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Impact of Labor Shortage on Employer Search Strategies: a Theoretical Model

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Master in Economics

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BUSINESS SCHOOL

CIÊNCIAS SOCIAIS E HUMANAS

Department of Economics/ Department of Political Economy

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Resumo

A escassez de mão-de-obra é uma questão importante na maioria dos países, para empresas e planeadores sociais, e tem sido pouco estudada relativamente à sua importância. Neste artigo, o autor cria um quadro teórico para estudar o efeito da escassez na perspectiva do empregador. O artigo centra-se no seu impacto na estratégia de procura de empresas, considerando a perspectiva de dicotomia extensiva/intensiva. O artigo investiga o impacto da escassez de mão-de-obra na estratégia de pesquisa do empregador, de acordo com a força da escassez. Para tal, o documento desenvolve uma versão modificada do modelo criado por Barron, Berger & Black (1997). Os resultados teóricos dão uma visão clara da relação entre a força da escassez de mão-de-obra, o lucro e o investimento em estratégias de procura. O artigo tem três conclusões principais. Primeiro, se a empresa tiver de se cingir à sua estratégia original, então, ao enfrentar uma escassez, deverá diminuir o investimento se for um investimento extensivo, qualquer que seja a força da escassez. Contudo, se investir numa estratégia intensiva, então, a empresa deve aumentar o seu investimento se a escassez for suficientemente forte. Em segundo lugar, quanto menos recursos a empresa tiver, mais rentável será a procura intensiva. Finalmente, o estudo mostra o impacto da escassez de mão-de-obra na estratégia de busca de um empregador, aumentando a importância da busca extensiva. Uma das principais implicações deste estudo é que poderá ser possível identificar a escassez de mão-de-obra através da evolução do investimento do empregador na estratégia de busca.

Palavras-chave: Escassez de mão de obra, Economia do trabalho, Procura sequencial, Estratégias de procura, Comportamento da empresa

Classificação: D21, J01

Abstract

Labor shortage is an important issue in most countries, for both firms and the social planner, which has been understudied relatively to its importance. In this paper the author creates a theoretical framework to study the effect of such a shortage from the employer perspective. The paper focuses on the impact a shortage may have on the firm search strategy by considering the extensive/intensive dichotomy perspective. The paper investigates how labor shortage impacts the employer search strategy according to the shortage strength. To do so, the paper develops a modified version of the model created by Barron, Berger & Black (1997). The theoretical results give clear insights on the relation between labor shortage strength, profit and investment in search strategies. The paper has three main findings. First, if the firm has to stick to its original strategy, then, when facing a shortage, it should decrease the investment if it is an extensive one whatever the strength of the shortage is. However, if it invests on an intensive strategy, then, the firm should increase its investment if the shortage is enough strong. Second, the fewer the firm has resources, the more rentable the intensive search is. Finally, the study shows labor shortage impact on the search strategy of an employer by increasing the importance of extensive search for the firm. One of the main implications of this study is that it may be possible to identify labor shortage via the evolution of employer's investment in search strategy.

Keywords: Labor Shortage, Labor Economics, Sequential Search, Search Strategies, Firm Behaviour

Classification: D21, J01

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I - Introduction

Nowadays, labor shortages are an important issue and a global problem. Indeed, whether it is in the US, in Australia, in Nigeria or in Malaysia, labor shortage cases have been reported all around the world by medias. Moreover, it is not specific to educated positions, for instance, such cases have been reported for cheesemakers in France, for construction specialists in Nigeria, for plumbers in the US and so on. However, despite its importance on the news, economists have been reluctant to study the subject, letting it to business scientists or only treating some very specific markets. As of today, the related literature is still relatively light, concentrated on some specific industries (nursing, specialized teacher, construction industry) and countries (US, South Africa, Australia) and we still know little about its impact on firm behaviour.

In order to start reducing this gap, we have chosen to theorize the effect of labor shortage on firm behaviour by focusing on where this phenomenon should show its first effects: recruitment. In order to do so, we have developed a specific model inspired by Barron, Berger, & Black (1997) which focuses on estimating the change in intensive and extensive search according to the extent of a shortage. Basically we have tried to answer the following research question:

How does labor shortage impact employer search strategy?

By doing a theoritical analysis of the model, we found that firms should increase their demand for extensive search when the shortage is increasing and we theorize some clear relations between labor shortage, profit and investment in firm search strategy.

This paper is organized as following: first we will review some literature related to labor shortage and search-matching model (section II), then we will review the

basic model (section III) before adapting it to a most comprehensible situation from which we will deduct our findings (section IV) then we will conclude by summarizing these work's limitations, contributions and what may further studies focus on (section V).

II -Review of literature

On this section we will provide you some academic background on the subject that will be treated during this thesis and explain you the development of these fields. In order to do so, we will divide this section in two parts. First, we will discuss the academic literature about labor shortage, then, on the second part, we will review some studies and authors that have been writing and researching about the search and matching theory.

The Labor Shortage

Due to the long history of research on this subject[1], it exists a large lexical field related to the concept of labor shortage, consequently it can be very difficult to talk about this term without being confused. In order to avoid such a confusion, we will use a slightly modified version of the definition used by Barnow, Trutko, & Piatak (2013) [2] and define a labor shortage in the economic sense as « A market disequilibrium between supply and demand in which the quantity of workers with a certain level of skill demanded exceeds the supply available and willing to work at a particular wage and working conditions at a particular place and point in time ». With this definition the term « level of skill » means « any characteristics that the employer is looking for ». So, the definition includes broader characteristics than only degree or experience, in order to be more coherent with the findings about the importance of soft skills on labor shortage (Cappelli, 2015). Indeed, he found, by

[1] Indeed, we can find papers discussing problematics related to «Labor shortage » or «skilled labor shortage» since the begin of the XXth century like Davis (1926) or Cresswell (1937)

[2] Their original definition is « A market disequilibrium between supply and demand in which the quantity of workers demanded exceeds the supply available and willing to work at a particular wage and working conditions at a particular place and point in time » and was apparently provided by the U.S. Department of Labor in a Request for Proposals (RFP) which was similar to the one used by Franke, Walter and Sobel (1970)

reviewing existing literature, that the most often shortfalls are associated with soft skills[3]. So, this understanding of the labor shortage is closer to what Arrow & Capron (1959) designed as a "social demand shortage"[4]. It is also possible to use the term of "skill shortage" to define this problem if you consider the definition used by Healy, Mavromaras, & Sloane (2012) according to whom, it is a situation where there is "insufficient supply of appropriately qualified workers available or willing to work under existing market conditions"[5]. Moreover, this definition rejects the vision of a two-dimensions labor shortage, by ignoring a possible aggregate or global labor shortage but since this dimension has never be proved empirically we can consider it as non-pertinent (Mishel & Teixeira, 1991)[6] and so we will only consider the other dimension. In other words, a labor shortage, in our definition, is specific to a firm and never global. In this paper we will consider skilled labor shortage and labor shortage to have the same meaning and we will also consider that a labor market where there is some depletion in the worker supply is in the path to shortage.

[3] Cappelli (2015) showed it by referencing to some examples on the literature (Cappelli, 1995; Business Roundtable, 2009; Wolf, Aspin, Waite and Ananiadou (2010)), who basically found that, according to the recruiters, the problem is more about attitude than hard skills and like a study of Career Advisory Board (2011) showed, there is only communication that is related to study. When the surveys are made by asking to high-level executives instead of recruiters, the results may change due to a lack of comprehension of the recruitment issues or / and to other incentives

[4] Arrow and Capron (1959) defined a social demand shortage as the following problem: « In particular, careful reading of such statements indicates that the speakers have in effect been saying: There are not as many engineers and scientists as this nation should have in order to do all the things that need doing such as maintaining our rapid rate of technological progress, raising our standard of living, keeping us militarily strong, etc. In other words, they are saying that (in the economic sense) demand for technically skilled manpower ought to be greater than it is - it is really a shortage of demand for scientists and engineers that concerns them. »(p. 307). In other words, it is a situation where there is less supply that we would like to have but the market can still find an equilibrium.

