Job Matching, Technological Progress and Worker-Provided On-the-job Training

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Abstract

According to data from the OCDE, almost one third of the total quantity of on-the-job training is worker-provided. The aim of this paper is to study, in a labor market characterized by frictions, the effects of technological progress on the optimal worker-provided on-the-job training. The paper shows that the greater the technological progress rate less is the probability of the worker investing in specific human capital, if the technology is of creative destruction type, and the greater is the probability of the worker investing specific human capital, if the technology is characterized by renovation; whilst the effect over the general human capital investment doesn't exist in both models. The paper also shows that the impact of human capital investments on labor market outcomes depend on the type of investment – either firm or the market oriented. If the investment is totally aimed at the market, we have as a result an increase in the rate of unemployment, whilst if the investment is totally directed at the firm, we have the opposite effect.

Resumo

De acordo com dados da OCDE cerca de um terço da quantidade total de investimentos em treinamento é financiada pelos trabalhadores. O objetivo principal deste artigo é o de investigar, em um mercado de trabalho caracterizado por fricções, os efeitos de variações na taxa de crescimento econômico sobre a decisão ótima de investimento em treinamento. Veremos que quanto maior for a taxa de crescimento econômico menor será a probabilidade do trabalhador investir em capital específico, caso o progresso tecnológico seja do tipo *creative destruction*, e maior será a probabilidade do trabalhador investir em capital específico, se no progresso tecnológico for permitida a renovação. Por sua vez, temos que o efeito sobre a decisão de investimento em capital geral é inexistente em ambos os modelos. Veremos ainda que os efeitos do investimento em treinamento sobre o mercado de trabalho dependem do tipo do investimento realizado– se totalmente voltado para a firma ou totalmente voltado para o mercado. Se o investimento for totalmente orientado para o Mercado, teremos como resultado um aumento na taxa de desemprego, enquanto que se o investimento for totalmente orientado para a firma, teremos o efeito oposto.

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Palavras-chave: Criação e Destruição de Empregos, Desemprego, Capital Humano.
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1. Introduction

Certainly, one of the least questioned facts in economic literature is the negative effects of higher technological progress rates on human capital stock. The usual argument is that the higher the economic growth the quicker the general and specific capital stocks lose value, due to the obsolescence created by the introduction of new knowledge and new production techniques[1].

However, this agreement is no longer clear if, in contrast to the effect of technological progress rate over human capital stock, we focus on the effect of growth over the human capital investment decisions.

Gould (2002), for example, defended that the highest technological progress rates verified in the last years created an increase in the demand for general human capital[2], due to the greater adaptation of this type of investment to the constant changes implied by technical progress; whilst Murnane, Willett e Levy (1995) defended, contrary to Gould, that given the high obsolescence levels created by higher growth rates it would be more advantageous to invest in specific human capital, rather than in general human capital[3]. The existence of skill biased technological change also creates incentives for people to acquire general human capital (general schooling but also computer skills) that protected them from negative shocks coming from higher labor demand for those skills.

The main objective of this paper is to approach these contradictory predictions, attempting to answer questions such as: given higher technological progress rates, what will be the best investment for the worker? What will be the impact of this decision on labor market outcomes, namely the unemployment rate?

However, one aspect of great importance to the labor market, and which should necessarily be considered in attempting to answer these previous questions, is the understanding of the relationship between technological progress and the dynamics of creation and destruction of jobs in a frictional labor markets[4].

In a seminal paper on the relationship between economic growth and the process of creation and destruction of jobs, in a frictional labor market, Mortensen and Pissarides (1998) defended that if technological progress is of the creative destruction type[5], the effect of a positive variation in the technological progress rate would be an increase in the unemployment rate.

The idea defended by the authors was that once a match has been formed, the firm would take on the costs of physical and human capital investments, in order to use the highest available technology in its production. However, once production began, the firm would not be able to change its human and physical capital stocks in order to accompany the technological frontier.

The consequences of this rigidity would be a progressive reduction in the productivity of the match, vis-à-vis new formed matches, at a rate proportional to the technological

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[1] Weiss and Lillard (1978), Welch (1970), MacDonald and Weisbach (2004) and Bartel and Sicherman (1998) defended these points.

[2] Mincer (1989) and Bartel and Sicherman (1998) also defended this idea.

[3] Welch (1970) and Bartel and Lichtenberg (1987) also defended this argument.

[4] See Pissarides (2000) for a complete justification of this argument.

