\frac{\alpha}{1-\alpha}\frac{2h_0 - b\bar{d}}{h_0 - 2b\bar{d}} + 2\right)(h_0 - 2b\bar{d})^{\alpha}} A \tag{30}$$

3.2.2 Economy

Now we would like to examine how choosing s and, thus, $q(s)$ affects our comparative statics results. This channel discovers an intensive margin, that reflects the density of entrepreneurs employed for each talent.

Proposition 4 *With endogenous s, higher level of development is associated with:*
(i) a smaller continuum of talents employed at the sectorial level. Formally, $\frac{\partial \bar{d}}{\partial A} < 0$.
(ii) a larger continuum of talents employed at the macro level. Formally, $\frac{\partial B}{\partial A} > 0$, *where* $B = 2J\bar{d}$.
(iii) a higher number of intermediate goods. Formally, $\frac{\partial J}{\partial A} > 0$.
(iv) a larger continuum of entrepreneurs employed at the macro level. Formally, $\frac{\partial E}{\partial A} > 0$, *where* $E = 2q(s)J\bar{d}$.
(v) a higher monopolistic price for selling the right for using her technology. Formally, $\frac{\partial r}{\partial A} > 0$

Proof.
(i) Follows directly from substituting (30) in (17) and applying the implicit function theorem (see Appendix).
(ii) See Appendix.
(iii) Follows directly from (ii) and $\frac{\partial \bar{d}}{\partial A} < 0$.
(iv) Follows directly from (i) and (21).
(v) See Appendix. ■

[8] It is worth explaining why such linear functions with respect to search produce an interior solution. An increase in search increases the probability to find the suitable sector, which acts as a positive intensive to search. As this probability increase, however, due to labor market clearing conditions, the equilibrium number of sectors, J declines which acts as negative intensive to search, providing an interior solution.

4 Concluding Remarks

This paper argues that small differences in productivity are amplified by talent utilization. We assume that talent utilization is a result of matching between technologies' requirements and individuals' talent. The amplification process works through three different channels. First, the variety of different talents utilized. Second, the density of a specific talent utilized. Third, the average match quality in the economy.

The analysis provides a tool to understand differences in economic structure across countries. It describes the forces that determine three different dimensions related to the structure of the economy: first, the number of sectors, each identified with a different technology; second, the size of each sector, which is reflected by the continuum of entrepreneurs utilizing their talents; third, the distribution of firms' size mirrored by the distribution of workers employed by entrepreneurs.

The paper could also shed some light on the determinant of income inequality within economies. This inequality could be affected by three factors. First, constant income earned by simple workers. Second, differentiated income earned by entrepreneurs. Third, the relative sizes of these two groups as determined by the structure of the economy. Moreover, the model could be extended to deal with unemployment, an interesting dimension that we leave for future research.

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APPENDIX

Proofs

Proof that the term $E(\pi) - w$ is increasing in A.

Let $Sur = E(\pi) - w$. Substituting (25) and (24) yields:

$$Sur = \gamma \frac{\frac{1}{2}b\bar{d}}{(h_0 - 2b\bar{d})^{\alpha}} A$$

Differentiating Sur with respect to A yields

$$\frac{\partial Sur}{\partial A} = \gamma \frac{\partial \bar{d}}{\partial A} \frac{\frac{1}{2}b + \frac{\alpha b^2 \bar{d}}{h_0 - 2b\bar{d}}}{(h_0 - 2b\bar{d})^{\alpha}} A + \gamma \frac{\frac{1}{2}b\bar{d}}{(h_0 - 2b\bar{d})^{\alpha}}$$

Substituting $\frac{\partial \bar{d}}{\partial A}$ from (28) and rearranging yields

$$\frac{\partial Sur}{\partial A} = \gamma \frac{b\bar{d}(h_0 - 2b\bar{d})^{1-\alpha}}{4(h_0 - 2b\bar{d} + \alpha b\bar{d})} > 0$$

■

Proof that when s is endogenous, $\frac{\partial \bar{d}}{\partial A} < 0$. Substituting (30) in (17) yields

$$F(A, \bar{d}) = 2\gamma^2 b^2 \frac{\bar{d}^3}{\left(\frac{\alpha}{1-\alpha}\frac{2h_0 - b\bar{d}}{h_0 - 2b\bar{d}} + 2\right)(h_0 - 2b\bar{d})^{2\alpha}} A^2 = C$$

$$\frac{\partial F}{\partial \bar{d}} = 2\gamma^2 b^2 A^2 \frac{\bar{d}^2 \left[2\left(\frac{\alpha}{1-\alpha}\frac{2h_0 - b\bar{d}}{h_0 - 2b\bar{d}} + 2\right)(h_0 - 2b\bar{d})^{2\alpha}\left(1 + \frac{2b\bar{d}}{h_0 - 2b\bar{d}}\right)\right] - \frac{\alpha}{1-\alpha}\frac{3h_0 b\bar{d}^3}{(h_0 - 2b\bar{d})^{2-2\alpha}}}{\left[\left(\frac{\alpha}{1-\alpha}\frac{2h_0 - b\bar{d}}{h_0 - 2b\bar{d}} + 2\right)(h_0 - 2b\bar{d})^{2\alpha}\right]^2}$$

