Labour Market Frictions, Social Policies, and Barriers to Technology Adoption

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Abstract

Barriers to technological changes have recently been shown to be a key element in explaining differences in output per worker across countries. This study examines the role that labour market features and institutions have in explaining barriers to technology adoption. I build a model that includes labour market frictions, capital market imperfections and heterogeneity in workers' skills. I found that the unemployment rate together with the welfare losses that workers experiment after displacement are key factors in explaining the existence of barriers to technology adoption. Moreover, I found that none of these factors alone is sufficient to build these barriers. The theory also suggests that welfare policies like the unemployment insurance system may enhance these kinds of barriers while policies like a severance payment system financed by an income tax seem to be more effective in eliminating them.

Keywords : Barriers to technology adoption; Unemployment; Unemployment insurance; Workers displacement; Welfare cost.

JEL classification: O14; O33; E24; J65; D69

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1 Introduction

Barriers to technological changes have recently been shown to be a key element in explaining differences in output per worker across countries (see Parente and Prescott (1999, 2000)). These barriers can have a first order effect on total factor productivity (TFP), which is the most important factor in accounting for differences in output per worker across countries (See, for example, Hall and Jones (1999), Cavalcanti, Issler and Pessôn (2000) and Prescott (1998)).[1]

In this paper I examine the role that labour market features and institutions have in explaining barriers to technology adoption. Technological changes imply many different changes for workers. Among the more important ones is the possibility of switching from operating a low productive technology to operating a more productive one, and this switch may imply higher future wages. If, however, the new technology is labour substituting or skill biased or the firm faces an inelastic demand the change may imply the displacement of part of the staff. In this case workers face the risk of becoming unemployed or of losing the skills accumulated with the old technology, since skills may not be transferable across technologies, if the technological change is implemented.[2] The possibility of being displaced or of loosing skill are associated with substantial earning losses, and these losses might make workers reluctant to adopt new technologies, specially when the likelihood of finding a new job is low.

Jacobson et al. (1993) and Topel (1990) present substantial evidence that job losses are associated with loss of skills and large earning losses. In particular, Jacobson et al.(1993) find that the earnings of displaced workers remain 25% lower than those of similar non-displaced workers even five years after displacement. Figure 1, taken from Jacobson et al.'s (1993), shows the disparate expected earning-patterns of long-tenure workers who were displaced in the first quarter of 1982 compared to workers who remained employed throughout the period.

I introduce technical change into an otherwise standard Mortensen and Pissarides model of unemployment. In my framework there is matching between workers and firms. When a worker

[1] Parente and Prescott (2000) argue that *"Differences in international incomes are the consequences of differences in the knowledge individual societies apply to the production of goods and services. ..., these differences are the primary result of country-specific policies that result in constraints on work practices and on the application of better production methods at the firm level. Many of these constraints, or barriers, are put in place to protect the interests of groups vested in current production processes. Such barriers at the individual production unit level imply differences in output per unit of the composite input at the aggregate level, that is, differences in total factor productivity (TFP). Most of the differences in international incomes, thus, are the result of differences in TFP."*(p.2).

[2] By skill I mean the experience that a work has with the technology and the industry specific knowledge that can imply an increase in wages while the worker is attached to the firm and which are lost when the worker becomes unemployed.

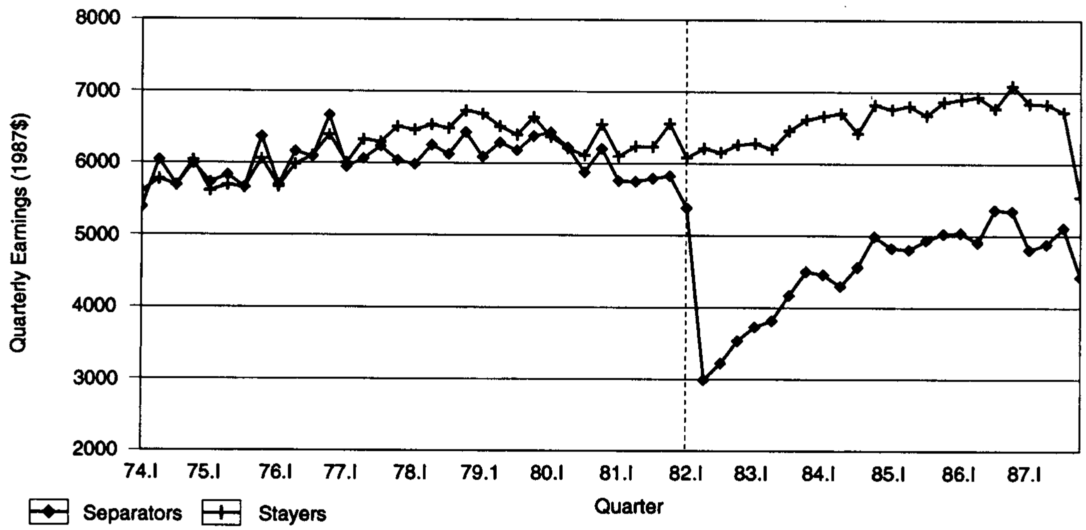

Figure 1: Source: Jacobson et al. (1993). Quarterly earnings of high-attachment workers separated in the first quarter of 1982 and workers staying through 1987. The sample is from Pennsylvania.

is match with a firm they bargain the wage at any moment in time. Firms receive stochastically opportunities of adopting a more productive technology. Workers are risk averse and face the risk of loosing their jobs or skills when a technological change is implemented. Because capital markets are imperfect, workers can not be insured against labour income risk, and the risk of becoming unemployed or losing skills can may workers reluctant to a technological change. Since my focus is on the circumstances that may lead workers to reject a technological change, I assume that workers have the power to block the technological change if it is not optimal for them. Therefore, the new technology is adopted if and only if the firm and workers agree on it. When the firm is willing to adopt the new technology but workers reject it, I say that *there is a barrier to a technological change.* Firms, however, cannot commit to compensate displaced workers after the technological change.

I study how unemployment affects barriers to technological change and examine the consequences of different welfare policies for technology adoption. Welfare policies may seem to be a natural way to provide commitment through institutions to distribute the aggregate gains of a technological improvement. Therefore, well defined institutions may help to reduce workers' resistance to those changes.

I find that both unemployment and the loss of skills cause by technological changes are key factors behind barriers to technological changes. This work also suggests that welfare policies have to be careful designed since no well designed policies can have undesirable effects on technological progress.

A well intentioned policy maker can think that an unemployment insurance(UI) system may reduce barriers to technological change because it can reduce the unemployment risk. My work suggests that UI may, instead, enhance the barriers. If we consider two economies with the same unemployment rate but with different level of unemployment benefits, the economy with the higher unemployment benefit is certain to exhibit weaker barriers because the unemployment risk is smaller. In a general equilibrium context an increase in the unemployment benefit leads to a higher unemployment rate, and a higher unemployment rate leads to higher barriers.[3]In contrast I find that a severance payment system financed by an income tax seems to be more effective in eliminating these barriers. Severance payments are a more effective device for dealing with the earnings variability induced by displacement and do not discourage employment, since they provide a cash transfer to the worker that is not contingent on the worker choosing not to work.

I present now a case study supporting my hypothesis that unemployment risk can lead to barriers to technological changes. This example shows that when new technologies threat the job stability of a group of workers in an industry, no matter how productive it may be, the introduction of that technology is certain to face strong rejection by the affected group. The case is provided by Randall (1991).[4]The example he provides is the attempts of Shearers to block the introduction of the gig machine at the end of the eighteen century in English woollen industry. The Shearers were responsible for the finishing of fine cloth and were the best paid. In 1793 the gig mill was found to be suitable for the finishing of fine cloth, although it was not a new invention at that time. With the use of this machine one man and two boys could accomplish in 12 hours what it took one man to do by hand in 88 to 100 hours. With this huge labour savings, the use of this machine was certain to finish the job of the majority of shearers.

[3]Ljungqvist and Sargent (1998), among others, argue that a significant component of the rise in European unemployment can be accounted for by the fact that displaced workers in Europe can receive unemployment benefits for very long periods.