[5] This definition was used in order to do the survey by the Australian Bureau of Statistics in order to create the dataset "Business Longitudinal Database" or BLD

[6] In their work, Mishel and Teixeira defines the conventional vision of labor shortage as « a shortage with two dimensions. The first dimension will be an aggregate labor shortage, due to a slow-growing labor force. The second dimension of this labor shortage will be a specific shortage of workers with adequate levels of skill and education » before proving that the first dimension is not likely to happen

Table 1 Cause of Labor Shortage

Increase in the labor demand	Increase in the demand of good or services produced thanks to this kind of occupations. Increase in the prices of substitute factors of production.
Decrease in labor supply	Decrease in the size of the population that works in the relevant positions, others activities has become more attractive , restrictions on entry into this specific labor market has increased
Restrictions on Prices	Change on the wages for a certain kind of occupation according to a regulation or change on the prices of products and services for labor-intensive industries

Barnow, Trutko & Piatak (2013) also gives an overview of the current academic consensus on the subject. They listed the labor shortage's causes (table 1), consequences, the factors that impact their length (table 2) and the responses that a firm could implement in order to fight the shortage (table 3). According to them, the consequences of a shortage are difficult to trace since it can be indirect consequences (negative externalities for instance) and it will depend on the industry but it should always decrease the aggregate production for a nation. It can be due to a decrease in supply, increase in demand or restriction on prices and the duration of this shortage depends on the reaction and response time of employer or/and workers, restrictions on occupational entry or the evolution of labor demand. These authors also found nine possible actions that firm can use in order to solve the shortage they are facing. However, all these actions are not likely to be taken, as an example, in the US while 20% of the executives know that they could solve the shortage by increasing wage, only 5% of the executives reported that they are willing do it (Manpower Group, 2014). By analyzing and simplifying the effects of these actions, it is possible to redefine these actions in three non-exclusive categories: increase of the labor cost[7], decrease of the product's quality or reduce the labor need (see table 3 to see the split). As said previously, these categories are non-exclusive, for instance, an action

[7] The labor cost refers to the labor cost of producing one unit of extra goods or service, for instance in the case of a teacher, the cost of one hour of class

may increase the labor cost while it decreases the product quality like it is likely to happen by using overtime work[8].

Employer	Slow reaction time	Employer may be not aware of the shortage or its magnitude, can be impacted by the lack of knowledge of the specific labor market (minimum wages, …), typical period for filling vacancies for that occupation,…
	Slow response time	Response may be risky, expensive or both to implement
Workers	Slow reaction time	Worker may be unaware of the excess demand on this particular market or recruiting effort. Plus, workers may be refractive about leaving their current employer/occupation/industry
	Slow response time	Mainly due to time of training in order to become qualified for the opportunity, but may also be due to insufficient incentives or training capacities.
Institution	Restrictions on Occupationnal entry	Regulator may have implemented a numerus clausus (limitation of enrolment capacity in a training institutions), licensing/certification requirements (so employer cannot lower the perquisites), restrictions on immigration, …
Market	Continuous increase in labor demand	Scenario of Arrow-Capron model (1959); a sustained rapid growth for a particular type of workers may impeach the market to get back into an equilibrium for a long period of time

Table 2 Factor of shortage strength

[8] Overtime increase the cost of labor since doing overtime is rewarded with a higher hourly wage while the productivity may decrease (Hanna, Taylor, & Sullivan, 2005), about the effects of overtime on work quality, there are plenty of studies showing the negative impact of overwork in products quality either directly or indirectly (by increasing stress, reducing sleep quality and so on) like (Akula & Cusick, 2008; Griffiths et al., 2014; Oliva & Sterman, 2001)

Table 3 Employer response to shortage

Response by employer	Explanation/factor	Effect/Categorisation
Increase recruiting efforts	Increasing short-term costs by implementing or developing some approaches (increase advertising, expand the recruiting area, co-optation, employment agencies,…)	Increase cost
Increase use of overtime	Increasing the number of overtime hours worked by the current employees, but the salary for an hour of work will be higher and the employee might be less productive	Increase cost Decrease quality
Substitute capital for labor	Using machinery and equipment in order to reduce the need of human resources	Reduce work need
Improve working condition	"working conditions include factors such as hours worked, upgrades in equipment and facilities used by workers, level and type of supervision, involvement in operation of the firm, training to deal with stress related to the job and recognition of the importance of workers in the occupation"	Increase cost
Train workers for the jobs	Training the new workers	Increase cost May reduce the quality (on the short term at least)
Offer bonuses to new employees	Using signing bonuses	Increase cost
Contract out the work	Paying another company to do the work that the employee should have	Increase cost or reduce quality

		(Does not reduce the work need)
Turn down work	Reducing the production	Reduce work need
Reduce minimum qualifications for the job	Reducing the minimum hiring prerequisites like experience or diploma	Reduce quality
Restructure work to use current or new employees in other occupations	Reassigning some duties, decompose complex jobs into simpler tasks	None, we don't consider that as an option since it can be used only in very specific situation

In order to confront the economic theory to reality, Barnow, Trutko & Piatak present four study cases about pharmacists, nurses, physical therapists and specialized educators. All these studies were held in the US, so their results may not hold in other contexts. However, from these cases, the authors made three conclusions. First, assessing and measuring a labor shortage is difficult for different reasons: the lack of databases on the subject (there is no databases large enough about job vacancies), and even if there were enough data assessing it is difficult (a tight labor market and a shortage are alike in terms of vacancies), these data may not correspond do the reality (the definitions of the occupations used by the institutions differ from the one used by firms) and finally, some agents have incentives to exaggerate or minimize the state of the market[9]. Second, they did not find any strong evidence of labor shortage using the economic definition (see note 3), instead, it was more a "social demand shortage" (see note 5). Consequently, it is important to go beyond the economic concept and consider the social shortage for policy purposes. Third, some occupations have seen their educational standards increased while they have tight market (pharmacy, physical therapist and nurse for instance). This fact is rather surprising since it may decrease the labor supply (people

[9] It has already be proven that some employers or lobbies exaggerate the tightness of the market, especially on the STEM domains in order to import some foreign cheap labor (Cappelli, 2015; Waterhouse, 2013). On the other hands, labor union may do the opposite and minimize it according to (Trutko et al., 2015)

being discouraged by the extended preparation) and it will delay the possible market adjustment.

However, the case studies used by Barnow et al., were only based on the US context and focused on (very) qualified occupations that are either service of public importance (nurse for instance) or publicly supported services (specialized teacher for example). Moreover, all these occupations presented institutional barriers or requirements[10]. Hopefully, it exists some studies that have been conducted on different conditions. Indeed, there is a large literature about labor shortage in the construction sector, mainly in developing countries such as Malaysia, Nigeria or South Africa (Bilau & Sholanke, 2015; Mateus, Allen-Ile, & Iwu, 2014; Mohd-Rahim et al., 2016; Oseghale, Abiola-Falemu, & Oseghale G E, 2015; Utting, 2010; Zaki, Mohamed, & Yusof, 2010) but also in developed countries or economies such as New Zealand, Australia or Hong Kong (Ho, 2016; Lobo & Wilkinson, 2008; Watson, 2012). Also, studies have been conducted on other unqualified sectors like hospitality in Australia (Davidson & Wang, 2011). These studies do not always use the basic economic sense of labor shortage, since a lot of them are not made by economist but more by specialists in business studies (e.g. human resources, management). However, since we do not use the basic economic understanding of the shortage either, it is not an issue. The existence of these studies confirm the possibility of shortage for occupations that does not require any specific or difficult qualification but requires skills and so the possibility of an unqualified skilled labor shortage. This fact is important since it is often assumed that almost anyone can do a work that does not require a formal education, for instance, in the construction industry, while for a job like nurse require specific education is required. A factor explaining this kind of shortage is the existence of the 3D opinion about some occupations like the construction related ones, 3D standing for “dirty, difficult and dangerous” (Mohd-Rahim et al., 2016).