[5] See Pissarides (2000) and Aghion and Howitt (1992) for a characterization of the creative destruction technological progress.

progress and an increase in the unemployment rate, due to the combination of the low incentives to create new vacancies with a higher obsolescence rate of the existing matches.
If the technological progress has the possibility of renovation, the authors showed that since the firm has the possibility to jump onto the technological frontier, undertaking the costs related to the physical and human capital renovation, this results in a fall in unemployment, due to a combination of renovation and increase in the creation of new vacancies.
In this manner, and considering both previous scenarios, Mortensen and Pissarides concluded that the impact of changes on the technological progress rate on the labor market depends on the firm decision on the type of technological progress: either to renew or not its production technology.
However, Mortensen and Pissarides considered that all decisions were taken by the firm, not taking into account any decision made by the worker[6].
In this manner, the aim of this paper is to add to the literature on the impact of technological progress on the labor market, the workers` decision to invest in training.
The basic model is based on Mortensen and Pissarides, with the introduction of on-the-job training.
We will consider (as in Mortensen and Pissarides) that the production technology is fixed at the highest existing level at the moment the match is formed. However, we will also assume that the worker may decide in a unilateral manner whether or not to invest in human capital, generating an increase in the match productivity. The workers have also to decide if the training is match oriented (specific human capital), market and match oriented (general human capital that is useful both inside the firm and in other firms) or market oriented (general human capital that is only useful at other firms).
We will see that if the worker invests in human capital totally directed at the market the result will be an increase in the unemployment rate, whilst if the investment is match specific we will have the opposite effect.
We will also see that the previous result is also obtained if we consider a different kind of technological progress – renovation – instead of a creative destruction type.
In fact, if growth is of the creative destruction form the greater the technological progress rate the less will be the incentive for the worker to invest in specific human capital. However, if we consider the possibility of renovation, we will have the opposite effect, as defended by Murnane, Willett e Levy. The effect of technological progress on human capital investment totally targeted at the market is inexistent in both models, as the investment benefits and costs will be equally affected[7].
This paper is carried out in the following manner. In the next section we will briefly review the literature on job matching and worker-provided on-the-job training. Section three presents the creative destruction and renovation models. In section 4 we will carry out two empirical exercises, whilst in the last section we present the main conclusions.

2. Job Matching and Worker-Provided On-the-job Training

Several authors have already investigated the impact of human capital investment on the labor market. However, little has been carried out concerning the subject of the optimum

[6] According to OCDE (2003) about one third of the total on-the-job training is worker-provided.
[7] Bartel and Sicherman (1998) also verified the ambiguity created by technological rate variations over training investment decisions.

level of worker-provided human capital investments in a frictional labor market[8]. Exceptions to this are Acemoglu (1997), Moen (1999) and Laing, Palivos and Wang (2003).

Especially interested in the theme of inefficiency, Acemoglu approached the question of the optimum level of physical and human investments both in a perfect and imperfect labor market.

The author verified that if the labor market is imperfect and human capital investment is totally targeted at the market, the investment level will be inefficient due to the positive externality created by the worker's decision over the remaining firms in the market. Acemoglu defended that as the worker is unfamiliar with his future employer, at the moment when he invests in human capital, we will have as a result low levels of investment, as the worker would not get all the benefits created by his decision.

Acemoglu also argued that the greater the process of innovation, the larger would be the human capital investments, although this increase would not be enough to solve the problem of inefficiency.

Moen is also interested in the question of inefficiency. He developed a model aiming to study the impact of human capital investments on the probability of finding a new job. According to Moen, when a worker invests in general human capital it creates a positive externality over the remaining firms in the market, as well as a negative externality over the remaining workers, and the efficiency problem depends on the magnitude of both effects.

Moen shows that as the numbers of new job offers depend on the worker education and on the volume of unemployed workers searching for a job, the greater the competition for jobs the greater will be the probability of a worker investing in human capital.

In its turn, Laing, Palivos and Wang developed a model that considers human capital investments as the basic source of economic growth. According to these authors, the worker invests in human capital in order to follow the knowledge boundary showing that, given the presence of generations, there will always be groups with obsolete human capital co-living with groups with the highest level of human capital.

We consider in the model formulation both the presence of the externality defended in the papers of Acemoglu and Moen, as well as the interaction between human and physical capital investments. However, there are some differences between the proposed model and the previous ones.

Firstly, we will consider a more generic formulation for human capital, where the worker can invest in three types of human capital: human capital totally targeted at the market, without any value for the firm, human capital totally targeted at the firm, without any value for the remaining firms in the market or human capital with value for the market and for the firm, as defended Kuhn and Sweetman (1999)[9].

Secondly, we will consider two types of technological progress: creative destruction and renovation.

Thirdly, we will put apart the effects of human capital investments on the probability of getting a new job while unemployed, concentrating basically on the income incentives generated by the investment for the employed worker.

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[8] See Leuven (2005) for a on-the-job training survey and Bishop (1997) for a survey on employed-provided training.

[9] Stevens (1994) also suggested the need for distinct formats to the traditionally adopted to human capital.

Finally, we will focus on the question of the optimum rule of investment instead of the question of efficiency, already widely approached in the literature.

3. Theoretical Models

In this section we will develop two theoretical models, whose basic difference lies on the form of technological progress: creative destruction or renovation.

3.1. Creative Destruction

The economy is formed by a constant population of workers, who live infinitely, and a great number of firms, which once matched, one by one, give way to a production activity. The firms and the workers are risk neutral and discount the future at an exogenous and constant rate r.

Before production, firms and workers are involved in a search process to find a partner, where $P(t)c$ measures the search cost for the firm and $P(t)=e^{gt}$ represents a common growth factor.

After finding a production partner the firms fix their production technology, which cannot be updated in the future.

The amount of job matches formed per period of time t is given by a nonnegative, concave, homogeneous of degree one and increasing in both arguments function $m(v,u)$, where v represents the vacancy rate and u the fraction of unemployed workers in the economy.

