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THE WORKING ENVIRONMENT AND SOCIAL INCREASING RETURNS[*]

ADRIANA BARONE[**] – CONCETTO PAOLO VINCI[***]

Abstract

In this paper we consider an economy characterized by a labour market framework with a costly search activity and a random matching technology function and constant returns to scale in both job vacancies and unemployed workers. We show that there are social increasing returns not only in human and physical capital but also in investments made in order to improve\ the starting level of the working environment within each firm. If some entrepreneurs decide to offer better working conditions to their employees, workers will choose to invest more in human capital in order to augment their level of education, increasing the rate of return for all the entrepreneurs active in the economy, this being true even for those who have not invested. The same happens if a group of workers decides to invest more in their educational level; entrepreneurs will increase their investment in the working environment and physical capital, benefiting also workers who have not invested.

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[*] The authors share all the contents of the paper, as well as the responsibility for any errors contained herein; in any case sections 2 and 5 are attributable to A. Barone, while sections 3, 4 and the appendix to C.P. Vinci.

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1 Introduction

In the last decade there has been an increasing interest towards health and safety at work issues. Deep changes in the structure and functioning of labour market and widespread application of new technologies to work processes have induced governments to consider these issues as strategic in their social and economic policies. Also among firms, at least among those with longer time horizons, there has been increasing concern about the importance of a healthy workforce by considering as strategic those firms' policies aiming at retaining their best workers. Building up a safer working environment can assure a firm in the future improved productivity and lower losses due to a reduction in fatalities and disease, damage, absenteeism and turnover. From their side, workers give increasing importance to working conditions and the working environment. This new scenario, where occupational health and safety at work is seen to have a key role for the growth/development of economic systems, is the starting point of this paper. From Adam Smith in his Wealth of Nations[21](p.111-112) ownwards, occupational safety and health issues can usually be found in the economic literature about compensating wage differentials[1], which can be seen as the market mechanism compensating the worker for the risks borne at work. For a profit-maximizing firm compensating wage differentials should be treated as a cost when deciding how much to invest in health and safety and more in general in the working environment in order to have a higher level of safety and health[2]. In a general equilibrium context we will openly model a production function where the working environment is treated as a factor of production together with human and physical capital. This hypothesis is based on Viscusi[22][23] and Dorman[6], who have often treated safety, health and working conditions as production inputs: according to Viscusi the enterprise's production of an output will depend on both the size of workforce and the safety levels, each input having a positive and diminishing marginal productivity. Higher levels of health and safety, in other words better working conditions, increase output by diminishing the disruptive effects of injuries and by increasing the stability of workforce by reducing workers' quitting. In this paper we will add that better working conditions will improve workers' educational level and their inclination to invest in human capital as well as entrepreneurs' willingness to invest in physical capital.

Our main purpose is to analyse the interaction between the variables under a firm's control such as physical capital and the working environment and those under a worker's control, that is human capital . In this paper we will show that there are increasing returns not only in human and physical capital, but also in the level of the working environment; as a consequence, a greater workers' investment in human capital will have a positive impact on entrepreneurs' investment in both

[1]See Rosen[20], p. 641-692.

[2]See Borjas[4](ch.11), Dorman[6].

physical capital and the working environment. Obviously, the same argument will naturally apply to an initially greater entrepreneurs' investment. This result is obtained by using the theoretical model by Acemoglu[1][2]. These increasing returns, defined as social or pecuniary, are not derived from particular assumptions made on the production process, but depend on the functioning of a labour market characterized by a costly search activity and a matching technology function, where the workers' barganing power is significant in affecting the outcome of the model.

The paper is organized as follows: in section 2 a few facts concerning the importance of working conditions are exposed; section 3 describes the basic environment and the Walrasian allocation; section 4 is devoted to presenting a general equilibrium model with random matching, first without and then with unemployment; in section 5 a numerical example is presented. The final section contains some concluding remarks and possible suggestions for further research.

2 Few Facts about Working Environment

In 1970 in the U.S. the Occupational Safety and Health (OSH) Act was introduced; it underlines that safe and healthy workplaces benefit not only workers but also employers and society at large. After the creation of the Occupational Safety and Health Administration (OSHA) within the Department of Labor, in the U.S. there was a marked decline in the rate of workplace fatalities from 29(per 100,000 workers) in 1948 to 18 in 1970 and finally to 7 in 1992. Nowadays the fatality risk is more concentrated in small firms ($\leqslant$ 10 employees) and in certain industries and jobs (healthcare workers, jobs such as foundry work, mining, stonecutting, coal mining, working in shipyards and food processing). Despite this marked reduction in the rate of workplace fatalities, approximately 50,000 workers still die every year due to occupational diseases, which have a rather long latency period, frequently lasting decades.

Regardless of the industry, type of occupation or firm's size, the introduction of new technologies produces changes both in work and in work practices, causing the emergence of new risks. Although modern cooling and ventilation systems, for example, allow for comfortable working conditions in closed office buildings, they could create problems in terms of air quality (e.g. Legionnaire's disease, passive tobacco smoke). Furthermore, as work environments change and new technologies emerge, there are new hazards to be considered. In this context the role of all the institutions (government, employers, workers, unions, etc.) is to address workplace conditions based on new technologies, that may endanger workers' safety and health in order to continue the improvements made in the recent past in OSH.

The importace of safety and health at work has been recently recognized also at the European level. In 1994 the European Agency for Safety and Health at work was established by Council Regulation no.2062. According to this Regulation, the aim of the Agency is to encourage improvements in the working environment by collecting and disseminating in the EU Member States technical, scientific and economic information related to OSH. Since it started its work in 1996, the first task undertaken by the Agency has been the compilation of data on OSH policy in a report published in 1998[9], followed in 2000 by an updated report[12].

The first Report contains summaries of national research priorities and strategies in order to improve OSH. As regards strategies, in European Member States, legislation and enforcement have been the traditional instruments for improving the level of OSH in all Member States. In addition to legal obligations, several forms of financial incentives have been specified: differentiation of premiums for insuring against occupational accidents and diseases; public subsidies for research and technological development; tax benefits for companies investing in safety and health at work; subsidies in order to assess the OSH situation at company level. A fairly new instrument for improving OSH has been the certification of products and services in the health area alongside the more traditional use of this instrument in the safety area. Training in OSH is undertaken in all Member States and is a very important and effective tool for prevention. For example, there are indications that workers who benefit least from training (e.g. temporary workers, home workers) run the greatest risk of accidents.

As far priorities are concerned, it is possible to outline three types of areas which EU Member States have paid attention to in the past, and which they will focus upon in the future:

a) Categories of risk agents: in the past particular attention was devoted to risks in the areas of chemical agents (asbestos), physical agents (noise) and safety (machine safety); in particular, the risk categories considered to be significant in the future are chemical agents (carcinogens), safety (machine safety) and psycho-social issues (stress at work);

b) Categories of workers at risk: in the past young workers received particular attention; in the future they will receive greater attention together with other categories of workers which are expected to have an increasing weight in the labour market, such as ageing workers, atypical workers (homeworkers, teleworkers) and self-employed;

c) economic activities at risk: during the last decade agriculture and related sectors, the chemical industry, the metal industry and construction, have received particular attention. In the future, interest will focus on concentrated on construction, commercial/transport/service and education, health (esp. hospitals) and public sectors.