[4]An extensive list of evidence concerning barriers to technology adoption or implementation of more efficient work practices can be found in Parente and Prescott (1999, 2000). Schmitz (2002) also provides an industrial case that illustrates how changes in work practices lead the U.S. and Canadian iron-ore industries to double their labour productivity in the middle 1980s. Some other examples about several innovations in English woollen industry, the adoption of which were delayed for many years on account of workers blocking then, can be found in Randall (1991).

Not surprisingly, the Shearers resisted the gig mill's application to the finishing of cloth and were successful in delaying its adaptation to finishing cloth for nearly twenty-five years in some regions.

Other historical episodes illustrate that workers are very concern about the distribution of the potential gains due to a technological change between the winners and losers of the process (see Parente and Prescott (2000)).[5]

Many resent papers can be related to my work. Aghion and Howitt (1994) discusses the relation between growth and long-run unemployment, where growth is modelled as technological progress, and shows that unemployment is affected by growth both directly through the job-destruction rate, and indirectly through its effects on the incentive for firms to create job openings and hence on the job-finding rate. In contrast, my work suggest that unemployment may have a negative effect on the growth rate by making more difficult the adoption of new technologies.

My findings complement those in a recent paper by Rogerson and Schindler (2002). They find that the welfare costs of the earning losses associated with the displacement of high tenure workers is substantial. Their analysis suggest that long duration unemployment insurance is likely to exacerbate this cost, and that government-financed severance payments are a more effective way of dealing with the displacement risk. In my paper I obtain similar conclusions in the context of technological changes, which makes the point more relevant.

My work is also related to the works of Acemoglu and Shimer (1999), and Marimon and Zilibotti (1999). These authors emphasize a positive effect of unemployment insurance on the efficient use of technologies. They show that unemployment insurance affects workers' productivity by allowing better matches between workers and firms. While their analysis abstract from the effect that this system may have on the adoption of more productive technologies, and hence on its effects on technological progress, our analysis suggest that UI may have negative effects on the adoption of better technologies.

The rest of the paper proceeds as follows: the next section presents the model. In section 3 and 4 I present some numerical examples that illustrate the results, and section 5 presents the

[5]Parente and Prescott (2000) document an increase in labour productivity by a factor of 3 in the U.S. subsurface coal mining industry in the 1949-1969 period. The reason for this increase in productivity was basically the introduction of the boring machine to replace pick-and-shovel technology. These machines were widely used to construct tunnels for many years before their use in coal mining. They had not been used in mining because union contracts had explicitly prohibited their use. They were introduced when their use benefited the miners, which was when cheap substitutes for coal, namely, oil and natural gas, became available in the late 1940s. When coal miners allowed the introduction of boring machines, they did an explicit agreement and, as part of the agreement, the coal miners subsequently receive $20 for every ton of coal mined to finance union pension benefits.

conclusions.

2 The Model

In this section we present the structure of the model economy. The economy consists of workers and firms, and in the matching process between them there is friction, which causes unemployment. Workers can be either employed or unemployed, and firms can have its jobs either filled or vacant. Time is continuous and the economy is populated by a unit measure of individuals, with utility function $\mathcal{U}(w_t) = \dfrac{w_t^{1-\sigma} - 1}{1 - \sigma}$, where w_t is income at time t, and discount the future at a rate of time preferences ρ. All unemployed workers are unskilled, but once they initiate a match they can become skilled with the technology in use at a rate π_h per unit of time. When the match is broken they lose their skill. The term "*skill* " means "*experience*" or the firm specific knowledge workers can learn to increase their productivity but that cannot be transferred to other firms.

A new firm incurs initial investment cost I and receives a technology with productivity normalize to one. Firms can freely enter the market, and they can have at most one worker. For the latter reason we are going to refer for the rest of the paper to a firm as a job. The output produced by an unskilled worker is θ_l and by a skilled is θ_h, where $0 < \theta_l < \theta_h = 1$. Firms matched with a worker receive a stochastic opportunity of adopting a new technology with productivity $\pi > 1$, and when a firm adopts the new technology it uses the new technology until it closes down. An individual who meets a firm that uses the new technology is able to operate the new technology with probability λ_a. This assumption implies that when a firms receives an opportunity of adopting the new technology, with probability $1 - \lambda_a$ the worker is not able to operate it and has to be dismissed. We can then study in a simple way workers' decisions when they face a technological change that may cause them to lose their jobs.

In order to study the effect that the possibility of losing skill may have on workers' decisions, we assume that with probability δ_h a skilled worker will remain skilled with the new technology, and before the change takes place he does not know whether he is going to remain skilled or not. Moreover, unskilled workers can only remain in the job as unskilled.

In addition we assume that workers have the power to block a technological change if they think it is not optimal for them. This assumption allows us to focus on the reasons workers have to block a technological change rather than the mechanism they use to do it. Note that in practice successful deterring of new technologies or better work practices seems to depend on how much political power do labour unions have in the economy and on the willingness of the government to protect workers employment. The implication of previous assumption is that a technological change would be adopted only if the firm and workers agree on doing it.

Finally, there is no physical depreciation of the technology but each job faces the risk of being destroyed with probability ϕ per unit time. This implies that in steady state equilibrium of the model both technologies may coexist.

2.1 Matching Process

The matching process between workers and firms is random and takes place in a pool comprising all workers and vacancies. All vacancies are alike.

Let λ_w and λ_f be the rates per unit time at which a worker meets a vacancy and a firm meets a worker.[6] The number of matches in any moment is given by a constant return to scale matching function $m(v, u)$, where v is the total measure of vacancies and u is the total measure of unemployed workers. We also assume that $m(v, u)$ is strictly increasing in both arguments and satisfy some standard regularity conditions.[7]Let $\theta = v/u$ denotes labour market tightness. Hence,

$$\lambda_w(\theta) = m(\theta, 1) \; and \; \lambda_f(\theta) = \frac{m(\theta, 1)}{\theta}.$$

Search only takes time and when a worker is unemployed he can work at home with a technology $\pi_0 < \pi$ earning $w_u = \pi_0$.[8]

2.2 Value functions

Let γ denotes the rate per unit time at which a firms receives the opportunity of adopting the new technology. Because there is no depreciation of the technology and firms' and workers' transition among the different states follow Poisson processes, the value of a vacancy, the value

[6]Implicitly, we assume that λ_w, λ_f, ϕ and π_h are Poisson processes.

[7]These conditions are:

$$\begin{aligned} m(0, u) &= m(v, 0) = 0, \\ \lim_{v\to\infty} m_v(v, u) &= \lim_{u\to\infty} m_u(v, u) = 0, \\ \lim_{v\to 0} m_v(v, u) &= \lim_{u\to 0} m_u(v, u) = \infty. \end{aligned}$$

[8]In section (3) we consider the inclusion of an unemployment insurance system and analyze the effect that it may have on the existence of barriers to technology adoption.

of a filled job, the value of being employed and the value of being unemployed do not depend on how long a worker or a firm has been in its current state or on its prior history. And because our focus is going to be on steady states, those values are constant over time.

For the rest of the paper, the terms "*low productive firm*" and "*high productive firm*" will refer to a firm that has not adopted the technology π and to one that has adopted it.