The unemployed workers move to an employed situation according to a Poisson Process with an arrival rate $\theta q(\theta)$, whilst a job vacancy moves towards a filled position also according to a Poisson Process with an arrival rate $q(\theta)$, where θ represents the ratio of v and u.

An occupied job may be destroyed due to an idiosyncratic shock which follows a Poisson Process with arrival rate λ.

Let $P(\tau)x$ represent the production generated, in each time t, by a job matching formed in moment τ and which later once production has begun, the workers may decide whether they invest or not in human capital, at the cost $P(t)z$, and the final destination of his investment – firms, market or both.

Suppose that, if the investment is totally targeted at the firm, there is an increase of $\varphi P(\tau)x$ in the productivity of the ongoing job matching, whilst if the investment is totally targeted at the market, there is both an increase of $\delta P(t)x$ in the productivity of the future job matching of that worker who invests and an increase of $\delta P(t)\varepsilon x$ in the opportunity cost of the job for this same worker[10].

Consider that if the investment in human capital is totally targeted at the firm, the production of the job matching is less than the production obtained at the highest technological level.

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[10] Also suppose that $\delta \in (0,1)$ and $\varphi \in (0,1)$.

Let $V(t)$ and $J(\tau,t)$ represent both the values of a vacancy and a job occupied in moment τ, to the firm, whilst $U(t)$ and $W(\tau,t)$ represent the values of unemployment and employment of a job created at moment τ, to the worker.

In this manner, the value function for the firm and the worker are given by:

(1) $$rV(t) = -P(t)c + q(\theta)\left[J(t,t) - V(t)\right] + \dot{V}(t);$$

(2) $$rU(t) = P(t)\varepsilon x + \theta q(\theta)\left[W(t,t) - U(t)\right] + \dot{U}(t);$$

(3) $$rJ(\tau,t) = Max\begin{Bmatrix} P(\tau)x\left[1+\delta(1-\psi)_{v,s}\right] + \alpha_{\tau,t}\psi_{\tau,t}\varphi P(\tau)x - \\ w(\tau,t) - \lambda\left[J(\tau,t) - V(t)\right] + \dot{J}(\tau,t);\ \ rV(t) \end{Bmatrix};$$

(4) $$rW(\tau,t) = Max\begin{Bmatrix} w(\tau,t) - \alpha_{\tau,t}P(t)z - \lambda\left[W(\tau,t) - U(t)\right] + \dot{W}(\tau,t); \\ rU(t) + (1-\psi)_{v,s}\,\delta P(t)\varepsilon x + \alpha_{\tau,t}(1-\psi)_{\tau,t}\,\delta P(t)\varepsilon x \end{Bmatrix};$$

where $\alpha_{\tau,t}$ is a variable that represents the decision to invest in human capital, in moment t, at a job created at τ; $w(\tau,t)$ is his wage rate at moment t, in a job created at τ; $P(t)\varepsilon x$ is the opportunity cost of the job and ψ measures the impact of the human capital investment over the ongoing matching[11].

We can observe from the previous equations that if the worker invests in human capital and chooses $\psi = 0$, his investment is totally directed at the market, not affecting the productivity of his actual job matching. On the other hand, if he chooses $\psi = 1$, his investment is totally directed at the actual job, affecting exclusively the productivity of his current job matching, whilst if he chooses $\psi \in (0,1)$, his investment affects both the productivity of his future job matching and the productivity of his actual job, at rates ψ and $(1-\psi)$, respectively[12].

In this way, the previous expressions tell us that if the worker has invested, at the time s of his previous job, $(1-\psi)$ in human capital, his current job matching will be $\delta(1-\psi)P(\tau)x$ more productive than another job matching formed with that firm and a worker that has not invested in human capital targeted at the market.

In turn, if the worker decides to invest, at the moment t of his current job matching, ψ in human capital directed at his actual job, his actual matching will be $\psi\varphi P(\tau)x$ more productive than another job matching made by a similar firm and a worker that doesn't take such level of investment.

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[11] We will also suppose throughout the paper that $\psi \in [0,1]$, $\varepsilon \in [0,1)$ and $r + \lambda > g$, so that exists strictly positive advantages for the existence of the job matching and the effective discount rate is positive.

[12] Note that when a worker loses his job he returns to search process in order to find another job.

An interesting aspect that we can observe from the previous expressions is that the human capital investments affect not only the actual job matching, but also the future job matching that the worker who invests might obtain, if he doesn't invest totally to his current job matching.
Considering the usual hypothesis of free entry, we have from (1), that

(5) $$\frac{J(t,t)}{P(t)} = \frac{c}{q(\theta)}.$$

In words, there is job creation up to the point where the value of a new job matching equals the search cost, expressed in terms of the rate that this vacancy becomes filled.
Supposing that the surplus generated by the matching is divided according to the Generalized Nash Bargaining Solution[13], where β represents the worker´s bargaining strength, then $w(\tau,t)$ satisfies:

(6) $$\beta\left[J(\tau,t)-V(t)\right]=(1-\beta)\left[W(\tau,t)-U(t)\right].$$

Using (1) – (6), we have that

(7) $$w(\tau,t)=\beta\left\{P(\tau)x[1+\delta(1-\psi)_{v,s}+\alpha_{\tau,t}\psi_{\tau,t}\varphi]\right\}+ (1-\beta)P(t)\left\{\omega(\theta)+\alpha_{\tau,t}\left[z+\delta\left(1-\psi\right)_{\tau,t}\varepsilon x\right]\right\},$$

where

(8) $$\omega(\theta)=\varepsilon x[1+\delta\left(1-\psi\right)_{v,s}]+\frac{\beta c\theta}{\left(1-\beta\right)}.$$

Note from the previous expressions that the wage rate is formed by two terms. The first one is related to the worker´s productivity in the current job, whilst the second one is related to his outside option.
We can also observe from (7) and (8) that if $\alpha=1$ the greater will be the worker´s wage, for a given technological progress rate.
Also note from the previous expressions that the greater the technological progress rate the greater will be the worker´s wage rate and that the firm pays part of the costs of human capital investment[14].

Lemma 1 Suppose, in a stationary setting, that if the costs of human capital investments are equal to the benefits, the worker decides to invest in human capital. Then, given ψ, if:

[13] See Binmore, Rubinstein and Wolinsky (1986) concerning the use of Nash Bargaining in job search models.
[14] Note that the firm is forced to pay part of the investment costs in human capital, due to the increase in the worker's outside option originated by the investment.

a) $\beta\psi\varphi P(\tau)x+(1-\beta)P(t)\delta(1-\psi)\varepsilon x \geq \beta P(t)z,$ the worker invests in human capital;

b) $\beta\psi\varphi P(\tau)x+(1-\beta)P(t)\delta(1-\psi)\varepsilon x < \beta P(t)z,$ the worker does not invest in human capital[15].

The previous lemma tells us that the worker will invest in human capital whenever the benefits are greater than the costs of the investment.
We can also see that if we consider that the advantages of investing in human capital totally targeted at the firm are larger than the advantages of investing in human capital totally targeted at the market, then we will have the worker investing in human capital whenever $\varphi P(\tau)x \geq P(t)z$.
In this way, the greater the technological progress rate less will be the probability that the worker invests in human capital towards the firm.
In its turn, if we consider that the advantages to invest in human capital totally targeted at the firm are smaller than the advantages to invest in human capital totally targeted at the market, then we will have the worker investing in human capital whenever $(1-\beta)P(t)\delta\varepsilon x \geq \beta P(t)z$.
Note, in this last case, that technological progress does not affect the probability of investment in human capital totally towards the market.

Lemma 2 Suppose, in a stationary setting, that $\alpha = 1$ and that the worker invests in perfect general human capital if indifferent between investing totally to the firm or totally to the market. In this way, if:

a) $\beta\varphi P(\tau)x > \beta\delta P(\tau)x + 2(1-\beta)\delta P(t)\varepsilon x,$ the worker invests in human capital totally targeted at the firm;

b) $\beta\varphi P(\tau)x < \beta\delta P(\tau)x + 2(1-\beta)\delta P(t)\varepsilon x,$ the worker invests in human capital totally targeted at the market;

c) $\beta\varphi P(\tau)x = \beta\delta P(\tau)x + 2(1-\beta)\delta P(t)\varepsilon x,$ the worker invests in perfect general human capital[16].

The previous lemma tell us that, once a worker has decided to invest, if the advantages of investing in human capital totally targeted at the market are greater than the advantages of investing in human capital totally targeted at the firm, the worker will always decide to invest towards the market.
Also note that for the worker to invest in human capital totally directed at the firm it is necessary that the benefits of this investment exceed the benefits that the worker obtains with the higher opportunity cost of the job, if his investment is totally directed at the market.
Also observe that, given the structure of the model, the worker also compares the benefits received with those which he would have received, had he invested in his previous job in

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[15] To show the previous lemma we only need to substitute (7) in (4) and differentiate it in function of α.
[16] As before, we only need to substitute (7) in (4) and differentiate it in function of ψ.

human capital totally directed at the firm. In other words, the worker also considers the benefits related with the greater opportunity cost of the job and those related to the higher productivity of the actual job matching given the investment carried out in the previous period.
The basic reason for the inclusion of these two latter terms in the worker's decision rule is due to the backward looking structure of the model. In this manner, the worker takes into account what he ceases to receive now and what he would cease to receive had he not invested in human capital totally directed at the market in his previous job.

Proposition 1 Let $\beta = (1-\beta)$ and $\frac{\varphi P(\tau)x}{P(t)} \geq z = \delta\varepsilon x$. Then, if:

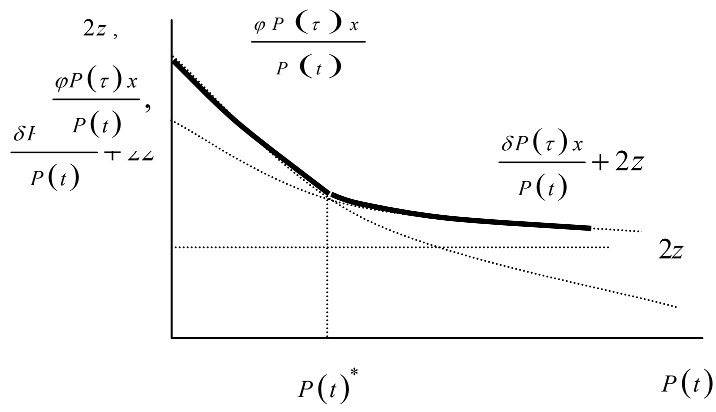
a) $\frac{\varphi P(\tau)x}{P(t)} > \frac{\delta P(\tau)x}{P(t)} + 2z$, the worker invests in human capital totally targeted at the firm;

b) $\frac{\varphi P(\tau)x}{P(t)} < \frac{\delta P(\tau)x}{P(t)} + 2z$, the worker invests in human capital totally targeted at the market;

c) $\frac{\varphi P(\tau)x}{P(t)} = \frac{\delta P(\tau)x}{P(t)} + 2z$, the worker invests in perfect general human capital.

For a better understanding of the optimal investment rule as well as the effects of the technological progress rate over it, let us consider a particular situation where the cost of human capital investments is low and $\varphi > \delta$. In this case, the optimum investment rule, for different values of $P(t)$, is given by darker line in the figure below.

Figure 1



Note that for values less than $P(t)^*$ the human capital investment is totally targeted at the firm. At $P(t)^*$ the investment is in general human capital, whilst on the right of $P(t)^*$ the investment is totally targeted at the market.

In this way, the optimum investment rule will depend on the relative behavior of the last expressions represented in the figure. The greater z is less is the probability that the worker has of investing in human capital. In turn, the greater are the net benefits of the investment totally targeted at the firm vis-à-vis the investment totally directed at the market the greater is the probability that the worker invests totally to the firm.
Once presented the optimum worker human capital investment rule, we will now see the optimum job creation and job destruction rules. From (3) and (5) we have that

(9) $$J=(1-\beta)x[1+\delta(1-\psi)+\alpha\psi\varphi]\int_0^T[1-e^{g(t-T)}]e^{-(r+\lambda)t}.dt;$$

(10) $$J=\frac{c}{q(\theta)};$$

(11) $$x[1+\delta(1-\psi)+\alpha\psi\varphi]=e^{gT}[\omega(\theta)+\alpha z+\alpha\delta(1-\psi)\varepsilon x];$$

characterize the optimum life of a job, T, in terms of market tightness and human capital investment decisions, and the optimum job creation rule in a stationary setting[17].

Proposition 2 Assume that $\varepsilon=0$, the human capital investment costs are low, so that the worker always invests in training, and that the benefits received are such that the investment is in perfect general human capital. In this way, if there is a change in the relative benefits received by the investment, in a manner that ψ varies to:

a) $\psi=1$, then the effects of human capital investment are a reduction in the job destruction and an increase in the job creation dynamics;
b) $\psi=0$, then the effects of human capital investment are an increase in the job destruction and a reduction in the job creation dynamics[18].

The idea behind the previous result is that when there is human capital investment the worker's wage rate will be greater, which induces a greater obsolescence rate, without necessarily existing an increase in the job matching productivity.
In this way, if investment suddenly starts to be totally directed at the firm the worker's investment decision leads to a reduction in the job destruction flow and an increase in the job creation process, as the effect of the increase in the wage rate are lower than the effect of a higher job matching productivity generated by the investment. In turn, if the investment starts to be totally directed at the market we will have the opposite effect.
If the investment continues to be at a rate $\psi=1-\psi$ the gains and losses created by the worker's decision doesn't change and, as a result, his decision will not affect the initial dynamics of creation and destruction of jobs.

[17] Note that given optimal human capital investment decisions (9) – (11) determine uniquely the equilibrium in $T-\theta$ space.

[18] We only need to differentiate (9) and (11) in terms of ψ, consider (10) and Lemma 2 to demonstrate the previous result.

Now, as in the steady state the job creation flow equals the job destruction flow, we have that

(12) $$JC = \theta q(\theta)u = \lambda(1-u) + e^{-\lambda T} JC = JD,$$

where JD represents job destruction and JC job creation.
In this way, we have that

(13) $$u = \frac{\lambda}{\lambda + \theta q(\theta)\left(1 - e^{-\lambda T}\right)},$$

represents the equilibrium unemployment rate.
We can observe from the previous equation that the entire effect of human capital investments over the unemployment rate occurs via θ and T. In this manner, the less is θ or T the higher will be the unemployment rate.

3.2. Renovation

Suppose the scenario where renovation is possible. The idea now is that if the worker invests in human capital totally targeted at the firm the actual job matching jumps to the technological boundary[19]. In this manner suppose that

(14) $$rV(t) = -P(t)c + q(\theta)\left[J(t,t) - V(t)\right] + \dot{V}(t);$$

(15) $$rU(t) = P(t)\varepsilon x + \theta q(\theta)\left[W(t,t) - U(t)\right] + \dot{U}(t);$$

(16) $$rJ(\tau,t) = Max\left\{\begin{matrix} P(\tau)x\left[1 + \delta(1-\psi)_{v,s}\right] + \alpha_{\tau,t}\psi_{\tau,t}P(t-\tau)x - \\ w(\tau,t) - \lambda\left[J(\tau,t) - V(t)\right] + \dot{J}(\tau,t); \;\; rV(t) \end{matrix}\right\};$$