The priorities outlined above stemmed from the significant changes occurring in the last decade in the economic structure of the EU Member States which had some effects on workplaces. They can be summarized as follows:

1) changes in the demography of the labour market (ageing of the workforce, increasing female participation rate, increasing labour market flexibility);

2) changes in the nature of economic activities (increasing number of small sized firms, the diminished importance of agriculture, manufacture and public sectors, the growth of the service sector, the globalization of trade, changes in management practices applying more outsourcing and downsizing);

3) changes in the nature of work (increasing usage of computers and telecommunications, the growth of telecommuting, the automation of work process and the increased knowledge content of work);

4) changes in thinking on health (increasing importance of preventive strategies, focus on general health and well-being, the growing importance of stress);

5) emergence of workplace related issues (new hazards at work, emphasis on health rather than safety).

The emergence of these changes challenges also the traditional role of legislation and enforcement in improving the level of OSH in all the EU Member States. Classic indicators for the level of OSH, such as accidents and diseases, have shown a substantial decrease over the years, but in a changing context, they can lose their significance. This may occur because changes in work-related technologies, in the labour market and in the nature of work produce new health risks and new groups at risk. The significant changes in the technologies being used in the workplace (especially machinery), for example, will reduce the manual skill levels necessary to do the job, will reduce safety hazards at work and will augment the knowledge content of the work. Labour market changes instead will produce a new set of groups at risk(shiftworkers, atypical workers and older workers), which is expected to rise in the number of people included in it. Finally, changes in the nature of work itself will increase the work pace, probably leading to increased levels of occupational stress, and will increase the knowledge content of many types of jobs, leading once again to probable increased stress for workers.

As regards the future role of legislation and enforcement, there is a common belief that they will continue to be important tools in setting levels of protection against safety and health hazards at work, but, as already stated above new tools, such as financial incentives, training, certification of the product and service quality in relation to occupational safety and health, have been introduced to complement it. Moreover, while at first the focus of legislation was mostly on safety issues, later the changing context forced the attention more on health-related issues. In recent years, social and organizational matters have been introduced through legislation in order to identify and measure the economic costs of occupational injuries and diseases and also to evaluate the effectiveness of regulation. Hence the necessary link between economic analysis, public policy and OSH clearly emerges.

A general aim of economic analysis of OSH is to make both firms and governments more responsible by measuring the economic costs of occupational injuries and diseases: on the one hand, firms tend to underestimate the real damage caused to their performance by worker ill-health; on the other, governments may not realize the impact that OSH problems have on economic development and growth. As regards firms, it is a principle of health and safety management that the great majority of accidents and diseases are due to working conditions, not to the performance of work; thus, even highly dangerous conditions could be regarded as safe if work were always performed with perfect attention and precision. But the aim of OSH management is to make the job compatible with the capacities of the workforce; so the OSH policy within firms should set the objective of which production methods to use, their implementation and the importance of safety and health issues. By improving the firm's knowledge of the costs due to accidents and diseases and through greater internalization of these costs now borne by society, there are gains to be made at each stage in order to close the gap between the social and firm optimal levels of safety[3].

With regard to governments, it is worth underlining that OSH regulation has a key role in economic development/growth. A better working environment (a higher level of OSH) produces several benefits at firm level, even if it is difficult to assess them: improved health, reduced fatalities and injuries, reduced damage, reduced production losses, increased productivity.

At a general level there are two reasons why employers might find higher OSH standards in their long-term interest. The first is the relationship between productivity and working conditions. There is a positive correlation between certain measures of safety and a country's level of development/growth. A country's economic aim should be development/growth; better working conditions should come later. But it is easy to imagine that this relationship could go the other way round, that is from working conditions to productivity. In every developed country, there have been, in the past, periods in which employers were obliged to improve working conditions, searching for better and more efficient solutions, and gaining from them in terms of productivity. The second reason is that, under the pressure of market competition, firms would be tempted to undercut safety in order to achieve competitive advantage. The result could be the prisoner's dilemma paradox, with no firm having any competitive advantage but low levels of safety and health at work. An economy-wide system of OSH regulation could lead all the firms towards a Pareto-efficient situation with none of the entrepreneurs having any competitive advantage but a high level of safety and health at work.

Firms which do not underestimate the importance of health and safety at work, and increase the level of it, have as their main aim a better use of human resources in the future, as well as more efficient and better controlled production methods. If there is no OSH regulation, severe market competition gives short-term advantages to firms that do not attend to the health and safety of their workers, leading the economy to a lower level of development/growth. In this

[3] Degree of market competition, unemployment, and transfer and social insurance programs are factors which can increase the extent to which it is society and not employer who pays for the costs of occupational fatalities, injuries and diseases.

respect, OSH regulation does not follow development/growth, but it is a condition for it.

Recently, at the EU level, the costs of occupational and health disease have been estimated in percentage of GNP, and figures, reported in Table 1[4], have induced EU governments to adopt strategies in order to reduce their impact on growth.

Table 1.

Year	Country	%GNP
95	Austria	1.4
95	Belgium	2.3
92	Denmark	2.7
94	Finland	3.8
95	France	0.6
95	Germany	ECU45billion
	Greece	N.A.
96	Ireland	0.4
96	Italy	3.2
96	Luxembourg	1.3 − 2.5
95	Netherlands	2.6
95	Portugal	0.4
95	Spain	3
95	Sweden	3 − 4
90	UK	1.1

Source: *European Agency for Safety and Health at Work* [10], p.25

The second aim of economic analysis ofOSH is related to the success of public policy. The deeper the understanding of the mechanisms connecting the functioning of firms and markets and the types of OSH problems that arise, the higher is the probability that a public policy is successful. For example, why are working conditions better in some sectors or regions than in others, and why are particular groups of workers at greater risk than others? It has been observed that all groups with lower socioeconomic status have, on average, more dangerous working conditions. Thus, based on the U.S. experience, racial and ethnic minorities have higher accident rates (Loomis et al. [16], Robinson [19]) as do immigrants (Bollini and Sienn[3]) and workers with less formal education [17].

[4]Source: European Agency for Safety and Health at Work(1999)- Economic Impact of Occupational Safety and Health at work in the EU Member States, p.25.

Indeed, the key test of this relationship is likely to be income itself and there is evidence proving that low income is associated with higher risk (Robinson[19]). Thus it is underlined that the distribution of risk is affected by inequity: those who suffer the most from poor working conditions are also the most likely to suffer from other social and economic costs. There is a hidden economic rationale behind this evidence: the types of jobs created, and the distribution of those jobs among workers, are the result of choices made by firms, workers and governments in order to pursue their economic objectives. Thus there are economic forces at work if there is a global trend towards more precarious or informal employment, which represents an obstacle to the improvement of the OSH conditions and worsens the conditions of those workers already exposed to this unequal distribution of risk. In this context, the main task of economic analysis is to understand the economic forces at work in order to suggest the proper policy measures.

It is worth underlining an aspect of the debate about the importance of working conditions. As stated above, firms benefit from good working conditions, but they result from a choice about the production strategy, involving products, production methods, work organization and machines. The cost of injury and disease depends on the extent to which workers are seen as economic assets and this depends on the time horizons considered by a firm. If the firm is interested in the quality of its workforce, a wage premium could be paid to attract the highest quality applicant pool and to retain its best workers. More generally, the most reliable policies for improving the working environment rely on employment relations oriented towards workers: a joint safety committee, effective communication through the organization and careful attention to the characteristic of the work process as regards performance. A work process can be made safer or healthier through additions and modifications, such as substitute materials, ventilation systems, extra safeguards attached to machinery, a more moderate work pace, etc.

