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Does the growth process discriminate against older workers?

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ABSTRACT

This paper seeks to gain insights on the relationship between growth and employment when considering heterogeneous agents in terms of their working horizon. Using an OECD database, our empirical estimations suggest that growth positively influences the employment rate of workers having a long working horizon (young workers) while negatively influences the employment rate of workers having a short working horizon (senior workers). We then provide theoretical foundations to this result by means of an endogenous job destruction framework à *la* Mortensen and Pissarides (1998) where we introduce life cycle features. We show that, under the assumption of homogeneous productivity among workers, growth negatively affects the employment rate of workers having a short working horizon before retirement (senior workers) while it positively affects the employment rate of workers having a long working horizon (young workers). Numerical simulations confirm these results, however a non-standard calibration is required to reproduce the elasticity values obtained in our empirical estimations.

1. Introduction

The relationship between growth and unemployment has been largely analyzed in the economic literature. In his seminal work, Pissarides (1990) claims that an acceleration of growth improves the employment rate, because growth increases "freely" the expected profits, as in the Solow model, and then provides incentives to open new jobs (the capitalization effect). In contrast, Aghion and Howitt (1994) argue that growth fosters a "creative destruction" process inducing more job destruction and less job creation, yielding lower employment rates.[1] What effect (creative destruction vs. capitalization) prevails in case of an acceleration in the growth rate? If the capitalization effect is dominant, we should observe an improvement in the employment opportunities when growth increases. Conversely, if the creative destruction effect dominates, employment opportunities should deteriorate.

Even if the link between growth and employment is ambiguous from a theoretical point of view, empirical studies report clearer results. Using a traditional econometric approach, *i.e.* a panel of OECD countries, Blanchard and Wolfers (2000) or Pissarides and Vallanti (2007) show that an increase in growth pushes down unemployment. Similarly, using several measures of co-movements in the frequency domain, Tripier (2007) shows that the long-run co-movement between unemployment and productivity is strongly negative in the US and Europe. Moreover, the simultaneous slowdown in productivity

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[1] Note though, that in Aghion and Howitt (1994), depending on the parameters, it is possible to have a non-linear relationship (an inverted U-shape) between growth and unemployment.

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growth and the rise in the unemployment rate in OECD countries support the positive correlation between these two phenomena. Empirical evidence suggests that the capitalization effect offsets the creative destruction effect, leading to a decrease in the long term aggregate unemployment rate (non-participation issues are not considered). Does this mean that the creative destruction effect of Aghion and Howitt (1994) associated with an acceleration of growth is always dominated by the capitalization effect? We believe the answer is negative as long as we consider heterogeneous agents.

In this paper, we show that the relative magnitude of the capitalization and the creative destruction effects depends on the working horizon of the worker, which is tightly correlated with her age. For simplicity, we consider that young workers have a long working horizon, whereas older workers have a short working horizon.[2]

When dealing with old workers we can adopt either a "backward" or a "forward" looking point of view. The backward point of view implies that when getting old, all workers suffer from skill obsolescence or simply get used. This view then predicts the same reduction in the employment rate of seniors at the same age in all countries. However, this biological perspective is not supported by the data.[3] In the second case, from the forward looking point of view, the heterogeneity across workers comes from the distance to retirement. Ljunqvist and Sargent (2008); Hairault et al. (2010) and Saint-Paul (2009) support the view that the short distance to retirement is the key feature to understanding the economics of older worker's employment.[4] Because our paper seeks to underline the role of the distance effect (or horizon effect) on the relationship between the employment rate and the growth rate, we consider as old workers those having less than ten years before retirement (when the distance effect applies) whereas young workers have more than ten years before retirement. We believe that the effect of growth on employment evolves along the life cycle, having a positive effect during the earlier period (when the worker is young) and a negative effect when approaching the legal retirement age.

Our paper distinguishes then between individuals at the beginning of the life cycle (young individuals) and individuals at the end of the life cycle (old individuals). The formers have a long working horizon[5] whereas individuals at the end of the life-cycle have a short working horizon. Following the related literature (Aghion and Howitt (1994) or Mortensen and Pissarides (1998)), we assume that when the technological frontier grows at a faster rate, the rate of job obsolescence accelerates. The firm can then destroy the job and create a new one at the technological frontier (creative destruction) or she may renovate the technology associated with an already existing job. The decision of the firm will be based on the comparison between the renovation cost and the cost associated with a vacancy (when a new job is created it takes some time to fill the vacancy). As pointed out by Mortensen and Pissarides (1998), if the cost of adopting the new and more productive technology in an already existing job is higher than the cost of creating a new job, the firm will not renovate and growth will yield a pure creative destruction effect (more unemployment). Conversely, if the renovation cost is below the creation cost, the firm prefers updating the technology associated with the job when growth accelerates. For a sufficiently low renovation cost, the expected net profits increase which promotes the opening of more vacancies. In this case, growth leads to a capitalization effect (employment opportunities are increased).

Our intuition (confirmed by the empirical evidence presented in Section 2) is that the capitalization effect only dominates for young workers. When the worker's horizon is long (for young workers) the time horizon during which a firm can recoup the updating cost of renovating an existing technology is longer than when it is short (for old workers). So, the optimal policy for the firm is to renovate more frequently jobs occupied by young workers than those occupied by old workers. When growth accelerates, the increase in the speed of obsolescence offsets the long-run positive impact of growth on the actualization factor if the time horizon during which the firm can recoup its renovation cost is short, *i.e.* if the job is occupied by a senior. At the limit, it could be optimal for firms not to renovate jobs occupied by old workers, separation becoming the best choice. It seems then to be intuitive that the creative destruction effect is likely to dominate in the old segment, whereas in the young segment, we may find that the capitalization effect dominates.

The effect of growth on the employment rate of heterogeneous agents has traditionally been analyzed using theoretical or empirical frameworks where the source of heterogeneity arises from the individual's skill level (see for example Berman et al. (1994); Machin and Van Reenen (1998) or Moreno-Galbis et al. (2007)). However, to our knowledge, few studies analyze whether a given individual is equally exposed to the consequences of growth along her life-cycle.[6] Our paper focuses on this issue. More precisely we analyze the conditions under which the acceleration of growth fostered by the diffusion of technological progress is biased against short working horizon workers. We consider here old workers, but we believe that for very young workers (with high turnover) conclusions would be similar.

[2] For very young workers the turnover is higher than for less young workers (not yet old). So, from the firm's point of view, the actual working horizon of very young workers may be as short as that of old workers. We should therefore consider three different worker categories, very young, less young (or middle age) and old workers. However, since the economic mechanisms at work for very young and old workers (short working horizon workers) are similar, and since introducing the very young category of workers implies considering on-the-job search issues, we adopt a simplified representation of the labor market by distinguishing only between two categories of workers: young and old.

[3] The employment rate of men aged between 55 and 59 are: 50% in Belgium, 60% in France, but 70% in the UK, 75% in the US and 80% in Sweden, whereas in the same countries, the employment rates of the 35–54 are around 90%. Divergences in institutions inducing heterogenous working horizons for senior workers may help explaining these differences.

[4] According to the empirical works of Hairault et al. (2010), the shorter the distance to retirement (whatever the age of the worker), the lower the probability of being employed. This distance effect becomes active from the tenth year before retirement.

[5] We neglect on-the-job search issues so as to focus exclusively on the role of the working horizon.

[6] For an empirical study, see Aubert et al. (2006) who analyze the effects of new technologies on the French labor flows (exits and entries) by age or the paper of Bartel and Sichermann (1993) who work with US data and analyze the impact of a technological change (permanent or transitory) on the retirement decision of employed workers.