Thus

$$\frac{\partial F}{\partial \bar{d}} > 0$$

$$\iff$$

$$2\left(\frac{\alpha}{1-\alpha}\frac{2h_0-b\bar{d}}{h_0-2b\bar{d}}+2\right)(h_0-2b\bar{d})^{2\alpha}\left(1+\frac{2b\bar{d}}{h_0-2b\bar{d}}\right)>\frac{\alpha}{1-\alpha}\frac{3h_0b\bar{d}}{(h_0-2b\bar{d})^{2-2\alpha}}$$

$$\iff$$

$$2\left(\frac{\alpha}{1-\alpha}\frac{2h_0-b\bar{d}}{h_0-2b\bar{d}}+2\right)\frac{h_0}{h_0-2b\bar{d}}>\frac{\alpha}{1-\alpha}\frac{3h_0b\bar{d}}{(h_0-2b\bar{d})^{2}}$$

$$\iff$$

$$2\left(\frac{\alpha}{1-\alpha}\frac{2h_0-b\bar{d}}{h_0-2b\bar{d}}+2\right)(h_0-2b\bar{d})>\frac{\alpha}{1-\alpha}3b\bar{d}$$

$$\Longleftarrow$$

$$2\frac{\alpha}{1-\alpha}(2h_0-b\bar{d})>\frac{\alpha}{1-\alpha}3b\bar{d}$$

$$\iff$$

$$4h_0>5b\bar{d}$$

Which is always hold since $h_0>2b\bar{d}$. Investigating $F(A,\bar{d})$ reveals that $\frac{\partial F}{\partial A}>0$, implying that $\frac{\partial \bar{d}}{\partial A}<0$ ■

Proof that when s is endogenous, $\frac{\partial B}{\partial A} > 0$. Isolating $q(s)$ in (17) and substituting it in (21) yields

$$B = 2J\bar{d} = \underbrace{\left(\frac{4\gamma b}{C}\right)}_{V} \underbrace{\left(\frac{1}{\frac{\alpha}{1-\alpha}\frac{2h_0 - b\bar{d}}{h_0 - 2b\bar{d}} + 2}\right)}_{U(\bar{d})} \underbrace{\left(\frac{\bar{d}^2}{(h_0 - 2b\bar{d})^\alpha} A\right)}_{W(A,\bar{d})}$$

While V is constant, the denominator of U is increasing in $\bar{d}$ and since $\frac{\partial \bar{d}}{\partial A} < 0$, it decreases in A, thus, $U(\bar{d})$ is increasing in A. We next show that $\frac{\partial W}{\partial A} > 0$ yielding $\frac{\partial B}{\partial A} > 0$.

$$\frac{\partial W}{\partial A} = \left(\frac{\partial \bar{d}}{\partial A} A\right) \frac{2\bar{d}(h_0 - 2b\bar{d})^\alpha + 2\alpha b \bar{d}^2 (h_0 - 2b\bar{d})^{\alpha - 1}}{(h_0 - 2b\bar{d})^2 \alpha} + \frac{\bar{d}^2}{(h_0 - 2b\bar{d})^\alpha} > 0$$

$$\Longleftrightarrow$$

$$\left(-\frac{\partial \bar{d}}{\partial A} A\right) 2\bar{d}(h_0 - 2b\bar{d})^\alpha \left(1 + \frac{\alpha b \bar{d}}{h_0 - 2b\bar{d}}\right) < \bar{d}^2 (h_0 - 2b\bar{d})^\alpha$$

$$\Longleftrightarrow$$

$$\left(-\frac{\partial \bar{d}}{\partial A} A\right) 2 \frac{h_0 - 2b\bar{d} + \alpha b \bar{d}}{h_0 - 2b\bar{d}} < \bar{d}$$

Applying the implicit function theorem on $F(A, \bar{d})$ above yields

$$-\frac{\partial \bar{d}}{\partial A} A = \frac{\frac{\partial F}{\partial A}}{\frac{\partial F}{\partial \bar{d}}} A =$$