A higher level of OSH standards within a firm has significant economic impacts on performance: improved health, reduced fatalities and injuries, reduced damage, reduced production losses, increased productivity, reduced absenteeism and turnover.

As a result, the firm is keen to improve the working environment in order to attract the best workers, while the workers have incentives to accumulate human capital in order to end up working for a firm with a high level of OSH. This reciprocal interest is fruitful for society, which could have both firms with a good working environment and a workforce with a high educational level. In the following section, we present a model where the reciprocal interaction between human capital and the working environment, giving rise to social increasing returns, is formally described.

3 The basic model and the Walrasian allocation

As in Acemoglu [1][2] and Carillo - Vinci [5], we will base our analysis on a simple Non-Overlapping Generation Model, where each generation is assumed to consist of a continuum of workers and firms normalized to one. The life of each agent consists of two parts. In the first, workers choose their investments in human capital, and entrepreneurs decide how much to invest in order to increase the physical capital and improve the working environment; in the second, production takes place in the form of a partnership of one worker and one firm. At the end of the period we assume that agents consume all their assets, leaving no bequests,and then die. Workers, in their investment decisions, consider the stock of human capital already present in the economy; by the same token, entrepreneurs consider the total existing amount of physical capital and the available working environment. We postulate a production function assumed to be constant returns to scale which takes the following form:

$$y_{ij,t} = Ah_{i,t}^{\alpha} k_{j,t}^{\beta} s_{j,t}^{(1-\alpha-\beta)} \quad \text{with} \quad 0 < \alpha, \beta < 1, \tag{1}$$

where $h_{i,t}$ is the human capital level of the $i.th$ worker, and $k_{j,t}$ and $s_{j,t}$ are respectively the physical capital level and the working environment endowment of the $j.th$ entrepreneur of the t generation; A is a positive parameter representing the technology level of the economy.

The utility function of the $i.th$ worker of the t generation is given by:

$$U_{i,t} = C_{i,t} - \frac{\theta_i (1 + l_{i,t})^{1+\gamma}}{1+\gamma} H_{i,t-1} \tag{2}$$

where $C_{i,t}$ is the consumption level, $l_{i,t}$ the human capital investment and γ a positive parameter; θ_i measures the relative disutility of human capital acquisition for the worker, and $H_{t-1}$is the stock of human capital of the economy inherited from the previous generation which is defined as follows:

$$H_{t-1} = \int_0^1 h_{i,t-1} di \tag{3}$$

The human capital of the $i.th$ worker is given by the following equation:

$$h_{i,t} = (1-\delta)(1+l_{i,t})H_{i,t-1} \tag{4}$$

according to which workers receive the stock of human capital of the economy by inheritance from the previous generation. Moreover, according to equation (4) we postulate human capital depreciation at rate δ if no worker invests in human capital. The utility function (equation (2)) has to be maximized subject to equation (4), and to the following budget constraint:

$$C_{i,t} \leq W_{i,t} = w_t h_{i,t} \tag{5}$$

where $W_{i,t}$ is the wage level earned by each worker, and w_t the human capital remuneration per unit.

Entrepreneurs have to invest in physical capital and improve the working environment in order to maximize the expected profits given by the following expression:

$$\Pi_{ij,t} = y_{ij,t} - w_t h_{i,t} - \mu s_{j,t} - r k_{j,t} \tag{6}$$

where $s_{j,t}$ and $k_{j,t}$ are the level of working conditions and physical capital, while μ and r, assumed to be constant and exogenous, measure respectively the per unit working condition cost and the rate of return to physical capital. From equation (6) it emerges that the product price is assumed to be equal to one. The physical capital and the working conditions functions are respectively given by:

$$k_{j,t} = (1-\delta)(1+m_{j,t})K_{j,t-1} \tag{7}$$

$$s_{j,t} = (1-\delta)(1+e_{j,t})S_{j,t-1} \tag{8}$$

which have a similar explanation compared to equation (4): entrepreneurs inherit from the previous generation the stock of physical capital $K_{j,t-1}$ and the working conditions endowment $S_{j,t-1}$ of the economy. Once again, physical capital and working conditions depreciate at rate δ [5] if no worker invests, and $m_{j,t}$ and $e_{j,t}$ measure respectively entrepreneurs' physical capital investments, and investments made in order to improve the working conditions of the firm. The stock of physical capital and the available working environment at time $t-1$ are similarly defined as follows:

$$K_{t-1} = \int_0^1 k_{j,t-1} dj \tag{9}$$

$$S_{t-1} = \int_0^1 s_{j,t-1} dj \tag{10}$$

In order to complete the description of this competitive economic system, as suggested in Acemoglu[1][2] we recall that in a frictionless Walrasian economy there is an auctioneer who calls out wages and other inputs' rates of returns functionally related not only to human and physical capital, but also to working conditions; as a consequence, trade will stop when all markets clear. In such a context, the Walrasian equilibrium will be reached, for a given distribution of investments, if and only if the workers allocation to entrepreneurs, and all the rates of return are in equilibrium, and if the ex-ante investment decisions are privately optimal. In a Walrasian economy each worker will be employed in the firm where he (she) is able to reach the highest level of marginal productivity. Consequently, given the hypothesis of complementarity among inputs, workers with the highest human capital will be matched with firms with the highest physical capital level where better working conditions are the rule. In a Walrasian equilibrium the wage rate, the per unit working condition cost and the physical capital rate of return will be given by:

$$w_t = \frac{A\alpha k_{j,t}^{\beta} s_{j,t}^{(1-\alpha-\beta)}}{h_{i,t}^{(1-\alpha)}} \tag{11}$$

[5] For simplicity we assume that there is the same depreciation rate δ for human and physical capital, and also for working conditions.

$$r = \frac{A\beta h_{i,t}^{\alpha} s_{j,t}^{(1-\alpha-\beta)}}{k_{j,t}^{(1-\beta)}} \tag{12}$$

$$\mu = \frac{A(1-\alpha-\beta) k_{j,t}^{\beta} h_{i,t}^{\alpha}}{s_{j,t}^{(\alpha+\beta)}} \tag{13}$$

from which it is possible to derive the total equilibrium income of each worker as $W_t = w_t(h_{i,t}, k_{jt}, s_{j,t})h_{i,t}$.

Since the representative worker maximizes his (her) utility function (equation (2)) the human capital accumulation rule (equation (4)) and the budget constraint (equation (5)), we have the following condition:

$$w_t = \frac{\theta_i (1 + l_{it})^{\gamma}}{(1-\delta)} \tag{14}$$

Combining the latter with equations (11), (12) and (13), and taking into account equations (4), (7) and (8), we may derive the following equilibrium values for workers' investments in human capital, and for entrepreneurs' investments made in order to increase physical capital and to improve working conditions in the firms:

$$e_{jt}^{*} = \frac{A^{\frac{\gamma+1}{\alpha\gamma}} (1-\alpha-\beta)^{\frac{(\gamma+1)(1-\beta)-\alpha}{\alpha\gamma}} (1-\delta)^{\frac{1}{\gamma}} \beta^{\frac{\beta(1+\gamma)}{\alpha\gamma}} \mu^{\frac{(\gamma+1)(\beta-1)+\alpha}{\alpha\gamma}} H_{t-1}}{\theta_i^{\frac{1}{\gamma}} r^{\frac{\beta(1+\gamma)}{\alpha\gamma}} S_{t-1}} - 1 \tag{15}$$