We use a vintage model inspired by Mortensen and Pissarides (1998). Beyond the heterogeneity arising from the age of the vintage, life-cycle features are also considered so as to distinguish between workers with a long working horizon and workers with a short working horizon. Following Castaneda et al. (2003) and Ljunqvist and Sargent (2008), agents age stochastically. The labor market is segmented between the young and the old workers. A firm hiring an old worker knows that he will retire with a given probability and, similarly, a firm hiring a young worker internalizes the fact that he will become old at a given probability. We assume that all new matches (for young and old workers) are created at the technological frontier so that, initially, they benefit from the highest possible productivity. However, once created their productivity remains constant, unless the firm decides to update the technology. Last, we assume that the productivity of old and young workers is the same. This assumption allows us, on the one hand, not to enter in the discussion concerning the impact of age on productivity: dexterity decreases continuously with age whereas, at the same time, experience/seniority can improve knowledge.[7] On the other hand, it allows us to isolate the ‘‘pure’’ impact of the working horizon (distance to retirement in our case) by keeping the characteristics of the young and the old segment as close as possible. The only difference between both segments will then be the working horizon of workers.

At equilibrium, wages increase at the same pace as the technological frontier. A match between the firm and the worker endures as long as the associated surplus is positive. The firm destroys the job when the surplus becomes negative. The shorter horizon of older workers decreases the incentive to renovate the technology employed in their jobs as well as the expected net profits associated with their position if renovation actually occurs. In contrast, young workers' positions are more likely to be renovated due to their longer working horizon.

Numerical simulations are consistent with our theoretical model and reveal that the working horizon determines by its own the positive or negative impact of growth on the employment rate. For a given set of reasonable parameter values, the capitalization effect offsets the creative destruction effect for young workers and the situation is reversed for old workers. However, to reproduce the size of the estimated elasticity of employment with respect to growth, we need to take into account the institutional specificities of each labor market segment. In the young segment, the low sensitivity of the matching process with respect to the number of unemployed, together with a weaker technological updating cost, arise as the main determinants of the elasticity of employment with respect to growth. In the old segment, the generosity of some policy measures, providing higher unemployment benefits in case of job loss and fostering early retirement, arises as the main determinant of the employment rate.

The paper is organized as follows. Section 2 presents the empirical evidence. Section 3 explains the assumptions of the model and the agents' behavior. In Section 4, we describe the main characteristics of an equilibrium where the firm does not have the possibility of updating a technology. We also analyze the effects of an increase in the pace of technological progress. Section 5 introduces the possibility of updating a technology rather than destroying the job. Unemployment rates are computed in Section 6 and an extension of the model with heterogeneous old workers is developed in Section 7. Section 8 presents some numerical results. Section 9 concludes.

2. Empirical evidence

Using the OECD database[8] employed by Bassanini Duval (2007) we propose a formal econometric analysis in order to test whether the effect of growth on employment evolves along the life-cycle, having a positive effect when the worker is young and a negative effect when approaching retirement.

We use heterogeneity in the social security rule across countries in order to test if in countries with shorter working horizon growth has a more negative impact on the old worker's employment. Following Gruber et al. (1999), we identify countries where the horizon of older workers is short using the implicit tax on continuing activity (see appendix A for a detailed description on the construction of this variable). This result is better understood if we consider the employment rates for the 55–59 years old and 60–64 years old people (our source is Cheron et al. (2007)). In countries like France or the Netherlands these employment rates equal, 60% for the 55–59 years old and 20% for the 60–64 years old, whereas in the UK they equal, respectively, 70% and 45% and in Sweden 80% and 50%. The implicit tax on continued activity largely influences the employment rate of workers above 55 years old. In countries with a high implicit tax, employment rates are lower than in countries with a low implicit tax. We compute the variable ‘‘Short working horizon’’, which equals one if the country has an average implicit tax on continuing activity larger than the average of the whole sample. This dummy variable equals zero for countries like the US, New Zealand, Japan, Denmark, Sweden, Norway, the UK, Spain, Australia or Canada, whereas it takes the unitary value for Italy, Portugal, France, Germany, Austria, Belgium, Finland or the Netherlands.

Estimated coefficients shown in Table 1 are obtained using the generalized least squares method. These estimates capture the long-run relationship between the growth rate (g) and the employment rate for males[9] for 18 OECD countries[10] over the period 1982–1999: the econometric model can be interpreted as the estimation of the conditional steady state employment rate

[7] See Saint-Paul (2009) for a discussion on this point.

[8] See appendix A for details on data sources and variables.

[9] Unfortunately our database does not provide information on the workers' skill level, otherwise it would have been interesting to analyze the impact of growth on the employment rate by skill level.

[10] The UK, the US, the Netherlands, Finland, New Zealand, France, Italy, Sweden, Canada, Spain, Portugal, Germany, Norway, Australia, Austria, Belgium, Denmark and Japan.

Table 1
Relationship between the employment rates of the young and old workers (males) and the HP component of the TFP growth, denoted by g.

	Employment rate 25–64	Employment rate 25–54	Employment rate 55–64	Employment rate 55–64
g	1.549459	1.49592	−.1155371	.4229675
	[1.043541 2.055378]	[.9833507 2.008489]	[−.8618552 .6307809]	[−.4800777 1.326013]
Short working horizon			−10.55693	−6.589546
			[−12.0271 −9.086755]	[−9.42212 −3.756972]
Short working horizon · g				−3.085733
				[−4.830378 −1.341088]
Average replacement rate	−.0629427	−.1509081	−.2590118	−.3015343
	[−.1038158 −.0220696]	[−.1943665 −.1074497]	[−.2976461 −.2203776]	[−.3451108 −.2579578]
Tax wedge	−.2324566	−.2344951	−.4733705	−.4788973
	[−.2896683 −.175245]	[−.2966844 −.1723058]	[−.5461345 −.4006065]	[−.5557659 −.4020288]
Employment protection	−.2165445	−2.082679	3.188212	3.485302
	[−1.317189 .8841003]	[−3.059957 −1.105402]	[2.660901 3.715522]	[2.918125 4.052478]
Union density	.029055	.056301	.0889389	.0824684
	[−.0109632 .0690733]	[.0127356 .0998664]	[.0642966 .1135812]	[.0566137 .1083232]
Union coverage	2.081073	2.034935	.8148807	.9899486
	[.4927806 3.669366]	[.2390767 3.830794]	[−.6595433 2.289305]	[−.4968803 2.476777]
Product market regulation	−.0224071	.2332945	.17789	−.1225293
	[−.4392614 .3944471]	[−.2089273 .6755163]	[−.4873526 .8431326]	[−.823706 .5786473]
Output gap	.4121304	.4457988	.2456202	.3115378
	[.3560549 .4682059]	[.3808301 .5107675]	[.0903614 .4008789]	[.1543545 .4687211]

5% Confidence interval in brackets. We control for time and country specific heterogeneity.
Estimated coefficients are obtained using the generalized least squares method.
We test heteroskedastic error structure with no cross-sectional correlation.
Countries: FIN, NZL, FRA, ITA, GBR, SWE, USA, CAN, ESP, PTR, NLD, DEU, NOR, AUS, AUT, BEL, JPN, DNK.
Period: 1982–1999: ♯ obs = 270.
Data set of Bassanini and Duval (2007).

associated with different total factor productivity (TFP) growth rates, because it abstracts from the transitional dynamics.[11] We control for business cycles, for the degree of product market regulation and for labor market institutions (the average replacement rate, the tax wedge, the employment protection for regular contracts, the union density and an indicator of union coverage). Most of the coefficients associated with labor market institutions are significant and display the expected sign. More precisely, high taxes or a high replacement ratio negatively influence the employment rates (these results are common to Bassanini Duval (2007)). In contrast, the effect of employment protection is negative for young workers, positive for old ones and not significant at the aggregate level.[12]

Concerning the impact of TFP growth on the employment rate, results can be decomposed as follows:

1. When considering all workers between 25 and 64 years old (column 1), results correspond well to the estimates of Pissarides and Vallanti (2007). A one percentage point increase in the growth rate induces a rise by 1.55 percentage points in the employment rate.[13]
2. When the horizon of workers is unambiguously long (the tax on continuing activity has no role), *i.e.* in the young worker case,[14] estimations in column 2 show that the employment rate increases with the TFP growth rate. The capitalization effect dominates for these agents, as one percentage point increase in the growth rate increases the employment rate by 1.49 percentage points.
3. The third column reveals that the average impact of TFP on the employment rate of old workers is negative but not significant.[15] A short horizon leads to a significant decrease in the employment rate of ten percentage points, which clearly shows that the employment rate of old workers decreases with the implicit tax on continuing activity. Although not displayed in the table, the non-significant effect of growth on the employment rate of seniors is also found when estimating a regression without the *"Short working horizon"* variable.