[10] Nurses need to have a specific degree, Pharamacists a license, Physical therapists also need a license to practice on the US and specialized teachers are supposed to be highly qualified with at least a bachelor degree and related experience (Boe, 2006)

However, we can see that there is a huge lack on the research about labor shortage. For instance, the labor shortage problems from the employer perspectives have been understudied (the most often it is either from the social planner perspectives or the worker one). Similarly, very few works have focused on a microeconomics or industrial organization vision of the phenomena. We can also observe that there is an absence of academic interest for the shortage problematic in some geographic areas. For instance, among the European Union, there is no recent studies on the subject. The most recent ones are focusing on the UK during the 80's, while we know that there are shortages in European countries. It is especially visible in some unqualified sectors if we base ourselves on the national data of employment agencies or on the European agencies report (Cedefop, 2016a, 2016b; Mourshed, Patel, & Suder, 2014; Pole Emploi, 2017)[11]. An explanation of this phenomena might be that we can see an issue about visa policy and immigration on the industrialized countries that are usually studied (the U.S., Australia and New Zealand are reputed to have very important and regular debate about immigration policy, visa reform, …). Meanwhile, in the European Union the question of visa policy is way less important due to the Schengen area and to the origin of the immigration[12].

Here our objective will be to develop a theoretical framework to model a labor shortage effect from the firm perspective, in order to assess the theoretical effect of

[11] However, it is interesting to notice that sectors suffering from a shortage change according to the source: according to European Institutions and for France, the shortage professions are Finance Professional, Legal professional, Engineers and health professionals (i.e. highly qualified professionals), while according to the work of the French national public job agency (Pôle Emploi), these sectors are way less glamourous: butchers, electricity professional, mechanics, … An explanation to this dichotomy may be that the studies of the European agencies are based on the one of the national agencies and consequently they go less in-depth than the national one. Also, there is an issue about the classification of these jobs: for statistical agency Engineering is one profession just as butcher, while we know that there is a huge diversity in engineering (for instance agronomical engineering and informatics engineering has nothing to see), while it is not the case for butcher. Consequently, the number reported for engineering needs are higher since they regroup more professions and give very little hint about the shortage.

[12] For example, lots of data used for the work on shortage in the US are provided by the US bureau of labor statistics and have for first use to determine the quotas of immigrate workers according to their professions.

labor shortage according to the industry and firm specificities. But, to do so it is important to introduce, first, some search economics theory features.

Search and matching theory

Search and matching models are far from being new, one of the first one to conceptualise it was G. J. Stigler in "the Economics of Information" (1961). So, search and matching models are a part of the Information Economics, and even a main stream of it given the importance of the authors specialised on the subject. For instance, three of the most famous economists specialised on search model are the 2010's Nobel prize winners C. Pissarides, D. Mortensen and P. Diamond. These models are used in different fields of the economic science either macroeconomics oriented or microeconomics oriented: Industrial Organisation (IO), policy decisions, Consumer theory and mostly Labor Economics. This section will focus on selected microeconomics and labor economics related literature.

Since Stigler (1961), job matching and on industrial organisation behaviour in labor markets (i..e. employer behaviour) have been well studied through a large literature for both sides of the "equation" (i.e. job supplier, employer, and job demander, worker). However, since these studies were more focused on the job-seeker side, we know way less about employer search strategies than we do about worker search behaviour[13]. About this phenomena Granovetter (1995) even said that ''While people are finding jobs, employers are finding people to fill them, and their behaviours, strategies, and purposes play a central but often neglected role in the

[13] A reason that could explain that fact may be that job seekers have been the first part of the equation studied. It's only later that economists started to be interested by the other side of the equation (i.e. the employers) via the search matchings model that have followed the works done by C. Pissarides, Diamond and Mortensen and their famous DMP framework (Diamond, 1982; Mortensen, 1982; Pissarides, 1985)(for which they have been awarded with a Nobel prize). Then, it just became more popular and more studied, for instance we can talk about the numerous works done by J. M. Barron and other authors on the subject (Barron et al., 1997; Barron, Bishop, & Dunkelberg, 2008; Barron, Black, & Loewenstein, 1987; BARRON & BISHOP, 1985; Brenčič, 2010; Rosén, 2003; Sicilian, 1995; Welters & Muysken, 2006)

process of matching people to jobs.". However, over the past two decades the gap between these two sides seems to reduce as can prove the numerous studies focusing on employer behaviour.

On the large existing amount of studies that are constituting the search and matching economics, we may differentiate some specific concerns to this field of study. One of the first matter (and of the most famous) has been introduced by Rees (1966). It concerns the distinction between formal and informal recruitment channel and methods. Indeed, we may differentiate these two kind of methods since they imply also different characteristics, but first let's explain what are they. The formal methods are the most classical ones: advertisement, newspaper announce, use of jobs agencies (either publicly owned or privately). On the other side, the informal methods regroup all the possible "networking" methods: co-optation, word to mouth advertisement, ask to employee for references, … On his studies (1961), (Rees & Shultz, 1970), Rees has shown the importance of the informal channel in the Chicago area for both white collar and blue collar. He also started to discuss extensive and intensive jobs information search strategies[14] by defining extensive information as the one related to the number of job seekers and vacancies covered by the information, while intensive information will provide more detailed information about job seekers, vacancies, their complementarity, … Consequently, some strategies are more related to extensive search since they are generating or increasing the flow of applicants (e.g. online job offer, Linkedin use) with a more limited amount of individual and reliable information about workers, these methods tend to be the formal ones. At the opposite, we have informal information channels that are providing deeper individual information but about a fewer number of applicants. On his paper, Rees explained that the informal methods since they are generating more intensive information for both sides lead to better employment matches. His hypothesis have been supported by a large number of empirical works proving that turnover are reduced and productivity tend to be higher when firms are relying on informal methods and consequently on intensive search (Brenčič, 2010;

[14] We will refer to them simply as intensive or extensive search strategies during this thesis.

DeVaro & Fields, 2005; J. C. va. Ours & Ridder, 1993; Ridder, 1992; J. van Ours & Ridder, 1991).

DeVaro (2005) has deepened these works by investigating the link between the characteristics of these recruitment methods or channels and the outcomes of the hirings resulting from their uses. For example, about the relation between vacancy duration and high quality applicant, he is explaining that "Methods that are slower but yield a higher quality applicant pool imply longer vacancy durations and more opportunities for the employer to increase the posted wage offers as the recruitment campaign progresses." He is also proving the existence of differences in recruitment behaviour according to the sector of firm. For instance, non-profit sector tends to search more intensively (i.e. longer recruiting campaign, more interviews, …) than for profit sector. It may be explained by the values of the sector and that the work is more ideological (i.e. the match specificity productivity function may be more important for this sector).

Another important question related to the search behaviour concerns the sequentiality or the non sequentiality of these searches. The most often we assume that firms are searching on sequential way (Mortensen, 2003), in other words (and by citing Van Ommeren & Russo, 2009) "firm screens each applicant immediately upon arrival, offers a job to the applicant when the productivity of the job applicant exceeds a certain threshold (the reservation productivity) and discontinues the search process if the job offer is accepted". On another hand, a non-sequential search is any way of searching that is different from the sequential one, in theory, firms will have a pool of applicants, screen them and offer a position to the most suitable one.

We can see that the basic theory of search economics theory is very dichotomistic, with, respectively, sequential search, informal search and intensive search on a side and non-sequential, formal and extensive search on the other side. We can also see that these ways of searching often imply each other: for instance, informal search is related to intensive search, while non-sequential is related to extensive search and so on. Also as Van Ommeren & Russo (2009) have shown that

some of these features are exclusive like formal search and sequential search (at least advertisement and employment agencies) and firms usually rely on the two possible searches when they can (extensive and intensive, sequential and non-sequential, formal and informal). Here one of our objectives will be to determine theoretically how does a shortage of a labor impact the firm dichotomist search strategy between the intensive and the extensive.

III - Model

Over the following section, the background of the model used on this paper will be shortly detailed. Idea is to introduce you the key concepts and rationale behind this model. The model used here is based on the one created and used by J. M. Barron, M. C. Berger, & D. A. Black in their paper "employer search, training, and vacancy duration" (1997).