$$m_{jt}^{*} = \frac{A^{\frac{\gamma+1}{\alpha\gamma}} (1-\alpha-\beta)^{\frac{(\gamma+1)(1-\beta-\alpha)}{\alpha\gamma}} (1-\delta)^{\frac{1}{\gamma}} \alpha^{\frac{1}{\gamma}} \beta^{\frac{\beta(1+\gamma)+\alpha\gamma}{\alpha\gamma}} H_{t-1}}{\theta_i^{\frac{1}{\gamma}} r^{\frac{\beta(1+\gamma)+\alpha\gamma}{\alpha\gamma}} \mu^{\frac{(\gamma+1)(1-\alpha-\beta)}{\alpha\gamma}} K_{t-1}} - 1 \tag{16}$$

$$l_{it}^{*} = \left[\frac{A\alpha K_{t-1}^{\beta} S_{t-1}^{(1-\alpha-\beta)} (1-\delta)}{\theta_i H_{t-1}^{(1-\alpha)}} \right]^{\frac{1}{(\gamma+1-\alpha)}} \left[(1+m_{jt}^{*})^{\beta} (1+e_{jt}^{*})^{(1-\alpha-\beta)} \right]^{\frac{1}{(\gamma+1-\alpha)}} - 1 \tag{17}$$

Proposition 1 .

a)Assuming that $\theta_i = \theta$ there is a unique Walrasian equilibrium;

b)the above equilibrium is Pareto-optimal;

c)in equilibrium each worker has a constant human to physical capital ratio and a constant human capital to working environment ratio, and each entrepreneur has a constant physical capital to working environment ratio.

As for all the other main results in what follows, Proposition 1 will be proved in the Appendix. The above equilibrium is Pareto-efficient since any small increase in the investment of all agents does not improve the welfare of any other subject in the economy; so this model does not exhibit any social increasing return.

4 Equilibrium with search in the labour market.

4.1 The case of random matching and full employment.

In this sub-section we consider the case of an economy characterized by a labour market framework with a costly search activity and a matching technology function assumed to be random and constant return to scale in both job vacancies and unemployed workers. The randomness of the matching function is in the sense that each worker has an equal probability of meeting an entrepreneur, and once a partnership has been formed it is too costly to break it up and find a new partner for each agent. This assumption implies that the rates of return of human capital, physical capital and working environment are no longer equal to the respective values of the marginal productivity as in the previous competitive equilibrium. It is also assumed that entrepreneurs and workers match one to one; thus no agent remains unemployed. As in Acemoglu[1][2], following the standard literature on search models, total wages and entrepreneurs' incomes are assumed to be determined by a bargaining process which leads to income distribution rules according to which the total output (the surplus from a match) is shared between workers and entrepreneurs in given constant proportions: b and $(1-b)$ where b captures workers' relative bargaining strength. Moreover, the assumption of random matching has another important implication: workers do not know who their employers will be when they invest in human capital, and so their expected wages depend on the whole distribution of physical capital and working environment across all the entrepreneurs. In a similar way, entrepreneurs' incomes will be based on the total distribution of human capital. Therefore the expected wage bill of the $i.th$ representative worker, and the expected revenue of the $j.th$ entrepreneur $(R_{j,t})$ will be respectively given by :

$$W_t = bAh_{i,t}^{\alpha} \int_0^1 k_{j,t}^{\beta} dj \int_0^1 s_{j,t}^{(1-\alpha-\beta)} dj \tag{18}$$

$$R_t = (1-b)Ak_{j,t}^{\beta} s_{j,t}^{(1-\alpha-\beta)} \int_0^1 h_{i,t}^{\alpha} di \tag{19}$$

As in the competitive model, each worker maximizes his (her) utility function given the human capital production and the budget constraint. By substituting equations (4), (5) and (18) in equation (2) the utility maximization problem of the representative worker of the generation t may be written as follows:

$$MaxU_{i,t} = bA\left[(1-\delta)H_{t-1}(1+l_{i,t})\right]^{\alpha} \int_0^1 k_{j,t}^{\beta} dj \int_0^1 s_{j,t}^{(1-\alpha-\beta)} dj - \frac{\theta_i (1+l_{i,t})^{(1+\gamma)}}{(1+\gamma)} H_{t-1} \tag{20}$$

From the f.o.c. we can easily derive that:

$$l_{i,t} = \left[\frac{bA(1-\delta)^{\alpha}\alpha \int_0^1 k_{j,t}^{\beta} dj \int_0^1 s_{j,t}^{(1-\alpha-\beta)} dj}{\theta_i H_{t-1}^{(1-\alpha)}}\right]^{\frac{1}{(\gamma+1-\alpha)}} - 1 \tag{21}$$

hence:

$$h_{i,t} = \left[\frac{bA(1-\delta)^{(1+\gamma)} H_{t-1}^{\gamma} \alpha \int_0^1 k_{j,t}^{\beta} dj \int_0^1 s_{j,t}^{(1-\alpha-\beta)} dj}{\theta_i}\right]^{\frac{1}{(\gamma+1-\alpha)}} \tag{22}$$

From equations (21) and (22) it can be easily seen that both the average physical capital and the average working environment within a firm have a first order impact effect on human capital investment and consequently on the human capital level of t-generation workers. An increase in the average physical capital and an improvement in working conditions will increase the human capital rate of return and the desired human capital level.

Similarly to the Walrasian allocation, entrepreneurs have to invest in physical capital and improve working conditions within the firms in order to maximize their expected profits, the latter given by the following equation:

$$\Pi_{ij,t} = R_{j,t} - rk_{j,t} - \mu s_{j,t} \tag{23}$$

where, as we stated above, $R_{j,t}$ is the expected revenue (equation (19)) and r and μ measure respectively the per unit working condition cost and the rate of return to physical capital. Note that profits and revenues are expected values because of randomness of the matching technology function and so entrepreneurs do not know the human capital level of the workers that they are going to meet. By substituting equation (19) in equation (23), the f.o.c. from the profits maximization problem gives us the following optimal rules:

$$k_{j,t} = \frac{\left[(1-b)A\right]^{\frac{1}{\alpha}} (1-\alpha-\beta)^{\frac{(1-\alpha-\beta)}{\alpha}} \left(\frac{\beta}{r}\right)^{\frac{(\beta+\alpha)}{\alpha}}}{\mu^{\frac{(1-\alpha-\beta)}{\alpha}}} \int_0^1 h_{i,t} di \tag{24}$$

$$s_{j,t} = \frac{\left[(1-b)A\right]^{\frac{1}{\alpha}} (1-\alpha-\beta)^{\frac{(1-\beta)}{\alpha}} \left(\frac{\beta}{r}\right)^{\frac{\beta}{\alpha}}}{\mu^{\frac{(1-\beta)}{\alpha}}} \int_0^1 h_{i,t} di \tag{25}$$

which show that not only are the values of $k_{j,t}$ and $s_{j,t}$ increasing functions of the average human capital, but they are also equal for all firms since the production function is assumed to be concave in $k_{j,t}$ and $s_{j,t}$. By solving the system formed by equations (22), (24) and (25), and taking into account equations (21), (7) and (8) we obtain the following equilibrium values:

$$h_t^* = \frac{H_{t-1} A^{\frac{1}{\gamma\alpha}} \left(\frac{b\alpha}{\theta_i}\right)^{\frac{1}{\gamma}} (1-\delta)^{\frac{(1+\gamma)}{\gamma}} (1-b)^{\frac{(1-\alpha)}{\alpha\gamma}} (1-\alpha-\beta)^{\frac{(1-\alpha-\beta)}{\alpha\gamma}} \left(\frac{\beta}{r}\right)^{\frac{\beta}{\alpha\gamma}}}{\mu^{\frac{(1-\alpha-\beta)}{\alpha\gamma}}} \tag{26}$$

$$s_t^* = \frac{H_{t-1} A^{\frac{1+\gamma}{\gamma\alpha}} \left(\frac{b\alpha}{\theta_i}\right)^{\frac{1}{\gamma}} (1-\delta)^{\frac{(1+\gamma)}{\gamma}} (1-b)^{\frac{(1+\gamma-\alpha)}{\alpha\gamma}} (1-\alpha-\beta)^{\frac{(1+\gamma)(1-\beta)-\alpha}{\alpha\gamma}} \left(\frac{\beta}{r}\right)^{\frac{\beta(1+\gamma)}{\alpha\gamma}}}{\mu^{\frac{(1+\gamma)(1-\beta)-\alpha}{\alpha\gamma}}} \tag{27}$$

$$k_t^* = \frac{H_{t-1} A^{\frac{(1+\gamma)}{\gamma\alpha}} \left(\frac{b\alpha}{\theta_i}\right)^{\frac{1}{\gamma}} (1-\delta)^{\frac{(1+\gamma)}{\gamma}} (1-b)^{\frac{(1+\gamma-\alpha)}{\alpha\gamma}} (1-\alpha-\beta)^{\frac{(1-\alpha-\beta)(1+\gamma)}{\alpha\gamma}} \left(\frac{\beta}{r}\right)^{\frac{\beta(1+\gamma)+\alpha\gamma}{\alpha\gamma}}}{\mu^{\frac{(1-\alpha-\beta)(1+\gamma)}{\alpha\gamma}}} \tag{28}$$

and also:

$$l_t^* = \frac{A^{\frac{1}{\gamma\alpha}} \left(\frac{b\alpha}{\theta_i}\right)^{\frac{1}{\gamma}} (1-\delta)^{\frac{1}{\gamma}} (1-b)^{\frac{(1-\alpha)}{\alpha\gamma}} (1-\alpha-\beta)^{\frac{(1-\alpha-\beta)}{\alpha\gamma}} \left(\frac{\beta}{r}\right)^{\frac{\beta}{\alpha\gamma}}}{\mu^{\frac{(1-\alpha-\beta)}{\alpha\gamma}}} - 1 \tag{29}$$

$$e_t^* = \frac{H_{t-1} A^{\frac{1+\gamma}{\gamma\alpha}} \left(\frac{b\alpha}{\theta_i}\right)^{\frac{1}{\gamma}} (1-\delta)^{\frac{1}{\gamma}} (1-b)^{\frac{(1+\gamma-\alpha)}{\alpha\gamma}} (1-\alpha-\beta)^{\frac{(1+\gamma)(1-\beta)-\alpha}{\alpha\gamma}} \left(\frac{\beta}{r}\right)^{\frac{\beta(1+\gamma)}{\alpha\gamma}}}{S_{t-1}\mu^{\frac{(1+\gamma)(1-\beta)-\alpha}{\alpha\gamma}}} - 1 \tag{30}$$

$$m_t^* = \frac{H_{t-1} A^{\frac{(1+\gamma)}{\gamma\alpha}} \left(\frac{b\alpha}{\theta_i}\right)^{\frac{1}{\gamma}} (1-\delta)^{\frac{1}{\gamma}} (1-b)^{\frac{(1+\gamma-\alpha)}{\alpha\gamma}} (1-\alpha-\beta)^{\frac{(1-\alpha-\beta)(1+\gamma)}{\alpha\gamma}} \left(\frac{\beta}{r}\right)^{\frac{\beta(1+\gamma)+\alpha\gamma}{\alpha\gamma}}}{K_{t-1}\mu^{\frac{(1-\alpha-\beta)(1+\gamma)}{\alpha\gamma}}} - 1 \tag{31}$$

From the above the following results can be stated:

Proposition 2 .

a) By supposing that the matching technology function is random, and given the above distribution rule, the decentralized search economy has a unique equilibrium value;

b) the equilibrium is Pareto inefficient and exhibits pecuniary increasing returns in the sense that a small increase in all agents' investments will make everyone better off;

c) when a group of workers (entrepreneurs) increase their investment, entrepreneurs (workers) respond to it, and the equilibrium rate of return of all other workers (entrepreneurs) will increase.

Proposition 2 states only that there is a difference between the competitive equilibrium values and those of a decentralized search economy (equations(26-31)) with the latter being inefficient in the Pareto sense. Moreover, as established at point b), the replacement of the competitive allocation by a costly search activity in the running of the labour market, and the incompleteness of contracts which naturally arises after this substitution, are responsible for the presence of social increasing returns in human and physical capital accumulation, and in the entrepreneurs' investment made in order to improve the working conditions within the firms. This is the first way in which social increasing returns operate. Point c), the last one, states that a stronger form of social increasing returns operates in such an economy. When, for example, a group of entrepreneurs decides to increase their investments in order to improve the working environment endowment, or their investment in physical capital, workers will choose as a response more education, and the rate of return to entrepreneurs who have not invested (or have invested less) will also increase as a result. Obviously the reverse is true: when a group of workers decides to increase investments and firms respond to it, the human capital rate of return of the remaining workers increases. These aspects are strictly related to imperfect matching.

Finally, following Acemoglu [2], if we consider the extreme opposite case, efficient matching, in which workers with the highest human capital level are allocated to firms with the highest physical capital level and with the best working conditions, the allocation of Proposition 2 will be once again the unique equilibrium. Even in this case, workers and entrepreneurs will choose inefficient levels of investment, in the sense that an increase in the latter will make everyone better off. Social increasing returns of the first type are still operating. On the contrary the second kind of social increasing returns (point c) of Proposition 2) disappears since, in efficient matching, an entrepreneur who has invested in physical capital, or to improve the working environment, will never meet a worker who has not invested in human capital[6].

4.2 The case with unemployment.

In this sub-section we will relax the assumption of full employment and make job creation and unemployment endogenous in the above framework. This will introduce a number of new effects and new sources of strategic interactions. In order to present these new results we introduce in our model a further choice for entrepreneurs: whether to be active or not. The cost of becoming active for each entrepreneur is given by the following:

$$CT_t = CT(E_t)H_{t-1} \text{ with } CT' > 0, CT" > 0 \text{ and } \lim_{E_t \to 1} CT_t = +\infty \tag{32}$$

where E_t measures at time t the share of entrepreneurs who decide to be active. Since in this model firms and workers are normalized to one, the parameter E_t identifies the rate of employment in the economy, and consequently $(1 - E_t)$ stands for the unemployment rate and also measures the probability of each worker remaining unemployed. As in Acemoglu[1], we have assumed that the cost of becoming productive depends upon H_{t-1} since entrepreneurs, like workers, have to acquire information about society's stock of knowledge; furthermore it is directly linked to the number of entrepreneurs who have decided to be active at time t since we assume that the congestion of the market implies a much greater cost of acquiring information. In this case the higher is the number of job vacancies available, the lower will be the probability of filling each one. As a consequence, not all the entrepreneurs decide to operate in the market and there will be unemployment among workers. Moreover, as the number of vacancies approaches zero the probability of filling each one approaches one. Because of the assumption that human capital is not productive when unmatched, the worker's expected return will be:

$$W_t = bAE_t h_{i,t}^{\alpha} \int_0^1 k_{j,t}^{\beta} dj \int_0^1 s_{j,t}^{(1-\alpha-\beta)} dj \tag{33}$$