(17) $$rW(\tau,t) = Max\left\{\begin{matrix} w(\tau,t) - \alpha_{\tau,t}P(t)z - \lambda\left[W(\tau,t) - U(t)\right] + \dot{W}(\tau,t); \\ rU(t) + (1-\psi)_{v,s}\delta P(t)\varepsilon x + \alpha_{\tau,t}(1-\psi)_{\tau,t}\delta P(t)\varepsilon x \end{matrix}\right\};$$

are the worker and firm value functions.
Note from the previous expressions that if the worker invests in human capital and chooses $\psi = 1$, his actual matching will jump to the highest level of technology existent in this moment[20].
Given the hypothesis that the surplus generated by the matching is divided according to the Generalized Nash Bargaining, we have that:

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[19] The model in this section is similar to the previous one in all aspects, except in the technological progress definition.
[20] Cavalcanti (2004) used a similar idea to study the effects of layoff costs, which increase with tenure, over the labor market.

$$(18)\qquad w(\tau,t)=\beta\left\{P(\tau)x[1+\delta(1-\psi)_{v,s}]+\alpha_{\tau,t}\psi_{\tau,t}P(t-\tau)x\right\}+ (1-\beta)P(t)\left\{\omega(\theta)+\alpha_{\tau,t}\left[z+\delta\left(1-\psi\right)_{\tau,t}\varepsilon x\right]\right\},$$

represents the wage rate received in a job matching created at τ, where $\omega(\theta)$ is also given by (8).

Note, the same as before, that the worker's wage is given by two terms, one representing his outside options and the other his productivity.

We can also observe that the worker´s wage grows with technological progress, due to the increase in the second term of the right hand side of the previous expressions. However, and contrary to before, the first term of the right hand side may also increase at the technological progress rate, if the worker does not invest in human capital totally directed at the market.

Using the same previous argument, we have that whenever the benefits with human capital investment totally targeted at the firm exceed those obtained with the investment totally directed at the firm, the worker will carry out this investment, as the next proposition clarifies:

Proposition 3 Let $\beta=(1-\beta)$ and $\frac{P(t-\tau)x}{P(t)}\geq z=\delta\varepsilon x$. Then, if:

a) $\frac{P(t-\tau)x}{P(t)}>\frac{\delta P(\tau)x}{P(t)}+2z$, the worker invests in human capital totally targeted at the firm;

b) $\frac{P(t-\tau)x}{P(t)}<\frac{\delta P(\tau)x}{P(t)}+2z$, the worker invests in human capital totally targeted at the market;

c) $\frac{P(t-\tau)x}{P(t)}=\frac{\delta P(\tau)x}{P(t)}+2z$, the worker invests in perfect general human capital.

Proof Differentiating the wage equation in terms of α and ψ, and considering $\beta=(1-\beta)$, we have that if:

$\psi P(t-\tau)x+P(t)\delta\left(1-\psi\right)\varepsilon x\geq P(t)z$ and $P(t-\tau)x>\delta P(\tau)x+2\delta P(t)\varepsilon x$, the worker invests in human capital totally directed at the firm;

$\psi P(t-\tau)x+P(t)\delta\left(1-\psi\right)\varepsilon x\geq P(t)z$ and $P(t-\tau)x<\delta P(\tau)x+2\delta P(t)\varepsilon x$, the worker invests in human capital totally directed at the market;

$\psi P(t-\tau)x+P(t)\delta\left(1-\psi\right)\varepsilon x\geq P(t)z$ and $P(t-\tau)x=\delta P(\tau)x+2\delta P(t)\varepsilon x$, the worker invests in perfect general human capital.

Finally, considering $\frac{P(t-\tau)x}{P(t)}\geq z=\delta\varepsilon x$, we demonstrate the proposition. ■

We can observe from the previous result that the greater the technological progress rate the greater will be the probability of the worker investing in human capital totally targeted at the firm, whilst its effects will be nil if the investment is totally directed at the market.
Note that the results are similar to those previously obtained. The only difference is that the investment in human capital totally targeted at the firm that happens now is more likely to occur at higher technological progress rates, contrary to the creative destruction scenario, where it was more likely to occur at lower rates.
Using (14) - (18) we have that T and θ are determinate by[21]:

(19) $$J=(1-\beta)x[1+\delta(1-\psi)+\alpha\psi e^{gT}]\int_0^T[1-e^{g(t-T)}]e^{-(r+\lambda)t}.dt\,;$$

(20) $$J=\frac{c}{q(\theta)}\,;$$

(21) $$x[1+\delta(1-\psi)]=e^{gT}[\omega(\theta)+\alpha z+\alpha\delta(1-\psi)\varepsilon x-\alpha\psi x]\,.$$

Proposition 4 Assume that $\varepsilon=0$, the human capital investment costs are low, so that the worker always invests in training, and that the benefits received are such that the investment is in perfect general human capital. In this way, if there is a change in the relative benefits received by the investment, in a manner that ψ varies to:

a) $\psi=1$, then the effects of human capital investment are an increase in the job creation and a complete renovation of the job matching;
b) $\psi=0$, then the effects of human capital investment are an increase in the job destruction and a reduction in the job creation dynamics.