In their paper, they have built a model of optimal employer search strategy (a combination of intensive or/and extensive search) with endogenous match quality information and assuming that employer only engages in sequential search. They have tested it with different data sets in order to prove the existence of a systematic variation on the employer search strategies based on the specificities of the jobs and on the characteristics of the people who applied for the jobs, and these specificities and characteristics also affects the duration of a job vacancy[15].
In this paper, only one firm is considered and the model works as following:

- The firm starts to look for hiring someone with a minimum productivity level p_r in a sector where the applicant pool is shrinking at a constant rate.
    - There is a probability α_t that an applicant reaches out to the firm during occurrence *t* (occurrence being the number of time the model is played). This probability will be determined by the wage offered by the firm (w) and its advertisement/recruitment effort (r). There are diminishing returns for increasing investment in *w* and *r*. Then $1/\alpha_t$ notes the expected number of periods before between applicants (a period being a certain amount of time), represented as o_t .
    - Having this vacancy unfilled has a cost *c* per period.

[15] On their paper J. M. Barron, M. C. Berger, & D. A. Black (1997) have shown that for jobs requiring higher formal education and, or training employer will search more extensively (on their paper, they meant that they will see more applicants per offer, see next note) and will result if ceteris paribus, in higher vacancy rate.

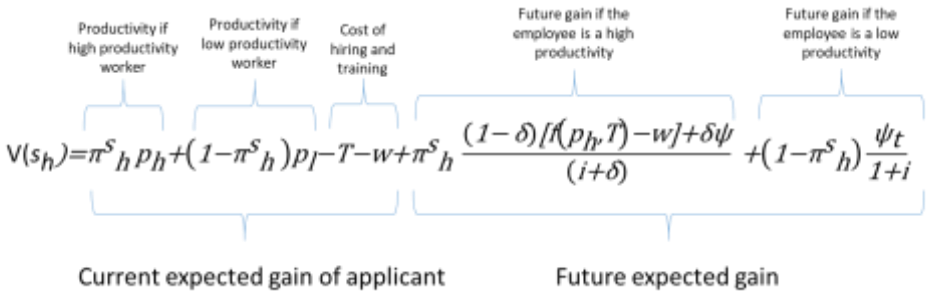
- After o_t periods the firm receives an application that will be evaluated before obtaining a signal *s* about the applicant productivity. The reliability of the signal is determined by the interview and screening expenses *I*. The firm will hire him if the applicant has a signal equal or superior to minimum signal level s_r.
    - If the applicant is hired, he will go undertraining for one period for a cost T before revealing his actual productivity. The productivity after one period of training is noted as f(p,T)
    - If no hiring the model starts over except if expected gains are equal or lower than zero.
- The applicant reveals its productivity. If its productivity is higher or equal to p_r then the firm retain him. If not, he is fired.
    - If the expected gains for firing him and start looking for a new employee ψ_t is equal or lower than 0 then the model stops, otherwise it restarts. ψ_t is strictly decreasing over time.
- And the model keeps going until either an applicant has a sufficient signal and productivity or expected gains for new applicant are negative or equal to 0.

The model can be simplified by assuming a Bernoulli distribution for productivity, with two levels of productivity, low and high (respectively, p_l and p_h), with $p_l > p_r > p_h$. Same logic applies to the signal with two levels, high and low, with $s_l > s_r > s_h$. To simplify we can consider $p_l = 0$. Let $\pi_{h,t}$ denotes the probability of having a high productivity applicant during an occurrence *t*, $\pi_{h,t}$ is strictly decreasing over time and tends to zero. Let $\pi^s_{h,t}$ be the probability that an applicant with signal *s* is a high productivity worker during a period *t*, $\pi^s_{h,t}$ is dependent on the interview and screening expenses *I* and on $\pi_{h,t}$, such as $\lim_{I \to \infty} \pi^s_{h,t}(I) = 1$ and $\lim_{\pi_{h,t} \to 1} \pi^s_{h,t}(\pi_{h,t}) = 1$.

Two main changes have been made in comparison to the original model. First, in our model α depends on occurrence (*t*), wage (*w*) and recruiting effort (*r*) when in their model it does not and we use the expression o_t to denote $1/\alpha_t$. Second, in their model, they have constant exit rate (δ) from the labor force of the trained workers, here an increase of this phenomenon over time is assumed and is included in the calculation of $\pi_{h,t}$. These two changes enable us to include a labor shortage in

their model, where skilled labor becomes scarcer over time at increasing rate, and the possibility for the firm to fight this shortage.

These changes result on changing the expected value of an applicant with signal *s*, from



(1)

To

$$V_t(s_h)=\pi^s{}_{h,t}(I)\; p_h+\left(1-\pi^s{}_{h,t}(I)\right)p_l\text{-}T\text{-}w+\pi^s{}_{h,t}(I)\frac{f(p_h,T)\text{-}w}{(1+i)}+\left(1-\pi^s{}_{h,t}(I)\right)\frac{\psi_t}{1+i}$$
$$=\pi^s{}_{h,t}(I)\; p_h-T-w+\pi^s{}_{h,t}(I)\frac{f(p_h,T)-w}{(1+i)}+(1-\pi^s{}_{h,t}(I))\frac{\psi_t}{1+i} \quad (2)$$

With

$$\psi=\underbrace{-\frac{(1+i)(r+c)+\alpha\, I}{i+\alpha}}_{\text{Cost for seeking a new applicant}}+\underbrace{\frac{\alpha}{i+\alpha}\left[\psi\int_{-\infty}^{s_r}dH(s)+\int_{s_r}^{\infty}V(s)dH(s)\right]}_{\text{Expected gain from keep seeking for a new applicant}} \quad (3)$$

To

$$\psi_t[w,I,r]=-\frac{o_{t+1}[w,r](r+c)(1+i)^{o_{t+1}[w,r]}+I)}{1+i}$$
$$+V_{t+1}[s_h]\,(1+i)^{o_{t+1}[w,r]} \quad (4)$$

The firm will try to optimize its profit (*Π*) by changing the wage it offers, its recruitment effort and its interview and screening costs, while the model will run until $\psi_t \leq 0$. To avoid a long and unintuitive backward induction model, it will be assumed that $\psi_2 = 0$, i.e after the second applicant the cost of looking for third

applicant will be higher than the expected gain from receiving his application. So, the problem can be expressed as:

$$\max \Pi(w, I, r) = V_1[s](1+i)^{o_1[w]} - o_1[w, r](r+c)(1+i)^{o_1[w,r]} + I) \quad (5)$$

$$V_1(s_h) = \pi^s{}_{h,1}(I)\, p_h - T - w + \pi^s{}_{h,1}(I)\frac{f(p_h, T) - w}{(1+i)} + (1 - \pi^s{}_{h,t}(I))\frac{\psi_t}{1+i} \quad (6)$$

$$\psi_1[w, I, r] = -\frac{o_2[w, r](r+c)(1+i)^{o_2[w,r]} + I)}{1+i} + V_2[s_h](1+i)^{o_2[w,r]} \quad (7)$$

$$V_2[s_h] = \pi^s{}_{h,2}(I)\, p_h - T - w + \pi^s{}_{h,2}(I)\frac{f(p_h, T) - w}{(1+i)} \quad (8)$$

Now that the model has been explained, it is important to analyse its outcome. Since the aim is to see the impact of a labor shortage according to its strengths and to its specificities, different cases with different sets of parameters will be simulated to show how the firm is reacting. These parameters will be explained and detailed later on. In order to avoid long unintuitive equation and to gain in intelligibility and in comprehension, these results will be mainly presented via different graphs. All the results have been computed via the software of mathematical calculus Wolfram Mathematica (version 11. 2) and the graphics that will be used in order to illustrate the results have also been drowned by this software. First the impact of a skill labor shortage in the case where the firm A choose to use pure search strategy will be considered, so either extensive one by modifying *w* and *r* (and so $\propto$ (w, r)) or intensive one by changing its interview and screening cost *I*. Then the other pure search strategy will be considered, and some conclusions will be drowned from these two situations.