2.2.1 Value functions for high productive firms

Let $J_{\pi,l}$ and $J_{\pi,h}$ be the value of a match with an unskilled and with a skilled worker, and V_π be the value of a vacancy for a high productive firm. Denotes by $w_{\pi,l}$ and $w_{\pi,h}$ the wages paid by a high productive firm to an unskilled and to a skilled worker. We derive the present discounted value of these value functions as is standard in search theory, although we can also use dynamic programming. Think of V_π, $J_{\pi,l}$ and $J_{\pi,h}$ as assets priced by firms, which are risk neutral investors, with required rate of return r, where r is the interest rate. The expected return on a vacancy V_π is the probability $\lambda_f(\theta)\lambda_a$ per unit time of finding a worker that is able to operate the technology and obtains a capital gain of "$J_{\pi,l} - V_\pi$" minus the probability ϕ per unit time of a capital loss of "V_π" if the firm closes down. Agents will be willing to hold the asset V_π if its expected rate of return, i.e., its dividends plus any expected capital gain or loss per unit time, equal rV_π. Thus the arbitrage equation determining the present discounted value of "V_π" is

$$rV_\pi = \lambda_f(\theta)\lambda_a \left(J_{\pi,l} - V_\pi\right) - \phi V_\pi. \tag{1}$$

If the firm is matched with an unskilled worker, the return for the firm is the dividend "$\pi\theta_l - w_{\pi,l}$" per unit time plus the probability π_h per unit of time of a capital gain "$J_{\pi,h} - J_{\pi,l}$" if the worker gains skill, minus the capital loss of "$J_{\pi,l}$" with probability ϕ per unit time if the firm closes down. Hence,

$$rJ_{\pi,l} = \theta_l\pi - w_{\pi,l} + \pi_h \left(J_{\pi,h} - J_{\pi,l}\right) - \phi J_{\pi,l}. \tag{2}$$

Similar reasoning implies

$$rJ_{\pi,h} = \pi - w_{\pi,h} - \phi J_{\pi,h}. \tag{3}$$

Let $W_{\pi,l}$ and $W_{\pi,h}$ be the present discounted value of being employed as an unskilled and as skilled worker in high productive firm, and let U be the value of being unemployed. Parallel to the previous analysis, we can think of $W_{\pi,l}$ as an option value that yield utility "$\mathcal{U}(w_{\pi,l})$" per unit time, has an expected capital gain of "$W_{\pi,h} - W_{\pi,l}$" with probability π_h if the worker gains skill, and an expected capital loss of "$W_{\pi,l} - U$" with probability ϕ per unit time if the match is destroyed. In order to hold this asset a worker requires that the expected rate of return equals $\rho W_{\pi,l}$. Thus,

$$\rho W_{\pi,l} = \mathcal{U}(w_{\pi,l}) + \pi_h \left(W_{\pi,h} - W_{\pi,l}\right) - \phi \left(W_{\pi,l} - U\right). \tag{4}$$

Finally, the expected rate of return of $W_{\pi,h}$ is the utility "$\mathcal{U}(w_{\pi,h})$" per unit time minus the expected capital loss of "$W_{\pi,h} - U$" with probability ϕ per unit time. Then,

$$\rho W_{\pi,h} = \mathcal{U}(w_{\pi,h}) - \phi \left(W_{\pi,h} - U\right). \tag{5}$$

To determine wages we use a Nash bargaining solution with workers' bargaining power equals to β. The Nash bargaining equation, which implicitly defines the wages $w_{\pi,h}$ and $w_{\pi,l}$, are

$$\beta\ k_\pi\ \mathcal{U}'(w_{\pi,l})(J_{\pi,l} - V_\pi) = (1-\beta)(W_{\pi,l} - U), \tag{6}$$

$$\beta\ k_\pi\ \mathcal{U}'(w_{\pi,h})(J_{\pi,h} - V_\pi) = (1-\beta)(W_{\pi,h} - U), \tag{7}$$

where $k_\pi = (r + \phi + \pi_h)/(\rho + \phi + \pi_h)$.

2.2.2 Value functions for low productive firms

Let J_l and J_h be the value of a match with an unskilled and with a skilled worker, and V be the value of a vacancy for a low productive firms. Denote by w_l and w_h the wages paid by a low productive firms to an unskilled and to a skilled worker. Since only operating firms can receive the opportunity of adopting the new technology, the arbitrage equations determining the present discounted value of V can be derived in the same way that V_π was derived. The main difference is that all workers can operate this technology. This implies that with probability $\lambda_f(\theta)$ per unit time a firm finds a worker that can operate the technology as an unskilled worker and obtain a capital gain of "$J_l - V$". Thus,

$$(r + \phi)V = \lambda_f(\theta)\left(J_l - V\right). \tag{8}$$

In order to derive the arbitrage equations for J_l and J_h, we have to take into account that with probability γ per unit time a firm has the opportunity of switching to the technology π. Firms take as given worker's decision and decide whether to adopt the new technology or not.

Hence,

$$rJ_l = \theta_l - w_l + \pi_h (J_h - J_l) - \phi J_l + \gamma\, \mathcal{I}(\mathcal{W}_a^l) \max\{\lambda_a J_{\pi,l} + (1-\lambda_a)V_\pi - J_l - \epsilon I, 0\}, \tag{9}$$

$$rJ_h = 1 - w_h - \phi J_h + \gamma\, \mathcal{I}(\mathcal{W}_a^h) \max\{\lambda_a(\delta_h J_{\pi,h} + (1-\delta_h)J_{\pi,l}) + (1-\lambda_a)V_\pi - J_h - \epsilon I, 0\}. \tag{10}$$

Equations (9) and (10) can be derived in the same way equations (2) and (3) were derived, but now with probability γ per unit of time firms have the expected gain of changing the technology, which are the last terms in equations (9) and (10). These terms merit an explanation. First, the function $\mathcal{I}(\cdot)$ is the indicator function, which equals one if the argument is greater or equal than zero and equals zero otherwise. $\mathcal{W}_a^i$, $i = l$ for unskilled and $i = h$ for skilled, represents workers' expected gain of accepting the technology π and will be derived later. A type i ($i = l, h$) worker will accept the technological change if and only if $\mathcal{W}_a^i \geq 0$. Conditional on workers' decision the firm will be willing to accept the technological change if and only if the value of expected gain with the new technology is greater or equal than the cost of adoption plus the value of expected gain of continuing with the current technology. That is,

$$\lambda_a J_{\pi,l} + (1-\lambda_a)V_\pi \geq J_l + \epsilon I, \tag{11}$$

and

$$\lambda_a(\delta_h J_{\pi,h} + (1-\delta_h)J_{\pi,l}) + (1-\lambda_a)V_\pi \geq J_h + \epsilon I, \tag{12}$$

for a firm that is match with an unskilled and with a skilled worker. Then equations (9) and (10) follow. We now explain expression (12), since (11) has a similar interpretation. The left hand side of (12) is the expected gain of adopting the technology π. Conditional on being able to operate the new technology, a skilled worker will remain skilled with the new technology with probability δ_h and will lose the skill with probability $1 - \delta_h$. If the worker is not able to operate the technology the match is broken and the firm changes its value to "V_π". The right hand side of (12) is the cost of adoption. This cost is the sum of the value of continuing with the current technology, "J_h", plus the cost of the new, "ϵI".

In order to study firms' decisions we define the following functions

$$\mathcal{F}_a^l = \lambda_a J_{\pi,l} + (1-\lambda_a)V_\pi - J_l - \epsilon I, \tag{13}$$

and

$$\mathcal{F}_a^h = \lambda_a(\delta_h J_{\pi,h} + (1-\delta_h)J_{\pi,l}) + (1-\lambda_a)V_\pi - J_h - \epsilon I. \tag{14}$$

Hence, a firm matched with a type i ($i = l, h$) worker will want to adopt the new technology iff $\mathcal{F}_a^i \geq 0$.