[11] Postel-Vinay (2002) shows that the short-run and the long-run correlations between employment and growth may be of opposite sign. Because we control for business cycle dynamics, and use the HP-filter component of the TFP growth rate, our estimation allows us to identify the long-run relationship between the employment rate and the growth rate, purged from the transitional dynamics of employment towards the long-run equilibrium.

[12] See Cheron et al. (2007) for the impact of the age-dependent employment protection.

[13] Even if not reported in the table, estimates are not modified if the *"Short working horizon"* variable is introduced.

[14] We consider as young workers those between 25 and 54 years old. Even if the OECD contains also information on the employment rate of workers between 20 and 24 years old, we prefer not to deal with this group of very young workers so as to avoid issues as the turnover (on-the-job search) linked to the need to acquire experience or the fact that they may combine university studies with work.

[15] Note that we use the employment rate because it is not biased by the unemployment and disability programs for old workers specific to each country. Indeed, these programs artificially lead to under-estimate the number of unemployed workers. Moreover, our data do not allow us to distinguish between unemployed individuals, people out of the labor force or retired individuals.

4. In order to test if there is a specific effect associated with the short working horizon in a growth context, we define an interacted variable resulting from multiplying the TFP growth rate and the variable *"Short working horizon"*. In this new regression, the coefficient associated with TFP growth becomes positive but not significant whereas the coefficients associated with the variables *"Short working horizon"* and *"Short working horizon · g"* arise as negative and significant. This clearly shows that the negative impact of growth on the employment rate of seniors is due to their short horizon, and not to their biological age (the individual variable g has a non-significant impact on the employment rate of seniors). More precisely, growth negatively affects the employment rate of seniors in countries where the working horizon is relatively short, whereas the impact is non-significant in countries where seniors have a relatively larger working horizon. The length of this horizon appears as one of the main determinants of the positive or negative impact of growth on the employment rate. These results remain robust when we control for the potential interactions between labor market institutions (see robustness checks in the following sections).

In sum, growth has a negative impact on the employment rate of workers with a short horizon, while it has a positive impact on the employment rate of workers with a long horizon. We relate these evidences to the labor market decisions made by firms and workers by simply introducing life-cycle features in the analysis of the relation between equilibrium unemployment and growth.[16]

2.1. The interacted effect of institutions

Estimations reported in Table 1 allow us to conclude that the acceleration of growth is associated with a decrease in the employment rate of workers having a short working horizon and an increase in the employment rate of those having a long working horizon. However, these estimates ignore the fact that the simultaneous presence of various institutions in a country may also influence the employment rate.[17] Simple descriptive statistics confirm that the presence of some institutions is positively correlated with the presence of others (see the unconditional correlation matrix in Table 2).

In order to disentangle the part of the variation in the employment rate explained by the acceleration in the growth rate, from the part explained by the interacted effect of various institutions, columns 1 and 2 of Table 3 replicate estimations in Table 1 but we introduce as additional control variables the interacted relation between the implicit tax on continued activity (*"Short working horizon"*) and other labor market institutions. In column 1, the joint effect of employment protection and short working horizon arises as strongly negative and significant while the interacted relation between the working horizon and the union density is significant but has a smaller impact on the employment rate. The other interacted terms arise as non-significant.

Column 2 in Table 3 adds as an additional control variable an interaction term between growth and the short working horizon. In spite of controlling for the potential interactions between labor market institutions, the coefficient associated with "*Short working horizon ·g*" is only slightly modified with respect to Table 1, where we ignored all correlations between institutions (the coefficient evolves from −3.085 to −3.258). This confirms the robustness of the results displayed in Table 1.[18]

2.2. Correlation between growth and the implicit tax on continued activity

The potential correlation between the growth rate of a country and the presence of a high implicit tax on continued activity promoting early retirement may affect the stability of the estimated coefficients. The shorter the working horizon, the fewer jobs are renovated, which fosters a reduced growth rate. To deal with this potential multicollinearity problem we proceed by steps. First of all, we estimate in a very naive manner the correlation matrix between growth and the implicit tax on continued activity (Table 4). This simple descriptive statistics suggests the absence of a significant correlation between both variables. In a second step, we replicate our benchmark regressions but we introduce the growth rate lagged by one period. Past growth rates are less likely to be correlated with the current tax on continued activity, so we believe that the introduction of a lag in the growth variable solves (at least partially) the potential multicollinearity problem. Columns 3, 4 and 5 of Table 3 address this issue. Columns 3 and 4 replicate the estimation of columns 3 and 4 in Table 1 but introducing growth lagged by one period. Whereas the size of the coefficients is slightly reduced with respect to the original estimations in Table 1, the sign and significance of the coefficients remain robust.[19]

Finally, in order to completely eliminate the potential correlation that could arise between the growth rate of a country and the implicit tax on continued activity, column 5 in Table 3 considers as a unique explicative variable the interacted term

[16] Since our setup does not consider participation issues, and since the labor force is constant, analyzing the link between equilibrium employment and growth is equivalent to analyzing the link between equilibrium unemployment and growth.

[17] We expect, for example, that the implicit tax on continued activity results in individuals retiring earlier. Simultaneously, a stringent employment protection encourages firms to "retire" their workers, rather than firing them. The effects of both institutions tend to reinforce each other and may drive the progression of seniors' employment even more than growth.

[18] For workers with a long working horizon, none of these interactions arises as significant since the variable "*Short working horizon*" is not significant for young workers.

[19] Results are also robust when considering the young segment.

Table 2
Correlation between institutions.

	Tax on continued activity	Average replacement rate	Tax wedge	Employment protection	Union density	Union coverage	Product market regulation
Tax on continued activity	1.00						
Average replacement rate	0.2821 (0.0000)	1.00					
Tax wedge	0.7736 (0.0000)	0.3539 (0.0000)	1.00				
Employment protection	0.4562 (0.0000)	0.2876 (0.0000)	0.3172 (0.0000)	1.00			
Union density	-0.0200 (0.7405)	0.2670 (0.0000)	0.2934 (0.0000)	-0.0072 (0.8845)	1.00		
Union coverage	0.5004 (0.0000)	0.5943 (0.0000)	0.5432 (0.0000)	0.4957 (0.0000)	0.3568 (0.0000)	1.00	
Product market regulation	0.5513 (0.0000)	0.1650 0.0008	0.3620 (0.0000)	0.3795 (0.0000)	0.1694 (0.0006)	0.4695 (0.0000)	1.00

Significance level of each correlation coefficient is reported in parenthesis.

between the growth rate and the short working horizon. We eliminate from the estimation the individual variables g and *Short working horizon* and exclusively focus on the impact of growth in the presence of a short working horizon (variable $SWH \cdot g$). The coefficient arises as negative and significant. Not surprisingly, the size of the coefficient is larger than in column 4 of Table 1 since now, the interacted term captures not only the effect coming from the simultaneous presence of growth and a short working horizon, but also the individual effect of these variables.

3. The model

3.1. Assumptions

We build a matching model based on Mortensen and Pissarides (1998) where the economy is populated by a continuum of firms and heterogenous workers.