$$\frac{4\gamma^2 b^2 \frac{\bar{d}^3}{\left(\frac{\alpha}{1-\alpha}\frac{2h_0 - b\bar{d}}{h_0 - 2b\bar{d}} + 2\right)(h_0 - 2b\bar{d})^{2\alpha}} A^2}{2\gamma^2 b^2 A^2 \frac{\bar{d}^2 \left[2\left(\frac{\alpha}{1-\alpha}\frac{2h_0 - b\bar{d}}{h_0 - 2b\bar{d}} + 2\right)(h_0 - 2b\bar{d})^{2\alpha}\left(1 + \frac{2b\bar{d}}{h_0 - 2b\bar{d}}\right)\right] - \frac{\alpha}{1-\alpha}\frac{3h_0 b \bar{d}^3}{(h_0 - 2b\bar{d})^{2-2\alpha}}}{\left[\left(\frac{\alpha}{1-\alpha}\frac{2h_0 - b\bar{d}}{h_0 - 2b\bar{d}} + 2\right)(h_0 - 2b\bar{d})^{2\alpha}\right]^2}} =$$

$$\frac{2\bar{d}^3\left[\left(\frac{\alpha}{1-\alpha}\frac{2h_0-b\bar{d}}{h_0-2b\bar{d}}+2\right)(h_0-2b\bar{d})^{2\alpha}\right]}{\bar{d}^2\left[\left(\frac{\alpha}{1-\alpha}\frac{2h_0-b\bar{d}}{h_0-2b\bar{d}}+2\right)(h_0-2b\bar{d})^{2\alpha-1}h_0\right]-\frac{\alpha}{1-\alpha}\frac{3h_0b\bar{d}^3}{(h_0-2b\bar{d})^{2-2\alpha}}}=$$

$$\frac{2\left(\frac{\alpha}{1-\alpha}\frac{2h_0-b\bar{d}}{h_0-2b\bar{d}}+2\right)}{\left[2\left(\frac{\alpha}{1-\alpha}\frac{2h_0-b\bar{d}}{h_0-2b\bar{d}}+2\right)(h_0-2b\bar{d})^{-1}h_0\right]-\frac{\alpha}{1-\alpha}\frac{3h_0b\bar{d}}{(h_0-2b\bar{d})^2}}\bar{d}$$

Thus

$$\frac{\partial B}{\partial A}>0$$

$$\Longleftrightarrow$$

$$\frac{2\left(\frac{\alpha}{1-\alpha}\frac{2h_0-b\bar{d}}{h_0-2b\bar{d}}+2\right)(h_0-2b\bar{d}+\alpha b\bar{d})}{2\left(\frac{\alpha}{1-\alpha}\frac{2h_0-b\bar{d}}{h_0-2b\bar{d}}+2\right)h_0-\frac{\alpha}{1-\alpha}\frac{3h_0b\bar{d}}{h_0-2b\bar{d}}}\bar{d}<\bar{d}$$

$$\Longleftrightarrow$$

$$2\left(\frac{\alpha}{1-\alpha}\frac{2h_0-b\bar{d}}{h_0-2b\bar{d}}+2\right)(h_0-2b\bar{d}+\alpha b\bar{d})<2\left(\frac{\alpha}{1-\alpha}\frac{2h_0-b\bar{d}}{h_0-2b\bar{d}}+2\right)h_0-\frac{\alpha}{1-\alpha}\frac{3h_0b\bar{d}}{(h_0-2b\bar{d})}$$

$$\Longleftrightarrow$$

$$2\left(\frac{\alpha}{1-\alpha}\frac{2h_0-b\bar{d}}{h_0-2b\bar{d}}+2\right)(-2b\bar{d}(2-\alpha))<-\frac{\alpha}{1-\alpha}\frac{3h_0b\bar{d}}{(h_0-2b\bar{d})}$$

$$\Longleftrightarrow$$

$$2(2-\alpha)\left(\frac{\alpha}{1-\alpha}\frac{2h_0-b\bar{d}}{h_0-2b\bar{d}}+2\right)>\frac{\alpha}{1-\alpha}\frac{3h_0}{(h_0-2b\bar{d})}$$

$$\Longleftarrow$$

$$2(2-\alpha)\frac{\alpha}{1-\alpha}\frac{2h_0-b\bar{d}}{h_0-2b\bar{d}}>\frac{\alpha}{1-\alpha}\frac{3h_0}{(h_0-2b\bar{d})}$$

$$\Longleftrightarrow$$

$$2(2-\alpha)(2h_0-b\bar{d})>3h_0$$

$$\Longleftarrow$$

$$2(2h_0-b\bar{d})>3h_0$$

$$\Longleftrightarrow$$

$$h_0>2b\bar{d}$$

Which always holds ■

Proof that when s is endogenous, $\frac{\partial r}{\partial A} > 0$. Using Corollary (2), (15) can be rewritten as:

$$r = \underbrace{(\gamma b)}_{X} \underbrace{\left(\frac{\bar{d}A}{(h_0 - 2b\bar{d}_j)^{\alpha}} \right)}_{Z(A,\bar{d})}$$

Notice that while X is constant, $Z = \frac{W(A,\bar{d})}{\bar{d}}$. Since $\frac{\partial W}{\partial A} > 0$ and $\frac{\partial \bar{d}}{\partial A} < 0 \implies \frac{\partial r}{\partial A} > 0$.
■