[6]For a rigorous formal proof of this statement see Acemoglu[2].

and hence the equilibrium values may be rewritten as follows:

$$h_t^* = \frac{H_{t-1} A^{\frac{1}{\gamma\alpha}} \left(\frac{bE_t\alpha}{\theta_i}\right)^{\frac{1}{\gamma}} (1-\delta)^{\frac{(1+\gamma)}{\gamma}} (1-b)^{\frac{(1-\alpha)}{\alpha\gamma}} (1-\alpha-\beta)^{\frac{(1-\alpha-\beta)}{\alpha\gamma}} \left(\frac{\beta}{r}\right)^{\frac{\beta}{\alpha\gamma}}}{\mu^{\frac{(1-\alpha-\beta)}{\alpha\gamma}}} \tag{34}$$

$$s_t^* = \frac{H_{t-1} A^{\frac{1+\gamma}{\gamma\alpha}} \left(\frac{bE_t\alpha}{\theta_i}\right)^{\frac{1}{\gamma}} (1-\delta)^{\frac{(1+\gamma)}{\gamma}} (1-b)^{\frac{(1+\gamma-\alpha)}{\alpha\gamma}} (1-\alpha-\beta)^{\frac{(1+\gamma)(1-\beta)-\alpha}{\alpha\gamma}} \left(\frac{\beta}{r}\right)^{\frac{\beta(1+\gamma)}{\alpha\gamma}}}{\mu^{\frac{(1+\gamma)(1-\beta)-\alpha}{\alpha\gamma}}} \tag{35}$$

$$k_t^* = \frac{H_{t-1} A^{\frac{(1+\gamma)}{\gamma\alpha}} \left(\frac{bE_t\alpha}{\theta_i}\right)^{\frac{1}{\gamma}} (1-\delta)^{\frac{(1+\gamma)}{\gamma}} (1-b)^{\frac{(1+\gamma-\alpha)}{\alpha\gamma}} (1-\alpha-\beta)^{\frac{(1-\alpha-\beta)(1+\gamma)}{\alpha\gamma}} \left(\frac{\beta}{r}\right)^{\frac{\beta(1+\gamma)+\alpha\gamma}{\alpha\gamma}}}{\mu^{\frac{(1-\alpha-\beta)(1+\gamma)}{\alpha\gamma}}} \tag{36}$$

and also:

$$l_t^* = \frac{A^{\frac{1}{\gamma\alpha}} \left(\frac{bE_t\alpha}{\theta_i}\right)^{\frac{1}{\gamma}} (1-\delta)^{\frac{1}{\gamma}} (1-b)^{\frac{(1-\alpha)}{\alpha\gamma}} (1-\alpha-\beta)^{\frac{(1-\alpha-\beta)}{\alpha\gamma}} \left(\frac{\beta}{r}\right)^{\frac{\beta}{\alpha\gamma}}}{\mu^{\frac{(1-\alpha-\beta)}{\alpha\gamma}}} - 1 \tag{37}$$

$$e_t^* = \frac{H_{t-1} A^{\frac{1+\gamma}{\gamma\alpha}} \left(\frac{bE_t\alpha}{\theta_i}\right)^{\frac{1}{\gamma}} (1-\delta)^{\frac{1}{\gamma}} (1-b)^{\frac{(1+\gamma-\alpha)}{\alpha\gamma}} (1-\alpha-\beta)^{\frac{(1+\gamma)(1-\beta)-\alpha}{\alpha\gamma}} \left(\frac{\beta}{r}\right)^{\frac{\beta(1+\gamma)}{\alpha\gamma}}}{S_{t-1}\mu^{\frac{(1+\gamma)(1-\beta)-\alpha}{\alpha\gamma}}} - 1 \tag{38}$$

$$m_t^* = \frac{H_{t-1}A^{\frac{(1+\gamma)}{\gamma\alpha}}\left(\frac{bE_t\alpha}{\theta_i}\right)^{\frac{1}{\gamma}}(1-\delta)^{\frac{1}{\gamma}}(1-b)^{\frac{(1+\gamma-\alpha)}{\alpha\gamma}}(1-\alpha-\beta)^{\frac{(1-\alpha-\beta)(1+\gamma)}{\alpha\gamma}}\left(\frac{\beta}{r}\right)^{\frac{\beta(1+\gamma)+\alpha\gamma}{\alpha\gamma}}}{K_{t-1}\mu^{\frac{(1-\alpha-\beta)(1+\gamma)}{\alpha\gamma}}} - 1 \tag{39}$$

from which we may observe that there is a positive linkage between the employment rate and the investment of all agents. The intuition behind this result is the following: the higher the number of entrepreneurs who decide to be active, the better it will be for all workers who experience an increase in their probability to find a job. It follows that workers will decide to invest more in human capital and entrepreneurs will be better off since they have captured the increased productivity of workers, and will increase their investments in physical capital and improve working conditions.

Finally, the equilibrium employment (or unemployment) rate may be easily determined by re-examining entrepreneurs' behaviour. New entries will stop when total firms' returns are equal to their costs, more precisely when:

$$(1-b)Ak_t^{*\beta}s_t^{*(1-\alpha-\beta)}h_t^{*\alpha} - \mu s_t^* - rk_t^* = CT(E_t)H_{t-1} \tag{40}$$

where the left-hand side measures the expected total return net of capital and working environment costs, while the rigth-hand is the total entry cost. By substituting the equilibrium values given by equations (34-36) in equation (40), and introducing a particular entry cost function, it is possible to determine the probable equilibrium rate (s) of employment.

5 A Numerical Example

In order to evaluate the impact that different values of b have on the equilibrium values of l^*, m^*, e^*, h^*, k^* and s^*, we present in this section a numerical example of the random matching version of the model without unemployment, presented in section 4.1. The values of parameters and exogenous variables have been set in a way to achieve a reasonable outcome for the model, and are as follows:

$A = 2$	$\alpha = 0.6$	$\beta = 0.3$	$1-\alpha-\beta = 0.1$
$\delta = 0.015$	$\gamma = 0.8$	$\mu = 0.03$	$r = 0.04$
$\theta = 0.15$	$H_0 = 10$	$S_0 = 4$	$K_0 = 10$

As regards the real interest rate r it seemed quite reasonable to set it at 4% as in Langot F. and M.Pucci[15]. For the depreciation rate δ a value of 1.5% was chosen as estimated by Fève and Langot [14].

From the model with random matching it appears that the parameter b is crucial because it represents the relative bargaining power of workers in sharing total output with the entrepreneur. We let b vary between 0.06 and 0.6, thereby allowing the bargaining power of the workers to increase at each round i by $\Delta b = 0.03$ $(i = 1, 2, 3......., 20)$ from the lowest level up to the highest. At each round both the equilibrium values of the investment in human capital l^*, in physical capital m^*, in working environment e^* and the optimal level of human capital h^*, physical capital k^* and working environment s^* were calculated. In Table 2 these values are expressed in terms of relative changes:

Table 2.