IV - Analysis

Basic equilibrium without skill labor shortage

In order to reach a stable equilibrium, the model shall need reshaping. However, for more simplicity, the game will start at a period where the firm was already at the equilibrium (i.e. it is maximising its profit) but just lost an employee. We will refer to this situation as the equilibrium. This equilibrium happens in normal conditions, i.e. there is no scarcity in the labor market, the worker flows is constant and abundant. The firm has reached a level P*(w, p, T) of production which is maximizing its profit according to the wage and worker's productivity. This level P* is fixed (and so are *w*, *T* and *p*) and will not evolve on the short run even if there are changes on the market like a supply skill labor shortage[16]. This production level also includes the discounted future productivity of the trained worker and costs directly related to the workers such as the wage *w* or the training cost *T*. On this equilibrium, there is an abundance of workers so $\propto$ (w, r)=1 and the firm takes the applicant with the best signal who has a chance π_t to belong to the high productivity category of worker. So basically π_t is the equivalent of π_h^s for a period *t* since the employer is taking the employee with the highest signal. This $\propto$, due to this abundance of application is nowadays representative of the arrival rate. With $\propto = 1$, there is at least one candidate with an acceptable signal every period (and the firm is doing its choice between the high signal applicants). On another hand, $\propto = 0$ will

[16] We are assuming wage stickiness (there are strong evidences of such a phenomena see for example R. E. Hall, 2005; or/and A. M. Sbordone, 2002 for either wages and prices stickiness): worker does not realize, yet, that there is a shortage, only employer realize it and consequently wage will not evolve so the combination of *w** and *p** that are maximizing profit are not evolving. Moreover, the firm will not start to hire people for a higher *w* if it trusts the shortage to betemporary since if they do former worker may also require an increase of their salary. Similarly, they will try to not lower their quality criteria yet, some evidences have shown that firm does not lower their quality standard, even if case of shortage, for regular workers, however they may hire temporary worker with lower productivity, education or signal.

signify a total shortage of candidate with a decent signal (and the firm will need to lower its reservation productivity signal, but this case will not be covered here). Since there is no shortage, $\propto (w, r) = 1$ at the equilibrium, then the expected vacancy duration o(w, r) is also equal to one. Periods are short such as $i \approx 0$[17], however the vacancy cost c will still be present. Interview and screening costs I will also be redefined as a function $I(j) = Ij$ where $j \epsilon [1; \infty]$ and will represent the effort or the complexity of the screening process and I may be associated as a unit cost. The same logic will be applied to the recruitment cost $r(k) = rk$ where $k \epsilon [1; \infty]$ and will represent the effort of the firm and its investment on the recruitment and/ or advertisement process and r may be associated as a unit cost. To these two search costs are associated to the vacancy cost c for the second period[18]. So, it is now possible to model this equilibrium as the following equation for the expected profit:

$$\Pi = \pi_1 P^*(w, p_h, T) + (1 - \pi_1)(\pi_2 P^*(w, p_h, T) - (Ij + C + rk)) - (Ij + rk) \quad (9)$$

With an implicit first order conditions implying that expected profit for rejecting a second candidate is zero:

$$\pi_3 P^*(w, p_h, T) - (Ij + c + rk) \leq 0 \quad (10)$$

It is assumed that the probability of π_t, which denotes, the probability that the worker with the highest signal of the pool of applicants, is indeed a high productivity worker during a certain occurrence t, will be given by the following equation:

$$\pi_t = \alpha_t (w, k)\, \pi_h - \varepsilon (j) \quad (11)$$

Where π_h is the original proportion of high productivity workers among the applicants, $\alpha_t (w, r)\, \pi_h$ denotes its evolution over time and $\varepsilon (j)$ represents the misjudgement, the error in the interpretation of a signal, the probability that a bad

[17] We consider that a firm will just not discount future value for a short period of time, instead we consider that this firm will just consider this opportunity cost (since the discount of future value represent an opportunity cost) as a non definite part of the vacancy cost c.

[18] The reason behind why the cost only exists for the second period is rather logical, it is due that we are considering this cost is representing the cost this vacancy between the two period, so the cost of having wait an extra period to get an employee. If we were putting it in first period, it will be a bit weird since it is not sure to occur (it only occurs if the firm fail to find a good worker in first period) and there will be a second vacancy cost on period two, which will be the opportunity cost for not hiring at all, here we are not considering this possibility as a cost.

productivity worker will have a high signal[19], with $\varepsilon(j) \in]0 ; \alpha_t(w, k)\, \pi_h[$. In order to represent it, *j* may be considered as the number of persons who will interview the worker and then the interview cost *I* may represent the cost that these employees will charge to the firm per interview. Meanwhile, $\alpha_t(w, k)$ is defined by the equation (12), since it is assumed that wages *w* are very sticky and consequently constant, it will not be used to define α_t which will be defined as $\alpha_t(w, .) = \alpha_t$.

$$\varepsilon(j) = \varepsilon^j \tag{12}$$

$$\pi_t \leq \varepsilon + \pi_t \leq 1 \; \forall \varepsilon \tag{13}$$

$$\alpha_t(w, k) = \alpha^{t/k} \tag{14}$$

$$\pi_t(j, k) = \alpha^{t/k}\, \pi_h - \varepsilon^j \tag{15}$$

So the profit is equal to:

$$\Pi = (\alpha^{1/k}\, \pi_h - \varepsilon^j) P^*(w, p_h, T) + (1 - (\alpha^{1/k}\, \pi_h - \varepsilon^j))\, (\alpha^{2/k}\, \pi_h - \varepsilon^j)\, P^*(w, p_h, T) - (Ij + C + rk) - (Ij + rk) \tag{16}$$

Now that the equilibrium and all its sub-parts have been described, it is possible to start analysing it.

Proposition 1: *Starting in an equilibrium with abundant skilled labor supply and assuming a pure intensive search strategy firm, if a decrease of quality in the*

[19] It may be interesting to note that here, we are only considering positive judging mistakes, the mistakes that are beneficial to the applicant since it allows him to gain access to a job that he could not get without this mistakes (however, we may be more mitigated about this gain since he will be discharged after and if he had to move in order to get the job, this judgement mistake might be damageable for the applicant but that is not the subject), the case in which an negative error occurs is not considered here. By negative mistake, we mean an error when judging a high productivity worker as a low productivity signal. There is different reasons to that choice: first, the cost for the firm of such a mistake is lower than for a positive mistake, it may even be null if the firm recruit a worker with a high productivity level after (if the firm were truly looking for optimizing the productivity of its worker it might be a different story, but here the firm aspire to hiring with at least a given productivity, not the one with the highest productivity level, so it might be the case for direction functions or similar functions but it is not what we are looking for here). Second, we assume that good worker knows how to give a good signal. This assumption might seem as cheap, but let's consider a case where productivity and education are assimilable and signal are given via interview and classic combo resume & cover letter (like the majority of junior position among big firms), the most often good schools or university trains their student to this kind of exercise by organizing numerous workshop about making a resume, how to prepare an interview, … so people from these schools will be abler to give a good signal. Another example might be about a random worker, on its resume there will be its former employer(s), a quick call to them will give a trustable signal, if he is good, its former firm will give a good signal, while if he is a low productivity type of worker the firm will give a bad signal (the opposite is also possible under certain condition, but it is very unlikely to happen).

applicant pool occurs, the firm may increase or decrease its screening and interview costs according to the strength of the decrease.

Foremost, even if the firm follows a pure intensive search strategy (represented by the function I(j)), there is a minimum effort for advertising recruitment *k* equal to one (they at least publish a job offer online or tell someone that they are recruiting).