Note that the results are also similar to those obtained above[22]. The main differences between the two models are:
- Considering renovation, if the investment is in human capital totally targeted at the firm, the production technology will jump to the technological boundary, implying a complete renovation of the job matching, whilst if the technological progress is of the creative destruction type this adjustment is merely partial;

- the higher the technological progress rate, the greater is the probability of the worker investing in human capital totally directed at the market, if the technology is of creative destruction type, and the greater is the probability of the worker investing in human capital totally targeted at the firm, if technology admits renovation.

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[21] Note that as (19) does not depends on T by the Envelop Theorem, whilst (21) is decreasing in θ, the equilibrium exists and is unique in $T-\theta$ space.
[22] Note that as the expression that determines the unemployment rate in the case of renovation continues to be given by (14), the results are identical in both models.

4. Empirical Exercises

We will develop in this section two empirical exercises intending to validate the model results. Initially we will estimate the impact of the technological progress rate on the probability of a worker investing in human capital totally targeted at the firm. The idea here is to verify if a greater growth rate implies an increase or a fall in the probability of a worker investing in human capital totally directed at the firm, supporting the model with renovation or the model with creative destruction technological progress.
In the next section we will also develop a numerical exercise to verify the impact of changes in the investment costs on the investment decisions by workers and its impact on the labor market.

4.1. Econometric Estimation

The model in the previous section showed that, if the benefits of human capital investments totally directed at the firm were greater than those benefits obtained from the investment completely targeted at the market, we should expect a greater technological progress rate to be associated with a lower probability of worker investment in match-specific human capital, if the technological progress were of creative destruction type. On the contrary, if renovation was possible, a greater technological progress rate should go along a larger probability of worker invests in match-specific human capital.
In this section, we use the European Community Household Panel (ECHP)[23] data base for Portugal, between the period 1995 – 1999, to demonstrate empirically what is estimated effect.
We use this data base basically due to the ability to follow the human capital investment decisions by workers over time.
Another important reason for using this data base is that it allows us to isolate all training decisions paid by the government and the firm, from those completely paid by the worker.
In order to obtain the information on the human capital investment decision totally financed by the worker, we considered the question of the ECHP concerning training participations which occurred in the previous year[24] and which were not financed by the government or by the firm.
We use data from the unemployment workers, leaving training decisions by unemployment workers out of our empirical models, since we are only interested in on-the-job training.
We also used data related with the firm, the worker and the match, in order to identify the main reasons that determine the human capital investment decisions[25].
The estimated econometric model is given by

(15) $$y^{*}_{i,t} = x_{i,t}\beta + c_i + e_{i,t},$$

[23] See Eurostat (2003) for a complete characterization of the ECHP.
[24] More specifically, we considered the question: "Have you been at any time since the last year in vocational education or training, including any part-time or short course?"
[25] The technological progress rate effects over the human capital investment decisions are obtained from the Instituto Nacional de Estatística – INE data, related to economic growth in Portugal, between the years 1995-1999.

where $y^*_{i,t}$ is a binary non-observable variable, taking value equal to one if the worker invests in human capital and zero if he does not invests; $x_{i,t}$ is a vector of individual characteristics, c_i represents fixed individual non-observable characteristics, while $e_{i,t}$ is a error term.

We estimated two different models, the fixed effect logit model and the random effect probit model[26], whose basic difference lies on the hypothesis about the way that $x_{i,t}$ and c_i are correlated and the distribution of the error term. In the first model, it is assumed that the individuals' non-observable characteristics are fixed, while on the second one it is assumed that c_i follows a conditional normal distribution with linear expectations and constant variance.

The estimated coefficients, together with their standard errors, are given in the table below[27].

We initially expect that the higher the wage and the work general condition happiness the lower is the probability to invest in training, if the worker is satisfied with his condition. However, we could also expect a positive sign if the worker is not satisfied with his condition. We also expect that the higher the financial help the lower is the probability to invest in training.

Estimation Results

	Fixed Effect Logit Model	*Random Effect Probit Model*
Constant		-.813(.921)
Growth Rate	-.432 (.268)***	-.076(.114)
Wage Happiness	-.480(.173)*	-.174(.055)*
Work Conditions Happiness	-.105(.155)	-.166(.063)*
Work Place Happiness	.084(.171)	.088(.053)***
Aggregate Work Happiness	.131(.183)	.297(.067)*
Tenure	-1.195(.481)*	-.479(.152)*
Single	-1.194(.815)	.361(.122)*
Financial Help	-2.186(1.106)**	-1.237(.326)*
Log-Likelihood	-127.587	-766.227

Note: *,** and *** represent significance at levels 1, 5 and 10 % , respectively. The estimates contain year dummies. As all variables are time varying, these are also identified in the random effect model.

We can observe from both models that technological progress affects, in a negative way, the probability of the worker investing in human capital totally directed at the firm, as predicted by the creative destruction theoretical model[28].

We can also observe in the fixed and random effect models that wage happiness, tenure and acceptance of financial aid from family and friends also affects, in a significantly negative way, the probability of the worker investing in training totally targeted at the firm.