For workers we proceed as follow. Let W_l and W_h denote the present discounted value of being employed in a low productive firm as unskilled and as skilled worker. The equations that determine U, W_l, and W_h are

$$\rho\, U \;=\; \mathcal{U}(w_u) + \lambda_w(\theta)\left(\frac{v_0}{v}(W_l - U) + \lambda_a \frac{v_1}{v}(W_{\pi,l} - U)\right), \tag{15}$$

$$\rho\, W_l \;=\; \mathcal{U}(w_l) + \pi_h\,(W_h - W_l) - \phi\,(W_l - U) + \gamma\; \mathcal{I}(\mathcal{F}_a^l)\max\{\lambda_a W_{\pi,l} + (1-\lambda_a)U - W_l, 0\}, \tag{16}$$

$$\rho\, W_h \;=\; \mathcal{U}(w_h) - \phi\,(W_h - U) + \gamma\; \mathcal{I}(\mathcal{F}_a^h)\max\{\lambda_a(\delta_h W_{\pi,h} + (1-\delta_h)W_{\pi,l}) + (1-\lambda_a)U - W_h, 0\} \tag{17}$$

where v_0 and v_1 are the number of vacancies in firms that use the low and the high productive technology, and $v = v_0 + v_1$ is the total number of vacancies in the economy. These equations have the following interpretation. According to (15) the flow return to an unemployed worker, $\rho\, U$, equals the utility provided by home production, "$\mathcal{U}(w_u)$", plus the gain from switching from unemployed to employed as unskilled worker in a low productive firm, "$W_l - U$", with probability $\lambda_w \frac{v_0}{v}$ per unit time and in a high productive firm, "$W_{\pi,l} - U$", with probability $\lambda_w \lambda_a \frac{v_1}{v}$ per unit time. According to (16) the flow return to an unskilled worker employed in a low productive firm, $\rho\, W_l$, equals the sum of four terms. The first is the utility provided by this asset, "$\mathcal{U}(w_l)$". The second is the rate at which an unskilled worker becomes skilled, π_h, times the gain from switching from being low productive to be high, "$W_h - W_l$". The third term is the rate at which a match is destroyed because the firm closes down, ϕ, times the capital loss from switching from employed to unemployed, "$-(W_l - U)$". Finally, the last term is the rate at which a firm receives the opportunity of adopting the high productive technology, γ, times the firm decision, $\mathcal{I}(\mathcal{F}_a^h)$, times the expected capital gain from accepting or rejecting the technology. Note that a worker decides whether to accept or reject the new technology taking as given the firm decision. Equation (17) can be derived following a similar reasoning.

A worker will accept the new technology if the expected gain of accepting it is greater or equal than zero. Since an unskilled worker will be able to operate the technology π with probability λ_a and will be dismissed with probability $1 - \lambda_a$, his expected gain of accepting the new technology is

$$\mathcal{W}_a^l = \lambda_a W_{\pi,l} + (1 - \lambda_a)U - W_l. \tag{18}$$

Similarly a skilled worker will remain employed as skilled with probability $\lambda_a \delta_h$, as unskilled with probability $\lambda_a(1-\delta_h)$ and with probability $1-\lambda_a$ the worker will be fired. Hence, the expected gain of accepting the new technology for a skilled worker is

$$\mathcal{W}_a^h = \lambda_a(\delta_h W_{\pi,h} + (1-\delta_h)W_{\pi,l}) + (1-\lambda_a)U - W_h. \tag{19}$$

Thus, a type i worker, $i = l\ h$, will accept a technological change if and only if $\mathcal{W}_a^i \geq 0$. Finally, in equilibrium we require $V = I$ so that there is no profitable entry by new firms. This is the so called free entry condition.

As for the firms with the technology π, wages w_l and w_h solve first-order conditions from a Nash bargaining solution with the workers bargaining power equals to β:

$$\beta\ k_l\ \mathcal{U}'(w_l)(J_l - V) = (1-\beta)(W_l - U), \tag{20}$$

$$\beta\ k_h\ \mathcal{U}'(w_h)(J_h - V) = (1-\beta)(W_h - U), \tag{21}$$

where $k_i = (r + \phi + \pi_h + \gamma\ \mathcal{I}(\mathcal{F}_a^i)\mathcal{I}(\mathcal{W}_a^i))/(\rho + \phi + \pi_h + \gamma\ \mathcal{I}(\mathcal{F}_a^i)\mathcal{I}(\mathcal{W}_a^i))$ for $i = l, h$

2.3 Distribution of employment

Since in the economy there is matching friction, we still need to determine the unemployment rate and the distribution of vacancies and employment across firms. Begin by letting $\mu_{0,l},\ \mu_{1,l},\ \mu_{0,h},\ \mu_{1,h}$ and u denote the proportion of the population who are employed in low and in high productive firms as unskilled and as skilled workers, and the proportion of the population that is unemployed. Then the model has the dynamic structure with transitions as illustrated in Figure 2, where $\gamma_i = \gamma\ \mathcal{I}(\mathcal{F}_a^i)\ \mathcal{I}(\mathcal{W}_a^i),\ i = l, h$. To determine its steady state we equate the flow out of and into each of the different states:

$$(\pi_h + \phi + \gamma_l)\mu_{0,l} = \lambda_w(\theta)\frac{v_0}{v}u\, label D1 \tag{22}$$

$$(\phi + \gamma_h)\mu_{0,h} = \pi_h\mu_{0,l}, \tag{23}$$

$$(\pi_h + \phi)\mu_{1,l} = \gamma_l\lambda_a\mu_{0,l} + \gamma_h\lambda_a(1-\delta_h)\mu_{0,h} + \lambda_a\lambda_w(\theta)\frac{v_1}{v}u, \tag{24}$$

$$\phi\mu_{1,h} = \pi_h\mu_{1,l} + \gamma_h\lambda_a\delta_h\mu_{0,h}. \tag{25}$$

In addition the flow equations for the measure of vacant low productive firms, v_0, is given by

$$(\phi + \lambda_f(\theta))v_0 = \phi(\mu_{0,l} + \mu_{0,h} + \mu_{1,l} + \mu_{1,h} + v_0 + v_1). \tag{26}$$

The left hand side of (26) is the measure of low productive vacancies that are destroyed, ϕv_0, plus the number of firms that finds a match, $\lambda_f(\theta)v_0$. In the steady state it should equals the

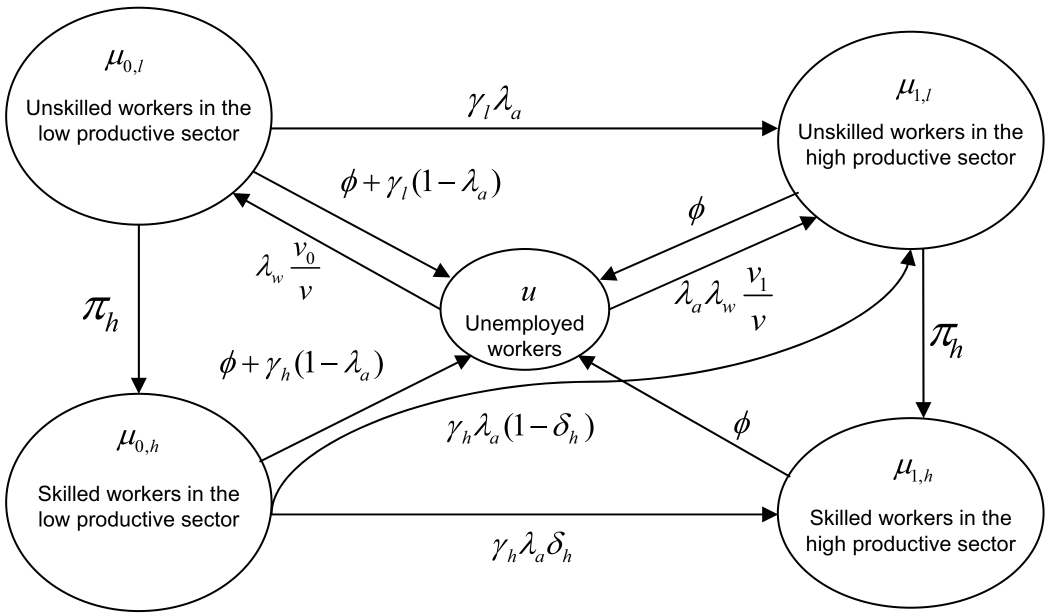

Figure 2: Dynamic Structure of the Model

number of firms that enter the market every instant, which is equal to the number of jobs and vacancies that are destroyed $\phi(\mu_{0,l} + \mu_{0,h} + \mu_{1,l} + \mu_{1,h} + v_0 + v_1)$. Hence, equations (**??**) to (26) together with the facts that $v\lambda_f(\theta) = u\lambda_w(\theta)$ and that the μ's plus u sum to 1, form a system of seven equations in seven unknowns, $\mu_{0,l},\ \mu_{0,h},\ \mu_{1,l},\ \mu_{1,h},\ v_0,\ v_1$ and u, which can be solved and expressed as functions of the value of the market tightness θ. In particular, for the ratios v_0/v and v_1/v we have

$$\frac{v_0}{v} = \frac{(\gamma_h + \phi)(\lambda_a \lambda_f(\theta) + \phi)(\gamma_l + \pi_h + \phi)}{(\gamma_h + \phi)(\lambda_a \lambda_f(\theta) + \phi)(\gamma_l + \pi_h + \phi) + \lambda_f(\theta)(1-\lambda_a)(\gamma_h(\gamma_l + \pi_h) + \gamma_l \phi)},$$

and

$$\frac{v_1}{v} = \frac{\lambda_f(\theta)(1-\lambda_a)(\gamma_h(\gamma_l + \pi_h) + \gamma_l \phi)}{(\gamma_h + \phi)(\lambda_a \lambda_f(\theta) + \phi)(\gamma_l + \pi_h + \phi) + \lambda_f(\theta)(1-\lambda_a)(\gamma_h(\gamma_l + \pi_h) + \gamma_l \phi)}.$$