3.1.1. The life-cycle

Workers may be young or old. We will denote X_y all variables referring to young workers and X_o those referring to old. The exogenous probability of becoming old is represented by λ_y, so that workers remain young for a period equal to $1/\lambda_y$. Older workers retire with probability λ_o, therefore they are old during $1/\lambda_o$ periods (see Fig. 1). In this stylized life-cycle model, we assume that the risk of becoming a retiree is borne for a short duration of time. We therefore restrict λ_o and λ_y such that $\lambda_o > \lambda_y$. The progression of the total population of young and old workers is respectively given by:

$$\dot{P_y} = \lambda_o P_o - \lambda_y P_y \tag{1}$$

$$\dot{P_o} = \lambda_y P_y - \lambda_o P_o \tag{2}$$

where $\lambda_o P_o$ stands for the fraction of old workers retiring and so leaving the old workforce. Because the aggregate workforce is assumed to be constant, the proportion of old workers retiring must equal the entries into the young workforce. Similarly, $\lambda_y P_y$ represents the exits from the young segment and the entries to the old one. Normalizing P_y to one we obtain $P_o = \lambda_y/\lambda_o$.

3.1.2. Age heterogeneity and specific ability requirement by age

Each firm employs only one worker. In order to control for the controversial effect of age on productivity, we assume that young and old workers produce the same amount of good. In this case, the segmented equilibrium in the labor market can be unstable. Indeed, firms prefer young workers because they can produce for a longer period of time. It is always in the interest of an old worker, to search in the young labor market segment since there are more job opportunities. In principle, for the firm, profits are always greater if the job is filled than if it is vacant, which makes it optimal to hire an old worker even if the vacancy was posted in the young labor market. In this case, the stability of the directed search equilibrium is not insured because old workers can credibly deviate from the segmented equilibrium. In this non-segmented directed search equilibrium, it could be also optimal for a young worker to search in the two segments.[20]

[20] See Albrecht and Vroman (2002) and Blasquez and Jansen (2008) for a discussion on the conditions of multiple equilibria in the standard matching model with worker and firm heterogeneity. See also Cheron et al. (2007) for a discussion on the equilibrium instability with directed search when there is age heterogeneity but not technological requirement.

Table 3
Relationship between the employment rate of the old workers (males), the interacted effect of institutions and growth.

	Employment rate 55–64	Employment rate 55–64	Employment rate 55–64	Employment rate 55–64	Employment rate 55–64
g_t	.0875716 [−.8255269 100.067]	.7779113 [−.3134736 1.869296]			
g_{t-1}			−.1438912 [−.9129741 .6251916]	.188581 [−.7659572 1.143119]	
SWH	6.838278 [−5.130008 1.880656]	5.224289 [−4.746194 1.519477]	−1.048779 [−1.198323 −8.992359]	−7.465601 [−10.40043 −4.530773]	
SWH · g_t		−3.258089 [−5.363181 −1.152996]			−6.421783 [−7.139921 −5.703644]
SWH · g_{t-1}				−2.398736 [−4.214654 −.5828181]	
SWH · ARR	−.0856388 [−.2591854 .0879078]	−.1221111 [−.2955457 .0513235]			
SWH ·TW	.0682903 [−.1898006 .3263812]	.246631 [.0759185 .4173436]			
SWH · EPL	−3.543181 [−5.502432 −1.583931]	−3.130691 [−5.200578 −1.060804]			
SWH · UD	−.0673239 [−.1196959 −.0149519]	−.0648147 [−.1147254 −.0149039]			
SWH · PMR	−.8178157 [−1.759702 .1240708]	−1.046152 [−1.916502 −.1758014]			
ARR	−.2129555 [−.3763807 −.0495304]	−.2177299 [−.383698 −.0517617]	−.268902 [−.3077699 −.2300341]	−.3036555 [−.3486385 −.2586725]	−.3567902 [−.4060057 .3075747]
TW	−.7147539 [−.8495813 −.5799264]	−.7096069 [−.8486069 −.5706069]	−.4873055 [−.5587742 −.4158368]	−.4960737 [−.5712336 −.4209138]	−.5775373 [−.6543393 −.5007354]
EPL	5.035866 [3.922169 6.149563]	5.396682 [4.202052 6.591311]	3.122909 [2.60174 3.644077]	3.328975 [2.770622 3.887328]	3.766797 [3.187132 4.346462]
UD	.1180772 [.0801801 .1559742]	.1065006 [.0676605 .1453407]	.0909869 [.0671412 .1148325]	.0852241 [.0593668 .1110815]	.1191853 [.0976639 .1407067]
UC	.2588334 [−167.734 2.195.007]	.2177326 [−168.946 2.124.925]	.5366138 [−.8791526 195.238]	.6868061 [−.7529213 2.126533]	2.097416 [.5989865 3.595845]
PMR	−.4582455 [−1.319.873 .4033825]	−.8882648 [−1.793.601 .017071]	.4085789 [−.2584136 1.075571]	.2658139 [−.4421445 .9737723]	−.6886506 [−1.263355 −.113946]
OG	.2266012 [.0633451 .3898572]	.2938431 [.1356239 .4520624]	.2658651 [.1123461 .4193841]	.3409235 [.1805171 .5013299]	.3628555 [.2316796 .4940313]

5% Confidence interval. We control for time and country specific heterogeneity.
Estimated coefficients are obtained using the generalized least squares method.
Short working horizon=SWH; *Average replacement rate*=ARR; *Tax wedge*=TW; *Employment protection*=EPL.
Union density=UD; *Union coverage*=UC; *Product market regulation*=PMR; *Output gap*=OG.
Due to collinearity issues the coefficient associated with *SWH · Union density* is omitted.
We test heteroskedastic error structure with no cross-sectional correlation.Countries: FIN, NZL, FRA, ITA, GBR, SWE, USA, CAN, ESP, PTR, NLD, DEU, NOR, AUS, AUT, BEL, JPN, DNK.
Period: 1982–1999: ♯ obs = 270. When introducing a lag variable the number of observations equals 255.
Data set of Bassanini and Duval [2007].

Table 4
Correlation between the implicit tax on continued activity and growth.

	Tax on continued activity	g_t	g_{t-1}
Tax on continued activity	1.00		
g_t	−0.0301 (0.6177)	1.00	
g_{t-1}	−0.0239 (0.7024)	0.9887 (0.0000)	1.00

Significance level of each correlation coefficient is reported in parenthesis.

The undirected search equilibrium exists because workers can impose their age-characteristics to the firm. But, the firm can counteract this worker's power with a technological requirement. Assume that young and old workers can produce the same amount of good, but with a different basket of characteristics, reflecting the technological requirement of the firm. More precisely, let's denote $(\overline{q}, \underline{p})$ the characteristics of young workers and $(\underline{q}, \overline{p})$ the ones of seniors. A firm searching for a young worker achieves the productivity level x with $(\overline{q}, \underline{p})$, whereas the one searching for a senior requires $(\underline{q}, \overline{p})$ to attain x. If a worker applies to a job not matching its age-characteristic, her production will be nil. Under this assumption, the

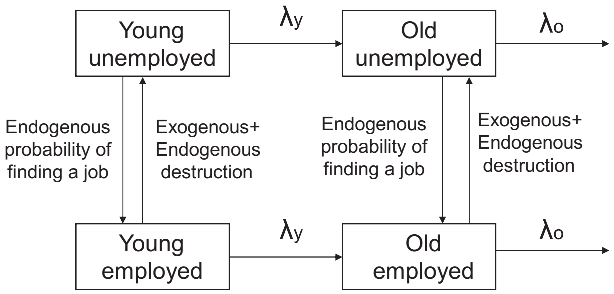

Fig. 1. Labor flows.

decentralized allocation with directed search is a stable equilibrium.[21] When directing the vacancy to a young worker the firm internalizes that the worker will become old with a probability λ_y. The young worker will remain productive in the same job when becoming old because the firm reorganizes the job so that the new technological requirement to produce x equals $(\underline{p}, \overline{q})$. Evidently, we are implicitly assuming that it is cheaper for the firm to reorganize production when the worker becomes old rather than destroying the job and opening a new position directed to an old worker, since in this case, the firm will have to support a search cost.