$\frac{l^*(i+1)}{l^*(i)}$	$\frac{m^*(i+1)}{m^*(i)}$	$\frac{e^*(i+1)}{e^*(i)}$	$\frac{h^*(i+1)}{h^*(i)}$	$\frac{k^*(i+1)}{k^*(i)}$	$\frac{s^*(i+1)}{s^*(i)}$
6.76	2.21	2.56	2.31	2.19	2.19
1.92	1.53	1.59	1.61	1.53	1.53
1.49	1.31	1.34	1.39	1.31	1.31
1.33	1.21	1.22	1.28	1.21	1.21
1.24	1.14	1.15	1.21	1.14	1.14
1.19	1.10	1.10	1.17	1.10	1.10
1.15	1.07	1.07	1.14	1.07	1.07
1.12	1.04	1.04	1.12	1.04	1.04
1.10	1.02	1.02	1.10	1.02	1.02
1.09	1.00	1.01	1.08	1.00	1.00
1.07	0.99	0.99	1.07	0.99	0.99
1.06	0.98	0.97	1.06	0.98	0.98
1.05	0.96	0.96	1.05	0.96	0.96
1.04	0.95	0.95	1.04	0.95	0.95
1.03	0.94	0.94	1.03	0.94	0.94
1.02	0.92	0.92	1.02	0.92	0.92
1.01	0.9	0.91	1.01	0.91	0.91
1.01	0.9	0.89	1.01	0.90	0.90
1.00	0.88	0.88	1.00	0.88	0.88
1.00	0.88	0.88	1.00	0.88	0.88

From Table 2 it may be observed that the relative changes for all the variables considered decrease, albeit at a different rate, with the rise of b. As predicted, an increase in the bargaining power works as a disincentive for firms to accumulate physical capital and working environment; so when b rises, the rate of relative change for the variables under the firm's control (m^*, e^*, k^*, s^*) decreases more rapidly than those more strictly controlled by workers (l^*, h^*). In Figure 1 the relative changes for k^*, s^* and h^* are plotted:

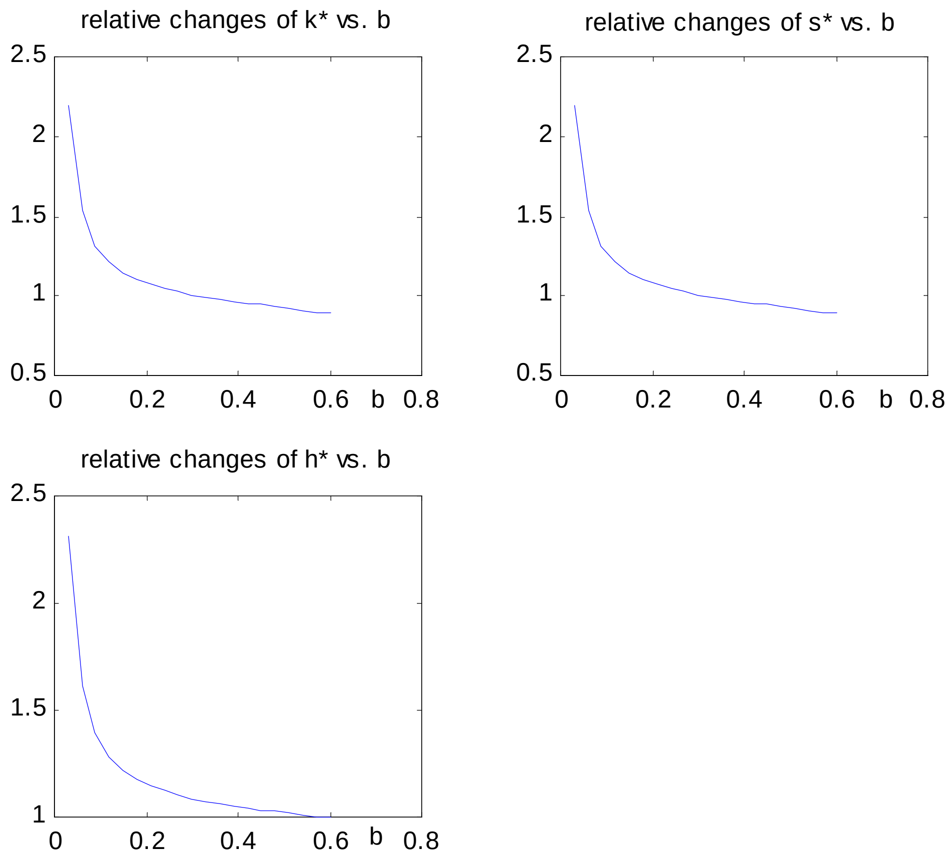

Figure 1.

To better capture the relationship between k^*/h^* and the relative bargaining power b, we proceed to plot it in figure 2; it has a positive relationship for $0.06 \leqslant b < 0.3$,with a maximum for $b = 0.33$ and then a negative relationship for $0.33 < b \leqslant 0.6$. The same type of relationship emerges between s^*/h^* and the relative bargaining power b. Figure 2 also shows elasticity values $\frac{\Delta k^*/k^*}{\Delta h^*/h^*}$ and $\frac{\Delta s^*/s^*}{\Delta h^*/h^*}$ with respect to b, increasing (in absolute value) at increasing rate as the relative bargaining power becomes higher.

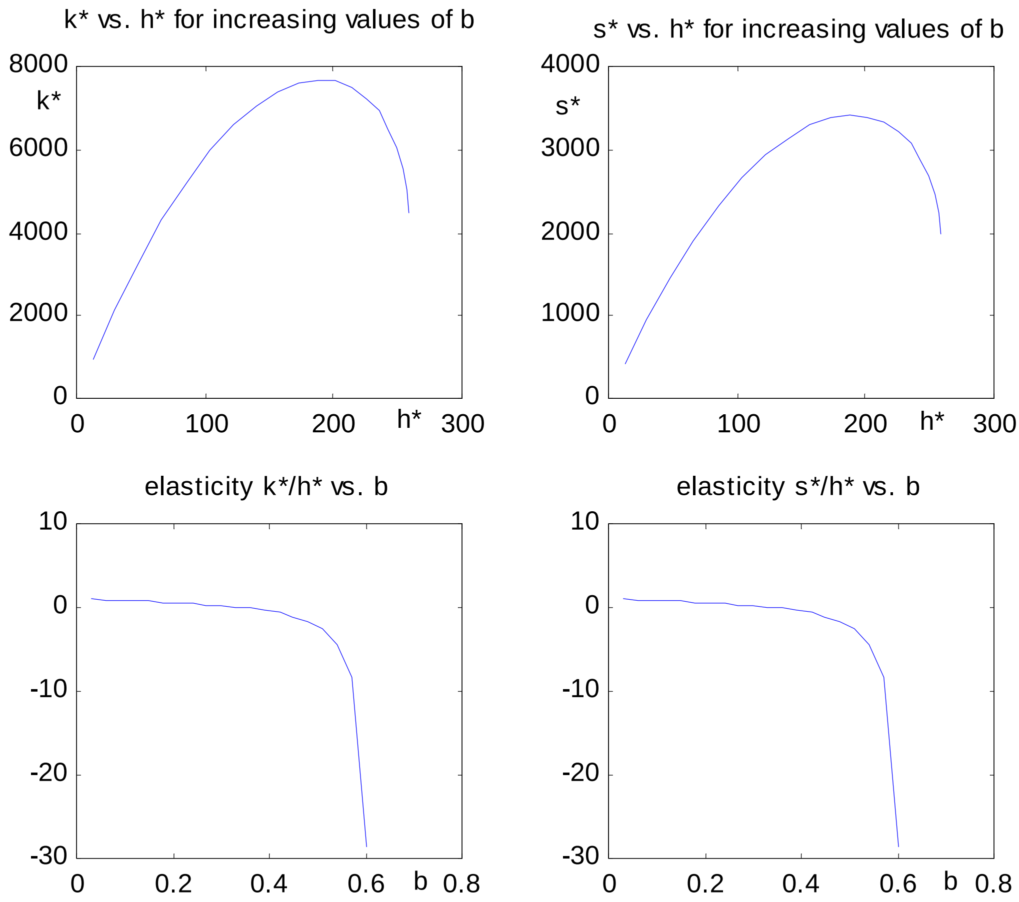

Figure 2.