2.4 Steady state equilibrium

In this section we define the equilibrium of the economy. Before proceeding we want to claim that each value function can be written as an implicit function of the value of the market tightness θ. The reason is the following. Equations (1)-(5) form a linear system of equations in the variables $V_\pi,\ J_{\pi,l},\ J_{\pi,h},\ W_{\pi,l}$ and $W_{\pi,h}$. We can solve this system and find the formulas that define each of these value functions as functions of $w_{\pi,l},\ w_{\pi,h},\ U$ and θ, which remain linear functions of U. Then, substituting these values into equations (8)-(10) and (15)-(17) we obtain another linear system of six equations in the variables $V,\ J_l,\ J_h, W_l,\ W_h$ and U. Solving this new system we can find the formulas that define these functions as functions of the wages $w_l,\ w_h,\ w_{\pi,l},\ w_{\pi,h}$ and θ. Finally, substituting all the value functions into the Nash bargaining equations (6), (7), (20) and (21) we obtain a non-linear system of four equations that implicitly define all wages as functions of θ. This, instead, allows us to write each value function as a function of the value of the market tightness θ.

Definition 2.1. For a given set of parameter values $\delta,\ \phi,\ r,\ \rho,\ \beta,\ \theta_l,\ \pi_0,\ \pi,\ I,\ \lambda_h,\ \lambda_a,\ \gamma$ and ϵ such that $\delta,\ \phi,\ I,\ \gamma,\ \epsilon > 0$, $0 < r,\ \rho,\ \beta,\ \theta_l,\ \lambda_h,\ \lambda_a,\ \phi + \delta < 1$ and $0 \leq \pi_0 < 1 < \pi$, and a functional form for the matching function, *a steady state equilibrium* for this economy is a vector of value functions $\{V, J_l, J_h, U, W_l, W_h, V_\pi, J_{\pi,l}, J_{\pi,h}, W_{\pi,l}, W_{\pi,h}\}$, wages $\{w_l, w_h, w_{\pi,l}, w_{\pi,h}\}$ and a value of the market tightness θ such that:

(i) The value functions $V, J_l, J_h, U, W_l, W_h, V_\pi, J_{\pi,l}, J_{\pi,h}, W_{\pi,l}, W_{\pi,h}$ and wages $w_l, w_h, w_{\pi,l}, w_{\pi,h}$ satisfy equations (1)-(7), (8)-(10), (15)-(17), (20) and (21).

(ii) The value of the market tightness, $\theta = v/u$, satisfies the free entry condition

$$V(\theta) = I. \tag{27}$$

2.5 Barriers to a technological change

The previous sections give us the necessary tools to define *a barrier to a technological change.*

Definition 2.2. Given the values $\pi,\ \lambda_h,\ \lambda_a$ and ϵ for the new technology, we say that there exist a ***barrier to a technological change*** in the economy by skilled (unskilled) workers if firms are willing to adopt the new technology, $\mathcal{F}_a^h \geq 0$ ($\mathcal{F}_a^l \geq 0$), but skilled (unskilled) workers do not, i.e., $\mathcal{W}_a^h < 0$ ($\mathcal{W}_a^h < 0$, respectively).

Proposition 2.1. *If workers are risk neutral, whenever a technological change is optimal for a firm matched with an unskilled worker, i.e.* $\mathcal{F}_a^l \geq 0$*, it is also optimal for unskilled workers to accept it. i.e.,* $\mathcal{W}_a^l \geq 0$.[9]

[9]This result seems to be true when workers are risk averse. In all numerical examples I have performed the result holds for risk averse agents.

Proof. Using the Nash bargaining equations (6) and (20), we can write $\mathcal{W}_a^l$ as

$$\mathcal{W}_a^l = \frac{\beta}{1-\beta}\left(\lambda_a(J_{\pi,l} - V_\pi) - (J_l - V)\right), \tag{28}$$

or equivalently

$$\mathcal{W}_a^l = \frac{\beta}{1-\beta}\left(\mathcal{F}_a^l - (V_\pi - V - \epsilon I)\right).^{10} \tag{29}$$

Solving for $\lambda_a(J_{\pi,l} - V_\pi)$ from equation (1) and for $(J_l - V)$ from equation (8) and substituting those values into equation (29) we obtain

$$\mathcal{W}_a^l = \frac{\beta}{1-\beta}\frac{r+\phi}{\lambda_f(\theta)}(V_\pi - V).$$

Hence, a necessary and sufficient condition for an unskilled worker reject a technological change is that $V_\pi < V$. But, if $V_\pi < V$, equation (29) would imply that $\mathcal{F}_a^l < 0$. The proposition follows. □

This proposition implies that in any equilibrium of the economy in which the new technology is at least optimal for a firm match with an unskilled worker, we will have both technologies in operation. Nonetheless, we still can have barriers by skilled workers, even if the change is optimal for the firm.

Corollary 2.1. *In an economy with only one type of workers, whenever it is optimal for the firm the adoption of a new technology, it is also optimal for the workers to accept it.*

Proof. This is the especial case when $\pi_h = 0$. Since proposition 2.1 is valid for all values of $\pi_h \geq 0$, the proof follows. □

This corollary tells us that there is no way we can generate barriers with only unemployment risk, independently of the level of unemployment, the home production wage, etc. A plausible explanation is that when there is only one type of worker the welfare losses of a displaced worker are very small. In fact, these losses consist of the reduction in wages while unemployed, since they can find similar jobs to the ones they had before displacement, and the losses can be easily offset by the possibility of getting a higher wage if the new technology is implemented. For instance, if the unemployment rate is large, workers' treat point is small and the bargaining process implies that wages should be close to the home production wage which makes workers

[10] Since workers are risk neutral I assume that they have the same discount rate than firms, i.e., $\rho = r$.

almost indifferent between working in a firm or being unemployed. Thus, the possibility of obtaining a higher wage in the event of remaining employed using the technology π offset the risk of becoming unemployed. It does not happen when there are more than one types of workers in the economy, because for a worker who has gain a wage premium with the technology π, the losses in the event of being displaced are much higher and may not be easily offset. On the other hand, if the unemployment rate is small, the probability of finding a similar job is high, which reduces the losses in the event of being displaced.

This result does not contradict the main point of this paper to be illustrated later, that unemployment is at the origin of barriers to technology adoption, but points out that the secondary effects of unemployment are very important.

3 Numerical examples I

The next examples illustrate the effect of unemployment on barriers to technological changes.

Example 3.1.

In this example we study the existence of barriers to technological change in economies that differ only in the level of unemployment. We consider economies with the unemployment rate varying from 2.5% to 20%. In order to generate economies with different unemployment rates I adjust the job creation cost, "I". This election is based on the fact that the relative price of investment is higher in poor countries than in rich countries (See for example Easterly (1993) and Jones (1994)), and according to Restuccia and Urrutia (2001) the relative price of investment is negatively correlated with investment rates. A lower investment rate generate fewer jobs, and a low rate of job creation leads to an increase in the level of unemployment or in the size of the shadow economy. In the simulation 1% increase in the job creation cost increases the unemployment rate by 18%.