3.1.3. A segmented labor market

At each moment of time a mass u_i for $i = y, o$ of unemployed workers and a mass v_i for $i = y, o$ of vacant jobs coexist on the labor market, implying a labor market tightness defined by $\theta_i = v_i/u_i$ for $i = y, o$.

Jobs and workers meet pairwise at a Poisson rate $M(u_i, v_i)$, where $M(u_y, v_y)$ stands for the matching function in the young segment and $M(u_o, v_o)$ for the matching function in the old segment. This function is assumed to be strictly increasing and concave, exhibiting constant returns to scale. Furthermore it satisfies the Inada conditions and $M(0,v_i) = M(u_i, 0) = 0$. Under these assumptions and knowing that $M(u_i, v_i)$ represents the number of matches per unit of time, we can represent the probability of filling a vacancy as $q(\theta_i) = M(u_i, v_i)/v_i = M(\theta_i, 1)/\theta_i$ for $i = y, o$. Equivalently, the probability of finding a job is given by $p(\theta_i) = M(u_i, v_i)/u_i = M(\theta_i, 1)$ for $i = y, o$.

3.1.4. Technological progress and firm opportunities

New jobs embody the most advanced known technology. However, once created, their productivity remains constant for the rest of their life. Job creation commits the firm to the technology available at that date.[22] Independently on whether a vacancy is directed to a young or to an old worker, a firm without a worker advertises a job vacancy at a cost $p(t)c$ per period, where c stands for the creation cost, $p(t) = e^{gt}$ is a common growth factor and g is the rate of productivity growth at the technological frontier (creation costs must grow at rate g to ensure the existence of a steady state with balanced growth). Across newly created jobs, match productivity grows at the exogenous rate $g = \dot{p}(t)/p(t)$ (new jobs always embody the most advanced known technology). Once the job is created at date τ its associated productivity, $p(\tau)x$ does not change (x is constant). The opportunity cost of unemployment is represented by $p(t)b$. Because the outside option of employment increases in response to productivity growth at the technological frontier whereas the job's productivity remains constant, the surplus associated with a match is decreasing over time.

Once the job is created several situations may arise. First, the firm can continue to produce with the same technology embodied in the job at the creation date. Secondly, the firm may decide to pay a fixed renovation cost to update the technology and continue producing with the same worker. Finally, the firm may decide to close down and exit production because the job is no longer profitable. To keep our representation as close as possible to Mortensen and Pissarides (1998) we will also assume that jobs might be destroyed by an exogenous shock with probability δ.

3.2. The agents' behavior

An open vacancy can remain empty or be filled and become productive. The associated asset value for each of these situations is represented by $V_i(t)$ for $i = y, o$ if the vacancy is empty at current date t. $J_i(\tau, t)$ for $i = y, o$ stands for the value of an existing job at date t which was created at time τ. Similarly, the value of employment in a job at date t which was created at time τ is represented by $W_i(\tau, t)$ for $i = y, o$ whereas the value of unemployment at date t is given by $U_i(t)$ for $i = y, o$.

[21] The implicit assumption is that, when a vacancy is directed to a young worker, it is never in the interest of the firm to hire a senior worker since the firm would have to support not only the search cost but also a reorganization cost if she wants to adapt the job to the old worker's characteristics and keep the productivity level at x.

[22] In Hornstein et al. (2007) the authors assume that vacancies are heterogenous in their starting technology, so some vacancies may embody the most modern technology whereas others may start with an older technology. We could have adopted a similar framework and impose old workers to start with an older technology. However, one can also argue that old workers benefit from a larger experience that is likely to improve their productivity. In order to avoid this debate and truly isolate the distance effect, we prefer to assume that young and old workers have the same productivity, so that the only difference between them is their working horizon.

3.2.1. The firms

When the firm opens a vacancy at date t it bears a cost $p(t)c$, whatever the type of worker, young or old, required to fill the vacancy. The vacancy remains empty next period at a rate $1-q(\theta_i)$ for $i = y, o$. On the other hand, the vacancy gets filled at a rate $q(\theta_i)$ for $i = y, o$. The asset value associated with a vacancy is then:

$$rV_i(t) = -p(t)c + q(\theta_i)(J_i(t,t) - V_i(t)) + \dot{V}_i(t)\ \forall\ i = y, o \tag{3}$$

In the equilibrium the firm opens vacancies until all rents are exhausted, i.e. $V_i(t) = 0$. Market tightness at date t satisfies then:

$$\frac{p(t)c}{q(\theta_i)} = J_i(t,t)\ \forall\ i = y, o \tag{4}$$

Even though we do not assume productivity differentials between young and old workers, the asset value at date t of a job filled at date τ varies depending on whether the job is directed to a young or to an old worker. In the former case, if at date τ the worker filling the vacancy is young, the firm internalizes the fact that the working horizon before retirement is longer than if the job is occupied by an old worker.

The asset values associated with a job filled by a young worker and by an old worker are respectively given by:

$$rJ_y(\tau,t) = \max\left\{\begin{array}{ll} p(\tau)x - w_y(\tau,t) - \delta J_y(\tau,t) & \\ -\lambda_y(J_y(\tau,t) - J_o(\tau,t)) & \\ +\dot{J}_y(\tau,t), & 0 \end{array}\right\} \tag{5}$$

$$rJ_o(\tau,t) = \max\left\{\begin{array}{ll} p(\tau)x - w_o(\tau,t) - (\delta+\lambda_o)J_o(\tau,t) & \\ +\dot{J}_o(\tau,t), & 0 \end{array}\right\} \tag{6}$$

where $w_i(\tau, t)$ for $i = y, o$ stands for the wage paid at date t in a job created at date τ, δ is the exogenous job destruction rate, λ_y the probability of becoming old and λ_o the probability of retirement. When the worker is old the asset value of the filled vacancy must take into account the fact that the worker will retire with probability λ_o. So, for older workers, aging implies that the continuation value is equal to zero. In contrast, for the young worker, aging leads to a strictly positive continuation value ($J_o(\tau, t)$).

3.2.2. The workers

An unemployed worker receives a flow of earnings $p(t)b$ including unemployment benefits, leisure, domestic production, etc. and increasing with productivity growth at the technology frontier. A young job seeker comes into contact with a vacant slot at rate $p(\theta_y) = \theta_y q(\theta_y)$ and becomes old with probability λ_y. Old job seekers enter into contact with a vacancy at rate $p(\theta_o) = \theta_o q(\theta_o)$ and they retire with probability λ_o. The asset value of unemployment to both types of worker is respectively given by:

$$rU_y(t) = p(t)b + \theta_y q(\theta_y)(W_y(t,t) - U_y(t)) - \lambda_y(U_y(t) - U_o(t)) + \dot{U}_y(t) \tag{7}$$

$$rU_o(t) = p(t)b + \theta_o q(\theta_o)(W_o(t,t) - U_o(t)) - \lambda_o U_o(t) + \dot{U}_o(t) \tag{8}$$

At date t, a job created at τ and filled by a young worker has a productivity $p(\tau)x$ and pays a wage $w_y(\tau, t)$ to the worker. If the job is filled by an old worker, the productivity also equals $p(\tau)x$ and we denote the wage as $w_o(\tau, t)$. The present value of a young and an old worker solves:

$$rW_y(\tau,t) = \max\left\{\begin{array}{ll} w_y(\tau,t) - \delta(W_y(\tau,t) - U_y(t)) & \\ -\lambda_y(W_y(\tau,t) - W_o(\tau,t)) & \\ +\dot{W}_y(\tau,t), & U_y(t) \end{array}\right\} \tag{9}$$

$$rW_o(\tau,t) = \max\left\{\begin{array}{ll} w_o(\tau,t) - \delta(W_o(\tau,t) - U_o(t)) & \\ -\lambda_o W_o(\tau,t) & \\ +\dot{W}_o(\tau,t), & U_o(t) \end{array}\right\} \tag{10}$$

Notice that we assume that the asset value corresponding to the retirement period is equal to zero. Without choice of the retirement age and heterogeneity of retirement value between unemployed and employed workers, this simplification does not change the results presented in the paper.