Proof of proposition 1:

For a given optimal production level P*(w, p, T), a recruitment effort $k = 1$ and an arrival rate of high signal applicant $0 < \alpha < 1$, by substituting from equation (10) into equation (9) the following profit function will be obtained:

$$\Pi = (\alpha\,\pi_h - \varepsilon^j)P^*(w, p_h, T) + (1 - (\alpha\,\pi_h - \varepsilon^j))(\alpha^2\,\pi_h - \varepsilon^j)P^*(w, p_h, T) - (Ij + C + r)) - (Ij + r)$$

And the first order condition is becoming (by substituting equation (10) into equation (10)):

$$(\alpha^3\,\pi_h - \varepsilon^j)\,P^*(w, p_h, T) - (Ij + C + r) \leq 0$$
$$\Leftrightarrow (\alpha^3\,\pi_h - \varepsilon^j)\,P^*(w, p_h, T) \leq (Ij + C + r)$$

By reorganizing this equation and with some algebra, it is possible to obtain the minimum value of j:

$$j \geq P(w, p_h, T)\,(\alpha^3\,\pi_h - \varepsilon^j)/I - (r + c)/I$$
$$\partial j/\partial\alpha \geq P(w, p_h, T)\,(3\,\alpha^2\,\pi_h - \varepsilon^j)/I$$
$$\partial j/\partial\alpha < 0 \Leftrightarrow 3\,\alpha^2\,\pi_h < \varepsilon^j$$
$$\Leftrightarrow \varepsilon^j > 3\,\alpha^2\,\pi_h \Leftrightarrow \sqrt{(\varepsilon^j/3\,\pi_h)} > \alpha$$
$$\Leftrightarrow j > [\,2\ln(3\,\alpha) + \ln(\pi_h)\,]/\ln(\varepsilon)$$

So a threshold *m* might be defined such as $m=\sqrt{(\varepsilon^j/3\,\pi_h)}$, if $\alpha > m$, then the intensive search effort are decreasing up to a point where $\alpha = m$, but if $m > \alpha$, then intensive search investment will increase until reach a *j* that solves $\alpha = m$. This value for which the intensive search investment *j* solves $\alpha = m$ will be denoted as j^m so, a change in α will result by the change from the original intensive search effort *j* to a new one j^m different from the original *j* if m and α are different. This phenomenon is logical. In fact, it means that there is point after which the benefits from reducing the effort of screening and interviewing will not compensate the loss incurred by the reduction of the skilled labor supply, point characterized by j^m.

Proposition 2: *Starting in an equilibrium with abundant skilled labor supply and assuming a pure extensive search strategy firm, if a decrease of quality in the*

applicant pool occurs, the firm may decrease its recruitment effort and cost according to the strength of the decrease.

Foremost, even if the firm follow pure extensive search strategy (represented by the function r(k)), there is a minimum effort for advertising recruitment *j* equal to one (they read the resume or do at least a quick interview).

Proof of proposition 2:

For a given optimal production level P*(w, p, T), a screening effort j = 1 and an arrival rate of high signal applicant $0 < \alpha < 1$, by substituting from equation (10) into equation (9) the following profit function will be obtained:

$$\Pi = (\alpha^{1/r} \pi_h - \varepsilon) P^*(w, p_h, T) + (1 - (\alpha^{1/r} \pi_h - \varepsilon)) (\alpha^{2/r} \pi_h - \varepsilon) P^*(w, p_h, T) - (I + C + rk)) - (I + rk)$$

And the first order condition is becoming (by substituting equation (10) into equation (10)):

$$(\alpha^{3/k} \pi_h - \varepsilon) P^*(w, p_h, T) - (I + C + rk) \leq 0$$
$$\Leftrightarrow (\alpha^{3/k} \pi_h - \varepsilon) P^*(w, p_h, T) \leq (I + C + rk)$$

By reorganizing this equation with some algebra it is possible to obtain the minimum value of k:

$$k \geq P(w, ph, T) (\alpha 3/r \pi h - \varepsilon) / r - (I + c)/ r$$
$$\partial j/\partial \alpha \geq P(w, ph, T) (3 \alpha - 1 + (3 / r) \pi h) / kr > 0$$

So the derivative of k is strictly positive, since all the terms are also strictly positive. It means the k is strictly growing in α, consequently, if α decrease, k will decrease. This fact implies that in case of a labour shortage, the firm will not try to fight it if it only relies on extensive search strategy. It also means that in case of an incoming labor shortage, the firm will just stop to invest money in recruiting since they expect that it is more profitable to save this money than to spend it in order to advertise.

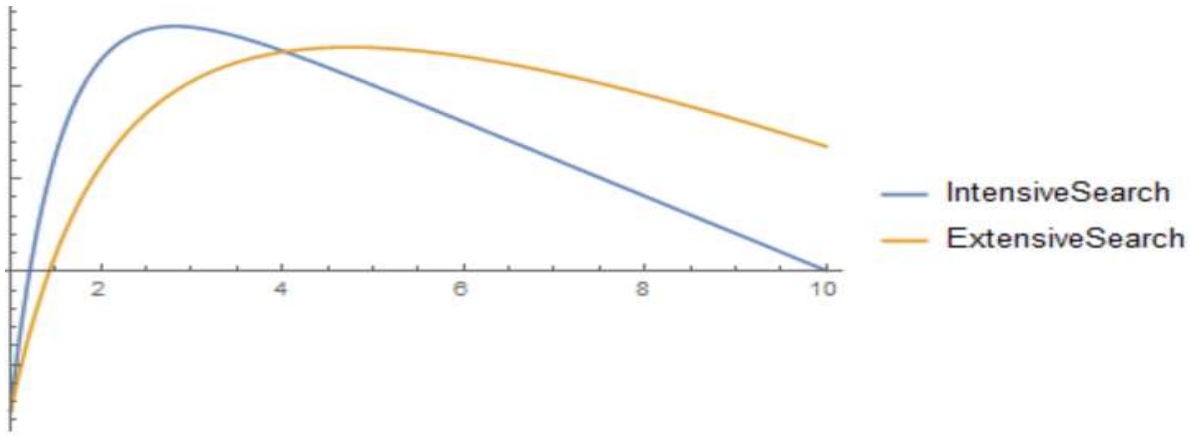
Pure Strategy and profit during a labor shortage

Now let's compare the profit for two similar firms who will use either a pure intensive search strategy (i.e. a strategy focusing on getting the more reliable information possible about the applicants, with the minimum investment of time,

money and/or human resources to broaden its applicants pool) or a pure extensive search strategy (i.e. a strategy focusing on getting the maximum number of applications and resumes possible, with a minimum investment in screening and interviewing the applicants). In order to study that, the analysis will be based on some graphs since the mathematic derivations that are proving it are too complex to be intelligible. As said earlier, these graphs have been traced by using the mathematical software Wolfram Mathematica.

First, let's give a look to the evolution of profit according to the search strategy of two identical firms with opposite pure search strategy (graph 1).

Figure 1: Search Strategy profit with fixed shortage



This figure 1[20] (the figure starts at *j* or *k* equal to one) shows us the evolution of the profit according to their investment in their own search strategy. The Y axis denotes the profit while the X axis denotes the investment in search strategy (respectively *j* and *k* for intensive and extensive search). Of course, we do not use this graph to conclude about the breakeven point of choosing pure intensive strategy or extensive strategy since we are assuming a specific case, however it gives us an accurate description of the profit function behaviour on the investment in strategy variables. Like most of the profit functions, it is first increasing then decreasing for both functions, but that is not that interesting. The interesting part is the shape of

[20] This figure has been traced with the following parameters: $\alpha = 0{,}5$; $\pi_h = 0.5$; $\varepsilon = 0.2$; $P^*(w, p_h, T) = 700$; $I = 10$; $r = 10$; $C = 20$; $j = 1$ when k is changing and $k = 1$ when j is changing

these two functions: we can see that the intensive search is quickly decreasing, way more quickly than the extensive one, while the extensive search curve is way more flat. Also we may notice that intensive search pure strategy may be more profitable than the extensive one (it is not only due to the parameters used, but it will be discussed later). This fact can have a very important implication: we assumed until now perfectly rational firms, with nearly perfect foresight, rationality and knowledge, with an absence of uncertainty in their decision. However, if we admit that firms are not rational then this difference of shape may constitute an important feature.