Before proceeding we need a functional form for the matching function. We follow the existing literature and use a Cobb-Douglas functional form: $m(v, u) = v^{\alpha}u^{1-\alpha}$, $\alpha \in (0,\ 1)$, which implies that $\lambda_f(\theta) = \theta^{\alpha-1}$ and $\lambda_w(\theta) = \theta^{\alpha}$. Hence, $\lambda'_f(\theta) < 0$ and $\lambda'_w(\theta) > 0$.

In the model there are sixteen parameters $\{\sigma, r, \rho, \beta, \alpha, \phi, \gamma, I, b, \pi_0, \theta_l, \pi_h, \pi, \lambda_a, \delta_h, \epsilon\}$. In the present example I choose then in the following way: the parameter of risk aversion is $\sigma = 1.5$, and a period is a month; the interest rate, r, and the rate of time preferences, ρ, are equal to 5% per year; the exogenous firm destruction rate, ϕ, is set such that the probability a firm closes down before 9 years equals 0.75; γ is set such that the probability a firm receives the opportunity of adopting the new technology before 9 years equals 0.75; b equals zero, so there is not unemployment benefit in the economies; the workers bargaining power β and the matching function parameter α are 2/3 and 0.6; $\pi_0 = 1/5$ and the productivity of an unskilled worker is 30% lower than the productivity of a skilled worker, i.e. $\theta_l = 0.7$; finally, π_h is chosen such that a worker gains skill in one year with probability 0.75.

The parameters of the technological change are π, λ_a, δ_h and ϵ. The new technology is 65% more productive than the current technology, i.e., $\pi = 1.65$. Workers' probability of being displaced is 0.15, which implies $\lambda_a = 0.85$. The probability that a skilled worker remain skilled with the new technology is $\delta_h = 0.75$. Finally, for the technological change to be optimal for all firms we take $\epsilon = 0.84$. Under these assumptions low and high productive firms are always willing to adopt the new technology. Table 1 summarizes the parameter values of the model.

Parameters	σ	r, ρ	β	α	ϕ	γ	I	π_0	θ_l	π_h	π	λ_a	δ_h	ϵ
$u = 2.5\%$	1.5	.0042	2/3	.6	.012	.012	27.7	.2	.7	.02	1.65	.85	.75	.84
$u = 20\%$	1.5	.0042	2/3	.6	.012	.012	38.3	.2	.7	.02	1.65	.85	.75	.84

Table 1: Parameters of the model. (Period 1 month)

Figure 3 (a) presents the expected gain of accepting the new technology for a skilled worker, $\mathcal{W}_a^h$, in economies with different unemployment rates. The continuous line represents the expected gain when technological changes are always implemented, and the dashed line when they are always rejected. Note that in all cases the adoption of the new technology is optimal for firms and also for unskilled workers. Hence, in what follows we restrict our attention to skilled workers only. When the unemployment rate is less or equal than 7% both lines are above the horizontal axis, which mean that workers are always willing to accept the new technology, and an equilibrium where there is always adoption of the new technology exists. If the unemployment rate is greater or equal than 15% both lines are below the horizontal axis. In this case there is *a barrier to the technological change* since workers will reject a technology that is optimal for firms. For unemployment rates between 7% and 15%, it is optimal for workers neither to accept the new technology when everybody is accepting nor to reject the new technology when everybody is rejecting. In this case there should be an intermediate level of adoption but a

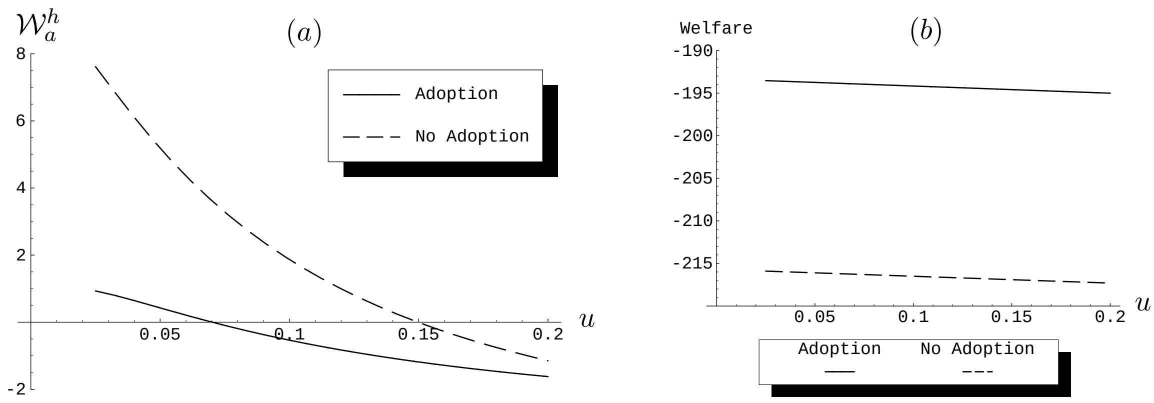

Figure 3:
(a) Skilled workers' expected gain of adoption for u changing from 2.5% to 20%.
(b) Social welfare for economies where there is adoption or rejection of the new technology.

transition must be computed in order to determine it. We can observe from these analysis that barriers to a technological change are stronger the higher is the unemployment rate and that they disappear when the unemployment rate is sufficiently low. This result indicates that labour market frictions can play an important role in explaining the existence of barriers to technology adoption.

Part (b) of figure 3 presents a measure of aggregate welfare for the economies where technological changes are always implemented and where the changes are always rejected. The measure of aggregate welfare is $W = uU + \mu_{0,l}W_l + \mu_{0,h}W_h + \mu_{1,l}W_{\pi,l} + \mu_{1,h}W_{\pi,h}$. We can observe from the figure that the whole economy is better off when the new technology is implemented than when it is rejected. Hence, the rejection of the new technology represents a welfare loss for the whole economy.

In figure 4 we perform the same experiment but increasing the probability of being displaced to 30% if the new technology is implemented, i.e., $\lambda_a = 0.7$. We can note that barriers are now stronger. This result suggests that new technologies are more likely to be rejected the higher is the labour substitutability of the technology, which in this case is modelled as the inability to operate the new technology.

Example 3.2.

In this example we consider economies with the same cost of creating jobs but different levels of unemployment benefit b. All unemployed workers receives a transfers b in addition to the home production π_0, i.e., the income of an unemployed worker is $w_u = \pi_0 + b$. The unemployment

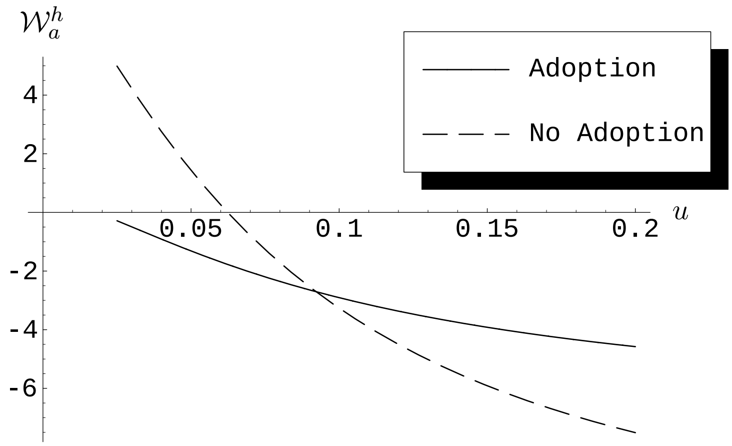

Figure 4: Skilled workers' expected gain of adoption for u changing from 2.5% to 20% and $\lambda_a = 0.7$.

benefit is financed by a lump sum tax to all employed workers. The economy with $b = 0$ has an unemployment rate equals to 15.75%, and the rest of parameters are like in the previous example. Note that for this level of unemployment, $u = 15.75\%$, there is already a barrier to the adoption of the new technology. The experiment consist in increasing b and observe how workers decision change in the economies with higher b. Figure 5 shows the evolution of $\mathcal{W}_a^h$ for the different economies. We observe that $\mathcal{W}_a^h$ decreases as b increases, which implies that