3.2.3. The wage bargaining process

There are two common concepts of wage bargaining. According to one concept, employers set wages and other terms and hire the most qualified applicant willing to work on those terms. The terms are offered to applicants on a strict take-it-or-leave-it basis. A second common concept, which forms the basis of extensive literature whose canon is Mortensen and Pissarides (1994), has wages and other terms of employment set by a Nash bargain.[23] Models using this formula assume that the threat point for bargaining is the payoff pair that results when the job-seeker returns to the market and the employer waits for another applicant. One consequence is that the bargained wage is a weighted average of the applicant's productivity in the job and the value of unemployment. The latter value, in turn, depends largely on the wages offered for other jobs. This flexible-wage conclusion, however, hinges on unrealistic assumptions about bargaining threats, which are challenged by Hall and Milgrom (2008). Once a qualified worker meets an employer, threatening to walk away and permanently terminate the bargain is not credible. The bargainers have a joint surplus arising from search frictions that bind them together. Hall and Milgrom (2008) use the bargaining theory proposed by Binmore et al. (1986) to invoke more realistic threats during bargaining. The threats are to extend bargaining (disagreement payoff) rather than terminate it (outside-option payoff). The result is to loosen the tight connection between wages and external conditions (market tightness).

In the Hall and Milgrom (2008) model, a job-seeker loses most of the connection with external conditions the moment she encounters a suitable employer, but before her wage bargain is made. The bargain is controlled by the job's productivity and by her patience as a bargainer in relation to that of the employer. In the alternating offer wage-bargaining environment, as long as reaching an agreement creates value, a bargainer who receives a poor offer continues to bargain, because that choice has a strictly higher payoff than taking the outside option. Threats to exercise the outside option are simply not credible. Since this is common knowledge, changes in the value of the outside option cannot affect the bargaining outcome.

Having found what appears to be a good match, the employer then makes a comprehensive job offer. The model assumes that the worker always accepts it at the equilibrium. The wage is higher than it would be if the employer had the power to make a take-it-or-leave-it offer that denied the worker any part of the surplus. The worker's right to respond to a low wage offer by counter-offering a higher wage -though never used in equilibrium- gives the worker part of the surplus. The authors assume the absence of any commitment technology that would enable the employer to ignore a counteroffer.

As in recent works by Pissarides and Vallanti (2007); Mortensen and Nagypal (2007) and Nagypal (2007) we adopt then the rigid wage definition proposed by Hall and Milgrom (2008). We suppose that the worker receives a payoff $p(t)b$ in case negotiation breaks down but also when the agreement is delayed. For the firm, we assume that there is no cost while bargaining continues. Firms and workers renegotiate the division of the match product $p(\tau)x$, so that the outcome of the symmetric alternating-offers game is:

$$w_i(\tau,t) = \eta p(\tau)x + (1-\eta)p(t)b = p(\tau)\eta x + (1-\eta)p(t)b \tag{11}$$

where η can be interpreted as the bargaining power of each party. The central result of this bargaining process is that the real wage does not depend on the labor market tightness.[24] So, the real wage is rigid. As in the usual wage setting-rule, the real wage increases with the generosity of the unemployment benefits (b).

4. Creative job destruction: why growth does not discriminate against old workers?

We start considering the simplest version of the model, where firms do not have the possibility to renovate the technology associated with a job if growth accelerates (only creative destruction is possible) and wages do not depend on the labor market tightness (they are rigid).

When the firm hires a young (an old) worker, it knows that the worker will become old (retire) with probability λ_y (λ_o). Therefore, when actualizing the flow of future profits generated by the job, it internalizes this probability.

$$J_y(\tau,t) = \max_{T_y}\left\{\int_t^{\tau+T_y}[p(\tau)x - w_y(\tau,s)]e^{-(r+\delta+\lambda_y)(s-t)}ds + \lambda_y\int_t^{\tau+T_y}J_o(\tau,s)e^{-(r+\delta+\lambda_y)(s-t)}ds\right\} \tag{12}$$

$$J_o(\tau,t) = \max_{T_o}\left\{\int_t^{\tau+T_o}[p(\tau)x - w_o(\tau,s)]e^{-(r+\delta+\lambda_o)(s-t)}ds\right\} \tag{13}$$

where the wage is given by (11), r stands for the interest rate and T_i for $i = y, o$ is the scrapping time.

Given a stationary time path for future labor market tightness, we conjecture that the value of a new job is proportional to productivity on the technology frontier, i.e. $J_i(t,t) = p(t)J_i$. Replacing in the previous expression when $\tau = t = 0$ confirms this conjecture and yields our job destruction rule:

$$J_y = \max_{T_y}\left\{(1-\eta)\int_0^{T_y}[x - e^{gs}b]e^{-(r+\delta+\lambda_y)s}ds + \lambda_y\int_0^{T_y}J_o(0,s)e^{-(r+\delta+\lambda_y)s}ds\right\} \tag{14}$$

$$J_o = \max_{T_o}\left\{(1-\eta)\int_0^{T_o}[x - e^{gs}b]e^{-(r+\delta+\lambda_o)s}ds\right\} \tag{15}$$

Replacing $J_i(t,t) = p(t)J_i$ in the free entry condition (4) confirms that the labor market tightness is stationary, for $i = y, o$:c

$$\frac{c}{q(\theta_i)} = J_i \tag{16}$$

[23] The resolution of the model under the hypothesis that wages are set through a Nash bargaining process is available from the authors upon request.

[24] Pissarides (2009) shows that only wages associated with new matches respond to market conditions.

where we refer to this expression as the job creation rule.

The job destruction curve is a horizontal line in the space (θ_i, J_i) whereas the job creation curve is positively sloped, determining a unique intersection point (θ_i^*, J_i^*) that stands for the equilibrium in segment $i = y, o$. Evidently, to be economically meaningful these equilibrium values should be positive, which requires b and c to be sufficiently small.

Property 1a. *The equilibrium optimal age of job destruction does not depend on the age of the workers when wages are rigid:*

$$T^* = \frac{\ln x - \ln b}{g} \tag{17}$$

Proof. See appenidx B. □

Replacing (17) in the job destruction curves permits us to obtain the relationship between J_i^* and $T^* = T_y^* = T_o^*$:

$$J_y^* = x(1-\eta)\int_0^{T^*}[1-e^{g(s-T^*)}]e^{-(r+\delta+\lambda_y)s}ds + \lambda_y\int_0^{T^*}J_o(0,s)e^{-(r+\delta+\lambda_y)s}ds \tag{18}$$

$$J_o^* = x(1-\eta)\int_0^{T^*}[1-e^{g(s-T^*)}]e^{-(r+\delta+\lambda_o)s}ds \tag{19}$$

Property 1b. *The equilibrium value of a young worker job is higher than the equilibrium value of an old worker job. This implies that the hiring rate for young workers is higher than the hiring rate for seniors.*

Proof. See appendix B. □

Property 2a. *When the growth rate of technical progress increases (↑g)*

(i) The optimal scrapping time T^* decreases.
(ii) This leads to a decrease in both J_y^* and J_o^* and then to less hirings.
(iii) The impact of an increase in the growth rate of technical progress on the match surplus is greater for young workers due to their longer time horizon. Then, when the retirement age is high (λ_o low), the negative impact of growth is smaller for the old than for the young workers.