Let's admit that firms know how the function looks like (their shape basically), but do not have the X axis information (in other words, they see the concavity of the function, but they do not see its maximum or minimum), or have an information about it but this information is biased (imagine that they know that k or j plus a random noise will lead them to a given profit). Then, firm's behaviour might change: in a basic homo-economicus situation, the players have full information and will just take intensive search since they can have more profit with it. But, if we incorporate some uncertainty then we have to consider the behaviour of our player according to the risk (if you need any proof of that, just open any game theory book and start looking for some Bayesian games). We will not dig deeply into our analysis and just stay on surface since our aim here is not to study this situation (and our current model may not be the most adapted model in order to try to get some understanding of this situation).Basically, if we look at the two possible strategies, we can see that an error in the estimation of optimal investment search level will be more prejudicial to the firm if they choose to invest mainly in screening and interviewing than if they were choosing to focus on doing advertising for the position. In other terms, following an intensive search strategy will be riskier than following a pure extensive strategy. Consequently, according to its behaviour toward risk, a firm may choose an extensive strategy even while knowing that it may not lead it to the maximum possible profit. Short long story, based on this graph, risk averse employer would be more likely to focus their effort on a purely extensive search strategy while risk

lovers firm would definitely choose to increase their effort in an intensive search strategy by increasing the quality of their screening. It is also rather logical, since we may logically think that a risk seeker is an optimistic (or confident) agent and the hypothesis that you will find a competent applicant during a shortage without changing your pool is an optimistic hypothesis (or show that you have some trust on the current market). In other words, the agent is trusting the market being good, having enough quality and, consequently, will prefer to focus on optimizing the existent pool by reducing the possible judgemental mistake in screening and interviewing period. On another hand, an agent who is pessimistic about the current state of labor market, who does not trust it to provide him good staff will prefer start looking beyond and increase its applicant pool via an increase in its recruiting effort.[21]Also, we may argue that if the firm decides to increase its investment in search strategies while not understanding the labor market (i.e. the firm does not fully understand it and have no idea about how deep is the shortage, what would be the optimal level of investment in search strategy *j* or *k*), then extensive search strategy is a better choice than an intensive search strategy. We can perfectly see that with SMEs (Small and Medium Enterprises) and MNCs (Multinational

[21] Though, this analysis is far from being representative of the reality, unlike the common wisdom would let us think, the relation between risk toward behavior and pessimism and/ or optimism is way more complicated. Indeed, some studies proved that there is correlation between pessimism and risk tolerance. For instance, S. B. Mansour, E. Jouini, J. M. Marin, C. Napp, & C. Robert (2008) on their paper "Are risk averse agents more optimistic? A Bayesian estimation approach" have showed via a complex method (based on Bayesian approach for the statistical analysis of the problem and a hybrid MCMC approximation method to estimate some distribution) and based on large lottery survey (1536 individuals) that in average, individuals are "pessimistic and that pessimism and risk tolerance are positively correlated". However, we need to mitigate the result of this study since it is based on a lottery survey and when people play to lottery they behave differently that when they manage a company or work, also people who plays lottery are always pessimistic about wining since they consider (truthfully) that they have more chance to loose than to win (but that a win may compensate all their possible loss), in another hands, business owner or manager behave differently, they expect to win. Anyway, long short story, we are considering that people who are pessimistic are probably risk averse and so may more considerate an extensive search strategy while the optimist agent are more risk seeker and will choose an intensive search strategy, but it is based on a common belief or wisdom that might be biased.

Corporations)[22]: the most often, MNCs have very complex and long application process, with different interviews, online test, … (for instance the French boutique Lazard has a Sovereign Advisory program with at least seven rounds of interviews and tests). Meanwhile, small firms like restaurant, baker or anything else, even when they have a very high level or reputation (like having at least one Michelin Star for a restaurant) they have very simple screening and hiring process with only one interview (sometimes not even one) and a resume check (sometimes they don't even check it). However, these small firms that tend to rely in both informal and formal recruitment will just increase their extensive search by posting more visible job offer, asking around them to other professionals, employees, … in order to find an employee (O. Henry, Z. Temtime 2010). Also we can see that this SMEs have less knowledge about labor market[23] than MNCs or big firms in general, so we can observe that there may be a confirmation of our hypothesis since these firms rely more on extensive search than on intensive one[24]. However, a study which will analyse this behaviour may be interesting.

So, we have seen that, with a constant α, arbitrary fixed, the profit of function for intensive and extensive pure search strategy are down concave, with extensive curve that is going lower than the intensive one, but which is more flat. Now we should see the impact on profit of both shortage strength α and investment in search strategies j and k.

[22] Here we are dividing firms between two categories, the SMEs and the MNCs, however, when we are talking about SMEs we are only considering small firms that are doing normal profit (i.e. not a start-up that has just started few months ago and raised some millions of dollars), so basically firms as a normal restaurant, a bakery or even a supermarket, while for MNCs we are considering firms like EY or PWC. In fact, the distinction that we are doing is that SMEs are looking for regular persons' jobs while MNCs are looking for graduated person jobs.

[23] It is common wisdom to assume that an owner of a small bakery has less knowledge about the current state of the baker labor supply than the chief of HR department of an Information Technology Consulting firm has about the engineer labor supply.

[24] Of course, there are other explanations that may explain that: small firms do not have Human Ressource department or specialized worker unlike MNCs, also their jobs require (in theory) less qualification (or at least education) and their employees are cheaper so a mistake in hiring will have a lower cost, meanwhile a MNC receive a lots of application for any job opening and must sometimes put lots of step in order to discourage people to apply for their job openings.

Pure Strategy and profit according to the strength of a labor shortage

You can see the evolution of the profit according to the shortage strength (the axis from 0 to 1) and to the investment in search strategy (the axis from 0 to 15) on three 3D graphs. The figure 2 shows us an intensive search, while the figure 3 shows us the profit of extensive search and the figure 4[25] offers us the vision of the profit function of the two pure search strategies with the intensive search in orange and the extensive one in blue.

First, we can observe that for any α the profit function for both search strategies follows the same pattern as being a concave function, first increasing then decreasing on investment in search strategy. It proves us that the interpretation of the figure 1 was not only due to a specific value of shortage strength and consequently should hold for any $\alpha \in]\,0;\,1[$. Second, we can see that profit is strictly decreasing with the strength of the shortage (in other words, the lower is α the lower is the profit, or the partial derivatives of the profit function with respect to α is strictly negative). This effect seems to have a more or less constant strength for intensive search (which is logic and makes sense when you are looking at the profit function for pure intensive search) while its second derivative for pure extensive

Figure 2: Intensive search strategy profit according to investment and shortage strength

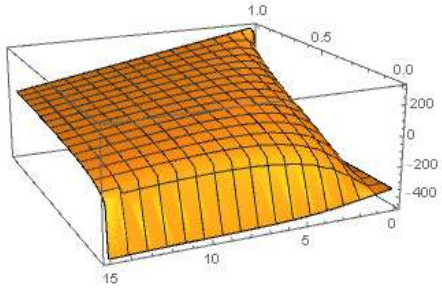
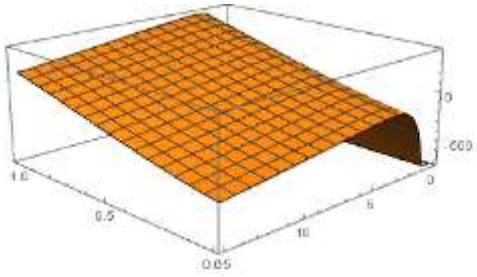


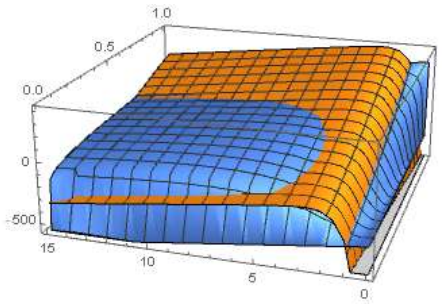
Figure 3: Extensive search strategy profit according to investment and shortage strength



[25] These figures have been obtained via some simulations performed on the software Mathematica, with similar parameters than the one of the figure 1 (see note 34)

profit function will be negative since there is a diminishing increase on it (you can see it on the figure 3 rather clearly). Finally, by looking at the last picture we can compare more efficiently the shape of this two pure search strategy profit functions according to the strength of the skilled labor shortage and to the investment on this search strategy. We can see that the pure intensive search is almost always more interesting than the extensive search for a small shortage[26], while if the shortage is strong an extensive search strategy will be a better choice. The explanation behind that fact is rather logic. If there is a small decrease in labor supply, it is still most interesting to look for more accurate information about the applicant since the firm have some choice. However, if the shortage is strong, investing in signal will become less useful since it does not matter to know accurately how productive are the applicants if they all have a low productivity level. Therefore, the firms should invest in extensive research in order to get more profile and to get more chance to get a good worker even if they may recruit a bad worker due to a lowly reliable signal.