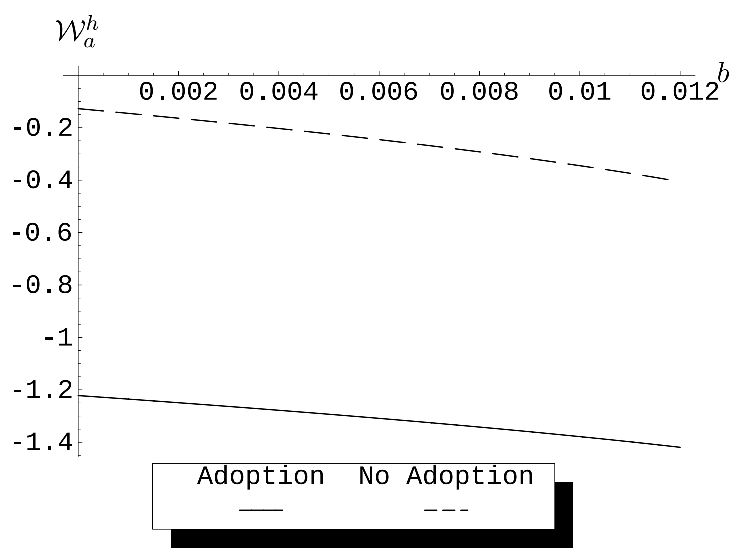

Figure 5: Evolution of $\mathcal{W}_a^h$ for economies that differ only in the value of b.

barriers to technological change are more severe in economies with high unemployment benefit. This surprising result was unexpected. In principle one could expect the insurance effect that the UI provides to offset the risk of becoming unemployed. In a general equilibrium context, however, economies with high unemployment benefit and the same cost of creating jobs exhibit higher unemployment rates. The higher unemployment rate offsets the insurance effect of the UI and leads to higher barriers. In the present example the unemployment rate increases from 15.75% when $b = 0$ to 22% when $b = 0.012$.

This result does not imply that if we consider two economies with the same unemployment rate but with different level of unemployment benefits, the economy with the higher unemployment benefit should exhibit higher barriers. The economy with the higher unemployment benefit is certain to exhibit weaker barriers because the unemployment risk is smaller. But, in order to have the same unemployment rate, the economy with the higher unemployment benefit requires a lower cost of creating jobs.

4 Severance Payment System

In example (3.2) we saw that economies with generous unemployment benefit exhibit higher barriers to the adoption of new technologies than similar economies with less generous unemployment benefit when they face the same cost of creating jobs. In this section we consider the inclusion of a severance payment system and study how barriers to the adoption of new technologies changes. The motivation of this experiment is the following. Severance payment system does not discourage employment, as the unemployment insurance system does, since it does not depend on the unemployment spell, and the increase in unemployment was the main reason why the UI performed badly in the previous section. In addition, according to Rogerson and Schindler (2002), a severance payment system seems to be appropriate to reduce the losses of displaced workers, which in our model is a key factor in the determination of barriers to technological changes.

The mechanism through which a severance payment helps displaced workers to reduce their losses is saving. When a worker is displaced he receives a severance payment and distributes it in an optimal way in order to smooth his future consumption. The possibility of distributing the severance payment throughout the future is essential when workers are risk averse sine for them consumption smoothing is very important. Unfortunately, we do not have saving in our model.

A simple approach to this problem, which allows us to use the same framework, is to assume that workers are risk neutral. Risk neutral workers are indifferent in the way the severance payment is distributed throughout the future, which makes saving unnecessary.[11] This simplification, however, makes more difficult the existence of barriers since the risk of becoming unemployed or losing skill have less importance.

We should note that the risk neutrality assumption rules out any insurance aspect of the system. In addition, the effect of a pure transfer from employer to worker is neutral under bilateral bargaining because the worker would compensate the employer for the expected transfer ex ante in the form of lower initial wages.[12] Although severance payments do not have any allocative effect on labour market outcomes, it can still have interesting redistributive consequences, and we will see that the redistributive effect can help to reduce barriers to technological changes.

The severance payment policy considered entitles all workers who are displace either because the firm closes down or because of a technological change to receive a payment T at the moment of separation, and the system is financed by a lump sum tax, τ, to all employed workers.[13] Since this payment is a one-time shock and because only workers who are displace either because the firm closes down or because of a technological change can receive the payment, the policy does not affect workers' bargaining power and has not direct effect on unemployment.

All value functions for the firm and the value of being unemployed remain unchange. The transition dynamics of the model also hold. The new value function for workers are

$$
\begin{aligned}
r\ W_{\pi,l} &= w_{\pi,l} - \tau + \pi_h \left(W_{\pi,h} - W_{\pi,l}\right) - \phi \left(W_{\pi,l} - (U+T)\right), && (30)\\
r\ W_{\pi,h} &= w_{\pi,h} - \tau - \phi \left(W_{\pi,h} - (U+T)\right), && (31)\\
r\ W_{l} &= w_{l} - \tau + \pi_h \left(W_{h} - W_{l}\right) - \phi \left(W_{l} - (U+T)\right) + \gamma\ \mathcal{I}(\mathcal{F}_a^l) \max\{\lambda_a W_{\pi,l} \\
&\quad +(1-\lambda_a)(U+T) - W_l, 0\}, && (32)\\
r\ W_{h} &= w_{h} - \tau - \phi \left(W_{h} - (U+T)\right) + \gamma\ \mathcal{I}(\mathcal{F}_a^h) \max\{\lambda_a(\delta_h W_{\pi,h} + (1-\delta_h) W_{\pi,l}) \\
&\quad +(1-\lambda_a)(U+T) - W_h, 0\}, && (33)
\end{aligned}
$$

[11]The results obtain in this section would be undoubtedly stronger if workers were risk averse. When workers are risk averse the barriers to a technological change are higher and the possibility of saving plays a more relevant role.

[12]Lazear (1988, 1990) notes that if contract were perfect, severance payments would be neutral. Burda (1992) also derives the Lazear result in a search environment with exogenous job destruction.

[13]This way of modelling the system does not increase workers bargaining power and, therefore, has neutral effects on real variables as the effects of a direct transfer from the firm to the worker.

where upon separation the insider worker receives the severance payment T. Since workers are risk neutral I assume that they have the same discount rate than firms, i.e., $\rho = r$. In equilibrium we also require $V = I$, so that there is not profitable entry by new firms. The Nash bargaining solution for wages are now

$$\begin{aligned}
\beta\ (J_{\pi,l} - V_\pi) &= (1-\beta)(W_{\pi,l} - U), \\
\beta\ (J_{\pi,h} - V_\pi) &= (1-\beta)(W_{\pi,h} - U), \\
\beta\ (J_l - V) &= (1-\beta)(W_l - U), \\
\beta\ (J_h - V) &= (1-\beta)(W_h - U).
\end{aligned}$$

Workers decisions are studied by the functions

$$\mathcal{W}_a^l = \lambda_a W_{\pi,l} + (1-\lambda_a)(U+T) - W_l, \tag{34}$$

$$\mathcal{W}_a^h = \lambda_a(\delta_h W_{\pi,h} + (1-\delta_h)W_{\pi,l}) + (1-\lambda_a)(U+T) - W_h. \tag{35}$$

As before a skilled (unskilled) worker will accept a technological change only if $\mathcal{W}_a^h \geq 0$ ($\mathcal{W}_a^l \geq 0$, respectively). From equations (34) and (35) we can observe that an increase in T increases the net gain of adopting the new technology for both unskilled, $\mathcal{W}_a^l$, and skilled, $\mathcal{W}_a^h$, workers. Since a high T does dot increase the bargaining power of workers the result of having a high T would be weaker barriers by workers.

4.1 Numerical examples II

In this section we study numerically the effect of a severance payment system on barriers to technological changes.

Example 4.1.

In this example we consider the same parametrization as in example (3.1), except for the technological change. The parameters of the technological change are as follow. The new technology is 40% more productive than the current technology, so $\pi = 1.4$. Workers' probability of being displaced is 0.30, which implies $\lambda_a = 0.7$. The probability that a skilled worker remain skilled with the new technology is $\delta_h = 0.7$. Finally, for the technological change to be optimal for all firms we take $\epsilon = 0.4$. Under these assumptions low and high productive firms are always willing to adopt the new technology, and low skilled workers do not reject the technological change. Figure 6 shows the expected gain of accepting the new technology for a skilled worker,

$\mathcal{W}_a^h$, in economies with different unemployment rates. For economies with unemployment rate less or equal than 7.5% it is neither optimal for workers to accept the new technology when everybody is accepting nor it is optimal for them to reject the new technology when everybody is rejecting. These economies should then exhibit an intermediate level of adoption. Workers, however, are more reluctant to the change the higher is the unemployment rate, and when the unemployment rate is greater or equal than 7.5% there exits *a barrier to the technological change*.