Proof. See appendix B. □

These results remain robust when considering flexible wages.[25]

Property 1b, showed that, at the equilibrium, the hiring rate for young workers was greater than that of old workers, $J_y^* > J_o^*$. Property 2a suggests that an increase in the growth rate of technical progress decreases the comparative advantage of young workers, since their labor market tightness decreases by more than the one associated with the old segment. Indeed, a higher growth rate fosters a higher labor cost for a longer period of time if the worker is young than if the worker is old. On the other hand, the decline in the scrapping time penalizes more the young because it reduces the relative advantage of being young in terms of life horizon. Moreover, assuming $\lambda_o = \lambda_y$ we deduce, from Eqs. (18) and (19), that the reduction in T^* has a stronger effect on J_y^* through the second integral in Eq. (18). Can we then deduce that growth discriminates against young workers? This result would be completely counterfactual. We can rather conclude that we are not taking into account an impact mechanism: the creative destruction process is not able on its own to explain the link between growth and employment. A model considering only the creative destruction option provides then unrealistic results.[26] The possibility of renovation when growth accelerates must be considered.

5. Renovation: why do firms prefer to fire old workers?

We introduce now the possibility for the firm of renovating its technology when growth accelerates: the firm pays a fixed cost giving access to the best possible technology. This assumption leads to less caricatural results: with renovation, the creative-destruction process is not the only link between employment and growth. By introducing the possibility of updating, we allow firms to increase their expected profits when growth accelerates by incorporating new technologies. This can foster the opening of more vacancies (capitalization effect) if the expected profit net of renovation costs increases.

[25] Available upon request.
[26] The introduction of labor market institutions, such as the firing cost, does not improve the predicting ability of the model. Available from the authors upon request.

More formally, the possibility of updating a technology at date t is possible after incurring a fixed cost $p(t)I$ that allows the firm to increase the value of a job from $J_i^R(\tau,t)$ to $J_i^R(t,t)$ for $i = y, o$. Under a fixed renovation cost, the firm that chooses to renovate always moves to the current technology frontier. For simplicity we assume that the renovation cost is the same for young and old workers.[27]

In this new framework, a job can then be destroyed by an exogenous shock, by an endogenous decision of the firm (if the relation becomes non-profitable) or the technology of the job may be updated if the firm pays a fixed renovation cost $p(t)I$ (rather than destroying the job and creating a new one, it may be more profitable for the firm to renovate). Evidently, when renovation takes place the implementation horizon T_i^R for $i = y, o$ is necessarily smaller than the destruction horizon ($T_i^R < T^* = T_y^* = T_o^*$ for $i = y, o$), since otherwise the job will be destroyed before the updating. When renovation occurs, the firm pays an implementation cost $p(\tau + T_i^R)I$ for $i = y, o$ in order to raise the value of the job from $J_i^R(\tau, \tau + T_i^R)$ to $J_i^R(\tau + T_i^R, \tau + T_i^R)$ for $i = y, o$.

The value of a filled job when renovation is possible is given by:

$$J_o^R(\tau,t) = \max_{T_o^R}\left\{\int_t^{\tau+T_o^R}[p(\tau)x - \eta p(\tau)x - (1-\eta)p(s)b]e^{-(r+\delta+\lambda_o)(s-t)}ds + e^{-(r+\delta+\lambda_o)(\tau+T_o^R-t)}[J_o^R(\tau+T_o^R,\tau+T_o^R) - p(\tau+T_o^R)I]\right\} \tag{20}$$

for a senior, and

$$\begin{aligned} J_y^R(\tau,t) = \max_{T_y^R}\Bigg\{&\int_t^{\tau+T_y^R}[p(\tau)x - \eta p(\tau)x - (1-\eta)p(s)b]e^{-(r+\delta+\lambda_y)(s-t)}ds + e^{-(r+\delta+\lambda_y)(\tau+T_y^R-t)}[J_y^R(\tau+T_y^R,\tau+T_y^R) \\ &- p(\tau+T_y^R)I] + \lambda_y\int_t^{\tau+T_y^R} J_o^R(\tau,s)e^{-(r+\delta+\lambda_y)(s-t)}ds\Bigg\} \end{aligned} \tag{21}$$

for a young worker.

As $J_i^R(t,t) = p(t)J_i^R$, when $\tau = t = 0$ we obtain:

$$J_o^R = \max_{T_o^R}\left\{(1-\eta)\int_0^{T_o^R}[x - e^{gs}b]e^{-(r+\delta+\lambda_o)s}ds + e^{-(r+\delta+\lambda_o-g)T_o^R}[J_o^R - I]\right\} \tag{22}$$

$$J_y^R = \max_{T_y^R}\left\{(1-\eta)\int_0^{T_y^R}[x - e^{gs}b]e^{-(r+\delta+\lambda_y)s}ds + e^{-(r+\delta+\lambda_y-g)T_y^R}[J_y^R - I] + \lambda_y\int_0^{T_y^R} J_o^R(0,s)e^{-(r+\delta+\lambda_y)s}ds\right\} \tag{23}$$

These new job "destruction/renovation" curves remain horizontal lines in the (θ_i^R, J_i^R) space for $i = y, o$, whereas we have the same positive sloped job creation curves defined in Eq. (16), leading to a unique labor market equilibrium $(\theta_i^{R*}, J_i^{R*})$ for $i = y, o$.

The optimal choice of the renovation horizon is obtained solving the right hand side problem of Eqs. (22) and (23):

$$b = \frac{x}{e^{gT_o^{R*}}} - (J_o^R - I)\frac{(r+\delta+\lambda_o-g)}{1-\eta} \tag{24}$$

$$b = \frac{x}{e^{gT_y^{R*}}} - \frac{(r+\delta+\lambda_y-g)}{1-\eta}(J_y^R - I) + \frac{\lambda_y}{e^{gT_y^{R*}}(1-\eta)}J_o^R(0,T_y^{R*}) \tag{25}$$

Replacing in Eq. (22) and (23) yields the optimal date at which the firm decides to renovate:

$$I = x(1-\eta)\int_0^{T_o^{R*}}[1 - e^{g(s-T_o^{R*})}]e^{-(r+\delta+\lambda_o)s}ds \tag{26}$$

$$I = x(1-\eta)\int_0^{T_y^{R*}}[1 - e^{g(s-T_y^{R*})}]e^{-(r+\delta+\lambda_y)s}ds + \lambda_y\int_0^{T_y^{R*}}[J_o^R(0,s) - e^{g(s-T_y^{R*})}J_o^R(0,T_y^{R*})]e^{-(r+\delta+\lambda_y)s}ds \tag{27}$$

Property 3a. *The optimal date at which the firm decides to renovate a position occupied by an old worker (T_o^{R*}) is an increasing function of the fixed renovation cost (I) and the probability of the worker becoming a retiree (λ_o). On the other hand, T_o^{R*} decreases with the growth rate of technical progress (g).*[28]

[27] Evidently, if we interpret this cost as a training cost, we should expect it to be higher for old workers, who are less likely to have the required skills to use the most recent technologies. This will simply tend to reinforce the fact that it is less interesting for firms to renovate positions occupied by old workers since they have a shorter working horizon and their training is more expensive.

[28] The optimal date at which the firm decides to renovate a position occupied by a young worker (T_y^{R*}) is an increasing function of the fixed renovation cost (I) and the probability that the worker becomes a retiree. On the other hand, T_y^{R*} decreases with the growth rate of technical progress (g). See Eq. (27), given that $\partial J_o^R(\tau,t)/\partial\lambda_o < 0$.

Proof. See Eq. (26). This result remains robust in the presence of flexible wages.[29] □

It is in the interest of the firm to renovate if and only if the renovation cost is lower than the optimal value it obtains without renovation:

$$I \leqslant J_o^* \iff T_o^{R*} < T^* \text{ for a senior}$$
$$I \leqslant J_y^* \iff T_y^{R*} < T^* \text{ for a young worker}$$

where $T^* = T_y^* = T_o^*$.

Because $J_y^* > J_o^*$ (given the equality in the obsolescence age), the firm may face three possible situations. First, renovation costs may be so high that it is never in the interest of the firm to update a technology, independently on the age of the worker ($I > J_y^* > J_o^*$). Secondly, the updating cost I may be such that $J_y^* > I > J_o^*$. That is, it is in the interest of the firm to update only if the worker is young. For old workers it is not profitable to renovate and the firm prefers to fire the worker and open a new vacancy.[30] For old workers, there is a pure "creative-destruction" effect: in this case, an acceleration in growth decreases the number of vacancies posted in the old segment, and thus the labor market tightness.