Figure 4: Comparison of pure search strategies profit according to investment and shortage strength



[26] Of course these result are dependent of the value of the error term ε but, the intuition behind it stay true, the smaller is the shortage, the most interesting it is to invest only in screening and interview process. At the opposite, the stronger is the shortage, the more interesting it is to invest in advertisement, co-optation and other measure that would increase the applicant pool. The error term only affects the breakeven point between intensive search strategy being more profitable than an extensive search strategy: the highest is the error term, the lower is the shortage level α^* on which the two strategy are more less equivalent

V - Concluding remarks

On this final section, we will discuss some of the possible extensions, limitations, added value of our findings and about what further researches should focus on. Some of these subjects have been already discuss among the paper or during a note so there may be some repetitions. We will first discuss the limitations of our findings, then their contributions to the scientific literature and finally we will start to think about future studies.

Limitations

Just like every paper, this one suffers from large number of limitations. The main one will be that this is a totally theoretical model with no empiric support, though most of the assumptions are based on existing literature with empiric proofs. So every findings derived from this study are not proved yet, it is more a paper economic mathematical philosophy than a paper that is proving any phenomena[27]. In other words, this paper is only reflectional and should not be used to analyse a real situation until some empirical work has been done. However, this limitation is principally due to the kind of this study and consequently is not specific to this paper especially. About the limitation specific to this paper we can start by talking about the pure strategy. We are assuming a kind of pure strategy investment choice: either a firm will invest on intensive search or on extensive search, never both. However, in reality both are often going together: if a firm hire a head hunter professional to

[27] However, we may argue that this limitation may be applied to a very large number of study, even with empirical work. One the most explicit example of that is the definition and the use of the p-value, in most of the studies a p-value of 5% is considered as the significant threshold and we assume that just getting a smaller value of this p-value is enough, but we know that p-value alone is not enough and that 5% is already too high (see the paper of Figueiredo Filho et al. (2013), Greenwald, Gonzalez, Harris, & Guthrie, (1996) Ioannidis (2005) Samargandi, Al-Taha, Moran, Al Youha, & Bezuhly (2018) or Sullivan & Feinn (2012) for more explanation).

get more candidates, he may also have more reliable signal about the candidate, so the reality will be more about a mix search strategy investment. Also we are not differentiating the fact that different investments may have different effects. Still about the search strategy, we are assuming that they have similar cost during our analysis ($r = I$) which might change the results[28]. On the same way, we are not considering the impact of wages and are assuming it as fixed for different reason, however a firm might want to modify this offer in order to change the size of the applicant pool and its quality distribution.

There is also a time limitation in this paper. It is not always clearly said but this paper only considers a short term problem, i.e. two periods in a short amount of time, so we do not discount time value and neither are the other problems related to that. For instance, if there are more periods than two, then the choice between the two pure strategies may evolve. Also we do not allow a firm to set a dynamical strategy: to change its strategy during the period. For instance, if it was the case, a firm will probably invest first in screening and interviewing methods then move to an extensive search strategy if they do not manage to find a decent worker on the first period. And this hypothesis is a way more realistic one.

Another limitation is that our work is on labor shortage. Here we are considering more a decreasing pool of applicants that we are assimilating to a labor shortage, while it is more social skill labor shortage than a basic economic sense shortage: we are considering a decrease in quantity of the good worker, a rarefication of the applicant quality, not a decrease in the quantity of worker. Consequently, this paper may not describe the phenomena behind a labor shortage, which is not a decreasing pool of candidates but an empty one. Moreover, during our analysis, we do not let the possibility for the firm to change its reservation productivity level or to reduce its need for worker (i.e. cut down the production, out-contract the work, buy machinery, … cf table 1). Also the effects of this shortage on the competition are

[28] In fact, it should just change the profit and move the breakeven point, if $r > I$ then the value of α after which it is more interesting to invest in intensive search will decrease. At the opposite if $r < I$ then the value of α after which it is more interesting to invest in intensive search will increase.

totally neglected in this model, and the fact that we assumed a monopoly does not mean labor monopsony. This model does not try to interpret or to understand the competition dynamics under a skill shortage and its possible effects on the pure search investment strategy.

Contributions of this paper

This paper brings some new contributions to the economic literature. Foremost, this paper stands out from the literature for different reasons. First, it is one of the few existing studies that is considering a general and theoretical analysis on a microeconomics point of view (or industrial organization) of a labor shortage (most of the studies on this subject are more macroeconomic or based on a very specific market like nursing or teacher) that is focusing on the employer behaviour and point of view and not the employee or social planner vision of the phenomena. Then, it is one of the rare papers that is studying a situation with a search model where the pool where you are looking for something is decreasing[29]. By doing so, we have (or at least we hope) created a framework that can be used as an inspiration to treat more complex search model with a decreasing applicant pool.

On another hand, despite its clear limitations explained on the previous section, this study gives clear insight of the relation between the strength of a labor shortage, profit and investment in a search strategy. It proves us that shortages have an impact on the search strategy of an employer. Indeed, the study gives a theoretical proof that when a shortage occurs, it impacts the search behaviour of an employer by encouraging the firm to prefer investing in extensive search. However, it happens if, and only if, the severity of this shortage is enough important, otherwise, the firm will still choose to focus on intensive search. If this relation is empirically demonstrated, it may give to policy maker an indication whether there is a labor shortage or not, or more if the firms perceive a labor shortage or anticipate one. It

[29] To our knowledge and the one of our supervisor, there is nothing like this kind of search model that is existing on the economic literature for now, so we may consider that this issue has never been studied or at least not enough.

might be interesting, since assessing labor shortage is very difficult with our current methods, while we could easily check the employers' search strategy in order to assess the current state of a labor market.

Furthermore, we also found that if the firm is not changing its investment strategy i.e. if it does not change from its original strategy (because the firm is not flexible enough for instance), the shortage impacts how much it should invest. Indeed, if the firm is following a pure extensive search strategy while a shortage occurs, it should decrease the investment. However, if the firm is following a pure intensive search, it is more complicated and the optimal move of the firm will depend on the shortage strength. Basically, a strong shortage is more likely to increase the investment, while a small one is more likely to decrease it.

Among the paper, we raise some points of interest that were not deepened since it was our purpose on the paper. Mainly, there are two points: risk behaviour and knowledge of market labor. Indeed, we have seen that if the firm is risk averse or has low knowledge about the labor market, then it should have a preference for an extensive search strategy. However, we did not deepen these points and, consequently, we did not manage to prove it during the paper. To these two points, we might add another point: the intensive search strategy seems to be more interesting if the investment is small. So even if the shortage is enough strong to make extensive search optimal, it might be more interesting for the firm to invest in intensive search if its investment capacity is very limited.

Also this paper might be interesting since it has endogenous level of both intensive search investment strategy and extensive search investment strategy which a is a rather rare feature and is somehow on the lineage of J. M. Barron, M. C. Berger, & D. A. Black (1997) which was one of the first paper to propose an endogenous level of intensive search.

Future researches and studies

Even if this paper brings some contributions to the depletion or shortage labor economics, it only brings the early steps of it. There are at least three directions that can be followed in order to polish this economic track of study[30]. Foremost, some empirical study may be done in order to confirm the intuition of our theory and maybe try to quantify that. Second, research that will focus on more complex investment choice will be interesting and may shows us even more variation in firms expected answer to labor shortage. For instance, the impact of reducing the requirements in order to get more candidates, the impact of out-contracting or just mixed search strategy investment behaviour with respect to the quality depletion rate evolution. The third, and probably the most interesting direction for further study, will be to develop a model that will take in count the search strategy on shortage context and implement them into a context where competition is involved with an explicit consideration of the production functions. These directions are not exhaustive, studies that will mix our framework and true bounded rationality theories (i.e. not unbounded rationality under constraint theories) might be very interesting as well, for instance combining the Aspiration Adaptation Theory (AAT) of the Nobel price R. Selten (1998) with a shortage search model could lead to better modelization of the reality.

[30] We are thinking that the subject of shortage of labor may be a very interesting phenomena and might be very interesting especially since it is considering subjects that may have an increasing importance, like quality labor management, shortage of specialised labor, …

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