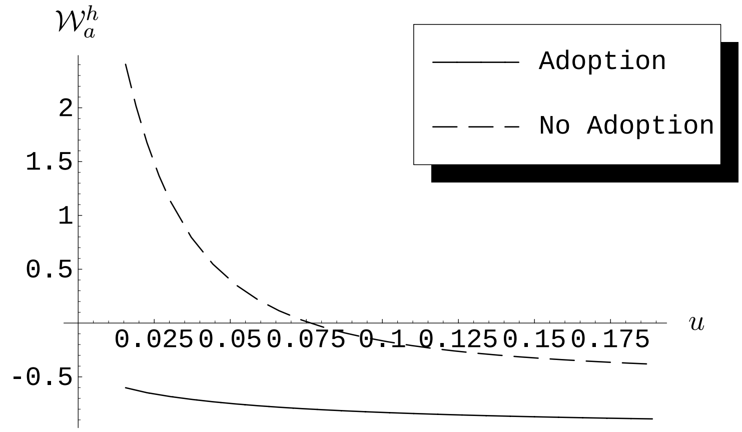

Figure 6: Skilled workers' expected gain of adoption for u changing from 2.5% to 20%.

Now we consider economies with the same cost of creating jobs but different severance payments T. The economy with $T = 0$ has an unemployment rate equals to 15%, and the rest of parameters are like in the previous example. Note that for this level of unemployment, $u = 15\%$, there is already a barrier to the adoption of the new technology. The experiment consist in increasing T and observe how workers decision change.

Figure 7(a) shows the evolution of $\mathcal{W}_a^h$ for the different economies. We can see from this figure that $\mathcal{W}_a^h$ increases as T increases. This implies that barriers to technological change are weaker in economies with high values of T, and the barriers disappear in economies with T large enough. In the present example the barriers vanish for values of T greater or equal than 3.6. Since the system plays only a redistributive role, social welfare is independent of the transfer T as figure 7(b) indicates. Nonetheless, an equilibrium with adoption exists in economics with transfers greater or equal than 3.6. Thus, those economies are better-off than economies with no transfer since the equilibrium with adoption exhibit a higher level of welfare than the equilibrium with no adoption. This result indicates that a severance payment system can help to eliminate

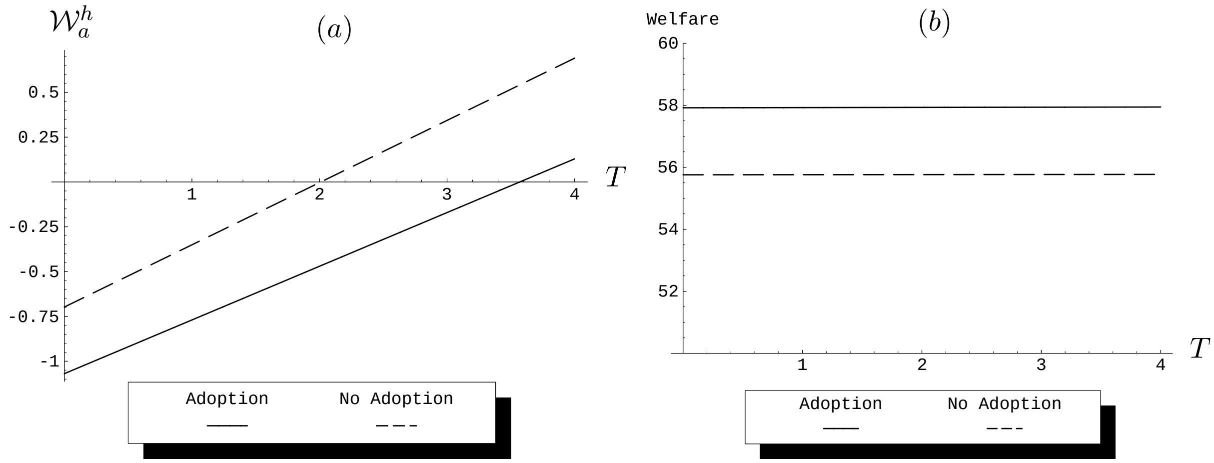

Figure 7:
(a) Skilled workers' expected gain of adoption for T changing from 0 to 4.
(b) Social welfare for economies where there is adoption or rejection of the new technology.

barriers to technological change, and that the elimination of such barriers may be desirable for the whole society since it implies an increase in the level of welfare.

Figure 8 shows that under this new set of parameters the unemployment insurance system continues performing badly. These observations indicate that a severance payment system financed by an income tax seems to be more effective in eliminating barriers to technology adoption than an unemployment insurance system, which suggests that caution must be taken when design welfare policies because they can have undesirable effects of technological progress.

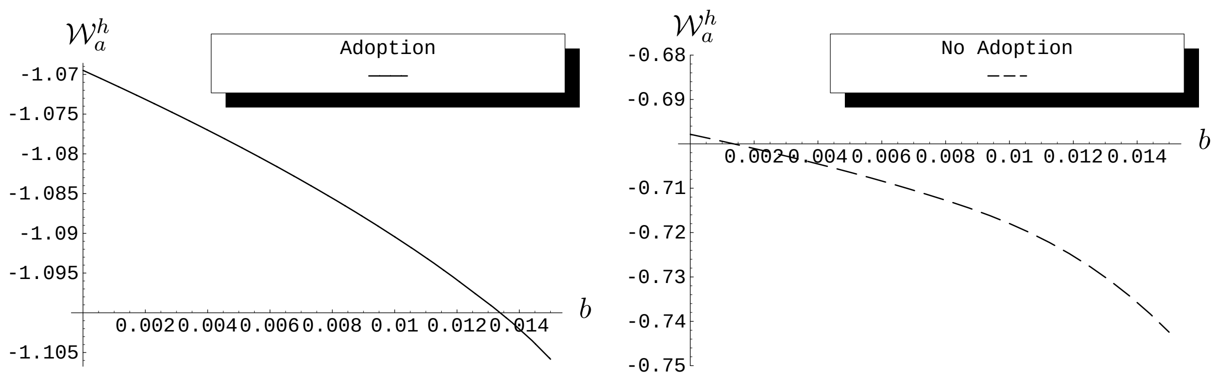

Figure 8: Evolution of $\mathcal{W}_a^h$ for economies that differ only in the value of b.

5 Conclusions

This paper presents a model that includes labour market frictions, capital market imperfections and heterogeneity in workers' skills in order to study the existence of barriers to the adoption of new technologies or implementation of better work practices.

I analyze numerically the effect of labour market frictions on barriers to technological changes by studying the circumstances under which workers may be willing to reject a new technology. I find that when the unemployment rate is large and workers have the possibility of losing skills if fired, new technologies are more likely to be rejected.

This work suggest that the design of social policies to deal efficiently with these barriers is not trivial. I consider two different social policies: an unemployment insurance system and a severance payment system. With respect to the unemployment insurance system I find that for economies differing only on the level of unemployment benefit, the one with the higher level of unemployment benefit has stronger barriers to technological change than the one with the lower level of unemployment benefit. The explanation is that economies with high unemployment benefit and the same cost of creating jobs exhibit higher unemployment rates. The higher unemployment rate offsets the insurance effect of the UI and leads to higher barriers. This suggests that welfare policies have to be careful designed since no well designed policies can have undesirable effects on technological progress.

Then I consider a severance payment system. Under this system all workers who are displace either because the firm closes down or because of a technological change are entitled to receive a lump sum payment at the moment of separation. The experiments show that barriers to technological change are weak in economies with high transfers. In practice this policy requires the identification of those workers who are displace because of a technological change which represent a limitation of the policy.

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