[26] See Wooldridge (2002) for more details on both models.
[27] See annex 1 for the description of variables.
[28] This result is only statistically significant in the model with fixed effects.

In turn, the work place and the aggregate satisfaction with the current job matching imply a positive probability, although not significant in the fixed effect model, of the worker investing in human capital.
We also note from the above table that the greater the job satisfaction the less is the probability of the worker investing in training totally targeted at the firm.
Two different results give us the fact whether the worker is single or not. In a fixed effect model its impact is negative, although not significant, whilst on the random effect model its impact is positive and strongly significant[29].

4.2. Numerical Simulation

In the previous section we saw that the greater the technological progress rates the lower the probability of a worker investing in human capital totally directed at the firm, giving empirical support to the model of creative destruction technological progress.
In this section we will develop a numerical exercise with the supported model. The idea is to verify the impact of greater investment costs on the labor market, and to evaluate if it is more advantageous to invest in human capital totally directed at the market or in human capital totally targeted at the firm.
The function that we used in determining the number of matches formed in each period was a Cobb Douglas, whilst the parameters used in the simulation, as well as its definition, are all in Annex 2.
We used this matching function and those parameters in order to generate an unemployment rate close to the actual Portuguese unemployment rate.
We considered 0,03 as an average GDP growth rate and 0,015 as the interest rate. We also used 0,03 as the idiosyncratic shock, 0,3 as the worker bargaining power, 1,3 as the employment opportunity cost and 2 as the productivity parameter.
The idea used in this section was one of sensibility analysis. In this way, we considered an initial scenario, where there was no human capital investment. After, we changed the investment costs, as well as the incentives to invest in human capital totally aimed at the firm and at the market, so as to verify its effects over job creation and job destruction dynamics, over the wage rate and over the unemployment rate.
The table below shows the results for those scenarios.

Simulation Results

Variables	*Scenario 1*	*Scenario 2*	*Scenario 3*
T	4,16	4,33	2,25
θ	10,89	24,74	1,46
u	0,07	0,04	0,27
w	1,88	2,62	2,33

Note: Scenario 1 – there are no investments. Scenario 2 – the worker invests in human capital totally targeted at the firm. Scenario 3 – the worker invests in human capital totally targeted at the market.

[29] We also test variables related with the worker, such as his level of education, his age and professional experience; and variables related with the firms, such as the production sector and the number of employees. However, all variables were strongly non significant in both models.

We can see that if there is a sudden reduction in the human capital investment costs and if the benefits of the investment totally directed at the firm are greater than the benefits of the investment totally targeted at the market we will have an increase in the job creation dynamics and wage rate, and a reduction in unemployment rate and job destruction flows.
In turn, if the benefits of the investment in human capital totally aimed at the market exceed the benefits of the investment totally targeted at the firm we will have a reduction in job creation dynamics and an increase in job destruction, unemployment rate and wage rate.

5. Conclusion

The main goal of this paper is to study the effect of technological progress on optimum worker-provided on-the-job training.
We showed, in a creative destruction scenario, that the greater the technological progress rate the lower would be the incentives of the worker to invest in human capital totally target at the firm, while on a renovation scenario the result was the opposite.
In both scenarios the impact of the technological progress rate on the investment in human capital totally target at the market were inexistent, as it affects equally the costs and benefits obtained with the investment.
We also saw that the aggregate effect of the investment in human capital over the labor market depends on the investment type. The more this investment is directed at the market the greater is the job destruction flow and the less is the dynamic of new job creation.
The empirical test developed for Portugal points in favor of the model of creative destruction technological progress, since the greater the technological progress rates the lower the probability of a worker investing in human capital totally directed at the firm.

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Annex 1

Description of the variables

Training	*Dummy variable that equals 1 if the worker participated in a worker-provided training in the last year and looking for a job and 0 otherwise;*
Wage Happiness, Work Conditions Happiness, Work Place Happiness and Aggregate Work Happiness	*Variable that takes value between 1 and 6. 1 if totally unsatisfied and 6 if completely satisfied;*
Tenure	*Number of years with the same employer;*
Single	*Dummy variable equals 1 if the worker is single and 0 otherwise;*
Financial Help	*Dummy variable equals 1 if the worker received financial help from family or friends and 0 otherwise;*

Summary Statistics

Variable	*Mean*	*Standard Error*
Training	0,04	0,19
Wage Happiness	3,23	1,03
Work Conditions Happiness	4,18	0,88
Work Place Happiness	4,25	1,05
Aggregate Work Happiness	3,92	0,92
Tenure	2,92	0,26
Single	0,22	0,42
Financial Help	0,01	0,08

Annex 2

Parameters definitions and values

Parameters	*Symbol*	*Value*
Growth rate	g	0,03
Matching Function Parameter	h	0,5
Interest Rate	r	0,015
Productivity Gain	δ	variable
Productivity Parameter	x	2
Investment Cost	z	variable
Search cost	c	0,1
Bargaining Parameter	β	0,3
Employment Opportunity Cost	εx	1,3
Productivity Parameter	φ	variable
Idiosyncratic Shock	λ	0,03
Investment Decision	α	variable
Actual Investment Decision	ψ_a	variable
Past Investment Decision	ψ_p	0,5