6 Concluding remarks

This paper has shown that there are social increasing returns not only in human and physical capital but also in investments made in order to improve the working environment endowment within each firm. If, for example, some entrepreneurs decide to offer better working conditions to their employees, workers will choose to invest more in human capital to increase their educational level, and consequently the rate of return will increase for all firms active in the economy, even for those entrepreneurs who have not invested. As we stated above, the reverse is also true, in the sense that if there is a group of workers who decide to invest more in their educational level, entrepreneurs will respond by increasing their investments in physical capital and by offering better working conditions to employed workers. As a consequence, all wages will increase, and workers with a lower human capital level will take advantage of this behaviour. These social increasing returns are not derived from a particular hypothesis made on the production functions, but depend on the running of a labour market characterized by a costly search activity and a matching technology function. What is important is not the total amount of human and physical capital and the working conditions of all firms operating in the product market of the above economy, but the average values since both workers and entrepreneurs base their decisions respectively on the expected values of physical capital and working environment and on the expected human capital level. As already stressed in Acemoglu[1][2] and in Carillo and Vinci[5], this kind of approach is also able to explain the spatial concentration of economic activity and the eventual divergences among countries: regions with higher levels of physical capital and better working conditions may be able to attract workers with higher educational level.

An interesting policy implication is that measures aimed at improving working conditions within firms, for example policies which aim to reduce the probability of being injured on the job or offer a safer working environment to employees, can lead the economy towards an equilibrium with a higher welfare level and with workers and entrepreneurs inclined to invest more respectively in their education and physical capital. These kinds of policies may be adopted in order to reduce the above divergences.

Some extensions of this model are probably worth exploring. It would be useful, among other things, to analyze the effects of an additional source of human capital accumulation: immigration of workers with different educational levels and different attitudes to risk exposure at work.

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7 Appendix

Proof. Proposition 1 ■

a)Since equations (15), (16) and (17) have unique solutions for investments respectively in human and physical capital and in working environment endowment, we will have a unique equilibrium;

b)as all markets are competitive the above equilibrium is obviously Pareto optimal;

c)taking into account equations (4), (7) and (8), the equilibrium values of $l_{i,t}, e_{j,t}$ and $m_{j,t}$ of equations (15),(16) and (17), give unique values for the human and physical capital and for the working conditions within each firm; as a consequence, the three ratios will always be constant.

Proof. Proposition 2 ■

a)When $W_{i,t} = by_{ij,t}$ and $\theta_i = \theta$, equations (26),(27) and (28)uniquely describe equilibrium. The equilibrium values of investments respectively in human and physical capital, and those made in order to improve working conditions within each firm, will directly follow from the accumulation functions (4),(7) and (8);

b)to demonstrate this point let us consider the firm's return given by the following equation: $\Pi = (1-b)Ak_j^{*\beta}s_j^{*(1-\alpha-\beta)}h_i^{*\alpha} - rk_j^* - \mu s_j^*$ and evaluate the effect produced by small changes to the equilibrium values k_j^*, s_j^* and h_i^*. The return of the firm will change in the following way:

$$d\Pi = \left[(1-b)\alpha Ak_j^{*\beta} s_j^{*(1-\alpha-\beta)} h_i^{*(\alpha-1)}\right] dh_i^* + \left[(1-b)\beta Ak_j^{*(\beta-1)} s_j^{*(1-\alpha-\beta)} h_i^{*\alpha} - r\right] dk_j^*$$
$$+ \left[(1-b)(1-\alpha-\beta)Ak_j^{*\beta} s_j^{*-(\alpha+\beta)} h_i^{*\alpha} - \mu\right] ds_j^*$$

from which we observe that the terms multiplied by dk_j^* and by ds_j^* are zero by the f.o.c., while the term multiplied by dh_i^* is positive. This implies that $d\Pi$ is positive and so the effect on the welfare of entrepreneurs will be positive too. A similar reasoning is applied to workers' welfare; they will be made better off too. In a context like this, if the Social Planner should impose the competitive levels, all agents can be made better off, and therefore this equilibrium is inefficient;

c)if we suppose, as in Acemoglu [2] that a proportion m of workers experiences a decrease in θ from θ_1 to θ_2 and considers always the same distribution rules, equation (22) may be rewritten as follows:

$$h_{1,t} = \left[\frac{bA(1-\delta)^{(1+\gamma)} H_{t-1} \alpha k_j^{*\beta} s_j^{*(1-\alpha-\beta)}}{\theta_1}\right]^{\frac{1}{1+\gamma-\alpha}} \quad (22.a)$$

$$h_{2,t} = \left[\frac{bA(1-\delta)^{(1+\gamma)} H_{t-1} \alpha k_j^{*\beta} s_j^{*(1-\alpha-\beta)}}{\theta_2}\right]^{\frac{1}{1+\gamma-\alpha}} \quad (22.b).$$

Evaluating the integrals in equation (18) and (19), from the f.o.c. of the profit maximization problem we have the following:

$$k_{jt}^{\alpha} = \frac{(1-b)A(1-\alpha-\beta)^{(1-\alpha-\beta)}}{\mu^{(1-\alpha-\beta)}} \left(\frac{\beta}{r}\right)^{(\alpha+\beta)} \left[(1+m)h_{1,t}^{\alpha} + mh_{2,t}^{\alpha}\right] \quad (I)$$

$$s_{jt}^{\alpha} = \frac{(1-b)A(1-\alpha-\beta)^{(1-\beta)}}{\mu^{(1-\beta)}} \left(\frac{\beta}{r}\right)^{\beta} \left[(1+m)h_{1,t}^{\alpha} + mh_{2,t}^{\alpha}\right] \quad (II).$$

If we divide equation (22.a) by (22.b) and substitute (I) and (II) in the f.o.c. we obtain:

$$\frac{k_{jt}^{\alpha}}{h_{it}^{\alpha}} = \frac{(1-b)A(1-\alpha-\beta)^{(1-\alpha-\beta)}}{\mu^{(1-\alpha-\beta)}} \left(\frac{\beta}{r}\right)^{(\alpha+\beta)} \left[(1+m) + m\left(\frac{\theta_1}{\theta_2}\right)^{\frac{\alpha}{1+\gamma-\alpha}}\right] \quad (III)$$

$$\frac{s_{jt}^{\alpha}}{h_{it}^{\alpha}} = \frac{(1-b)A(1-\alpha-\beta)^{(1-\beta)}}{\mu^{(1-\beta)}} \left(\frac{\beta}{r}\right)^{\beta} \left[(1+m) + m\left(\frac{\theta_1}{\theta_2}\right)^{\frac{\alpha}{1+\gamma-\alpha}}\right] \quad (IV)$$

which demonstrates that both the physical capital to human capital ratio and the working environment endowment to human capital ratio for workers who have not modified their cost of acquiring human capital increase with m.

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