Finally, the firm can also face a situation where it is in her interest to update jobs occupied by both young and old workers, *i.e.* $J_y^* > J_o^* > I$. In this case, does an acceleration of growth increase the employment rate of old workers? Not necessarily, because the impact of a variation in g on the value function of a filled job is ambiguous.[31] If the renovation cost is close to zero, it is always optimal for firms to renovate: technological updating is a continuous process as in the Solow model. In this case, the value of a filled job increases with the TFP growth rate which leads firms to open more vacancies, yielding a "pure capitalization effect". For a higher renovation cost, even if it is in the interest of the firm to renovate, the expected profit net of renovation cost may decrease when growth accelerates, so the firm reduces the number of open vacancies.

The predominance of renovation rather than destruction when I becomes very small, can be interpreted in two ways. First, we can focus on the specific abilities of the workers. If the skills of an old worker are close to (far from) the abilities required by new jobs, the training cost is low (high) and then the renovation (scrapping) strategy is optimal. Secondly, we can focus on the sector-specific investment costs. In sectors where the cost of new equipment is low, the probability of renovating a job occupied by an old worker is higher than in sectors where the investment cost is high.[32]

What about the impact of the retirement age? Does a low retirement age discriminate against old workers? As the optimal renovation date increases with the probability of retirement, $\partial T_o^{R*}/\partial\lambda_0 > 0$, we are less likely to find $T_o^{R*} < T^*$ when the impending retirement age is low. Indeed, for a high probability of retirement, λ_o, the horizon of the worker is shorter. The probability of recouping the renovation cost is then lower than in an economy characterized by a higher retirement age (low λ_o). Furthermore since $\partial J_o^*/\partial\lambda_o < 0$ the renovation condition $I \leqslant J_o^*$ also becomes less likely. The increase in λ_o reduces then the probability of updating.[33]

6. The young and old unemployment rates

At the steady state, we must find that, in each of the two labor market segments (young and old), job creation flows must equal job destruction flows. In the economy, jobs are destroyed either because they experience an exogenous job destruction shock or because they reach the age of obsolescence. When considering the young segment we will also have to take into account the flows of entry into unemployment coming from "new born". And when focusing on the old segment we will have to consider the entries to unemployment coming from the young segment. Let us first consider the exits and entries to unemployment in the young segment. The formers correspond to the rate at which workers are matched with jobs plus the fraction of unemployed young workers becoming old, that is: $OUT_y = p(\theta_y)u_y + \lambda_y u_y$. Entries to unemployment come from new born, $\lambda_o P_o$, exogenous job destruction, $\delta(P_y - u_y)$ and from the fraction of job creation that survives in the same age-class (young) to exogenous destruction, $p(\theta_y)u_y e^{-(\delta+\lambda_y)T_y^*}$,[34] where $T_y^* = T_o^* = T^*$. Then, we have $IN_y = \delta(P_y - u_y) + p(\theta_y)u_y e^{-(\delta+\lambda_y)T_y^*} + \lambda_o P_o$. At the steady state entries and exits from unemployment are equalized, leading to the following equilibrium young unemployment rate (because the young workforce is normalized to one, u_y stands also for the unemployment rate):

$$\underbrace{p(\theta_y)u_y + \lambda_y u_y}_{OUT_y} = \underbrace{\delta(P_y - u_y) + p(\theta_y)u_y e^{-(\delta+\lambda_y)T_y^*} + \lambda_o P_o}_{IN_y} \Rightarrow u_y = \frac{\delta + \lambda_y}{\delta + \lambda_y + (1 - e^{-(\delta+\lambda_y)T_y^*})p(\theta_y)} \quad (28)$$

[29] Available upon request.

[30] This result is moderated if we introduce the possibility of heterogeneous productivity among old workers. As shown in Section 7, in this situation it may be in the interest of the firm to update positions occupied by old skilled workers.

[31] The ambiguity concerning the impact of g on job creation arises independently on whether we assume rigid or flexible wages.

[32] This result is clearly observed in France for the period 1996-2004, where we estimate that the average share of exits for workers aged above 50 is almost 23% per year in the industry whereas in the service sector it falls to 13%.

[33] This effect is less clear in the presence of flexible wages, since the increase in the optimal renovation date is also associated with an increase in the scrapping time, so at the end we might have $T_o^{R*} \gtrless T_o^*$. Because wages are flexible, we might find that the fall in wages is sufficiently steep to induce a rise in the scrapping time such that the final updating horizon T_o^{R*} remains lower than T_o^*. In this case it will be in the interest of the firm to update rather than to destroy the job (under the assumption that $I < J_o^*$), in spite of the increased probability of retirement.

[34] Note that $p(\theta_y)u_y e^{-(\delta+\lambda_y)T_y^*}$ is the number of people who got jobs $T_y^* = T_o^* = T^*$ periods ago ($p(\theta_y)u_y$) times the probability that someone will neither become old nor become exogenously unemployed during those $T_y^* = T_o^* = T^*$ years ($e^{-(\delta+\lambda_y)T_y^*}$). We assume that becoming old and exogenous job loss happen according to independent exponentials with parameters λ_y and δ, respectively.

So, the employment rate of young workers is $n_y = 1 - u_y$, since participation issues are not considered.

The reasoning is fairly similar for the old segment, however some particularities must be considered (see appendix C for a detailed derivation of the unemployment rate in this segment), since some young workers may lose their jobs (endogenously or exogenously) while simultaneously becoming old. The unemployment rate of seniors can be written as follows:

$$u_o^R = \frac{\delta + \lambda_o - \lambda_o u_y p(\theta_y)\left(\frac{1-e^{-(\delta+\lambda_y)T_o^*}}{\delta+\lambda_y}\right)}{\delta + \lambda_o + p(\theta_o)(1 - e^{-(\delta+\lambda_o)T_o^*})}$$

where $T_y^* = T_o^* = T^*$.

When all jobs are updated, the only source of destruction is the exogenous shock represented by δ, so that the young and the old unemployment rates are respectively given by $u_y = \frac{\delta+\lambda_y}{\delta+\lambda_y+p(\theta_y)}$ and $u_o^R = \frac{\delta+\lambda_o u_y}{\delta+\lambda_o+p(\theta_o)}$.

Finally, note that if the creative-destruction effect dominates in the old labor segment, when g increases there will be both more endogenous destructions (since $\partial T^*/\partial g < 0$) and also less job creations, ($\partial \theta_o/\partial g < 0$). This is, however, not sufficient to ensure that $\partial u_o/\partial g > 0$. If the capitalization effect dominates in the young labor market segment, there is a mechanical effect coming from the fact that young employed workers become old. Therefore, if employment increases in the young segment, it will also rise in the old segment. So, the impact of growth on the employment rate of the older workers remains ambiguous.

7. Match heterogeneity and aging: why are some old workers retrained?

One of the main limits of our framework is to suppose an homogeneous impact of growth on all jobs occupied by seniors. When looking to data, results are somewhat different. Two main raisons can explain the heterogenous impact of the acceleration of growth on the employment rate of older workers. First, at the same biological age in a given country, workers can have heterogenous educational histories and then heterogenous horizons. Actually, in France,[35] 34% of managers between 56 and 60 years old receives training paid by the firm in case of technological change, whereas this proportion falls to 8% for manual workers. This gap mainly comes from the gap in the retirement age: 64 years old for managers, and 60 years old for manual workers. Nevertheless, if we control for the horizon by keeping only the population groups that go on retirement at the age of 60, some differences remain: 21% of technicians between 56 and 60 years old receives training paid by the firm in case of technological change, whereas they are only 9% in the group of employees and 8% in the group of manual workers.

In spite of their short working horizon, firms continue to invest in old workers, suggesting that there must be some good quality matches such that productivity gains obtained by updating the technology associated with the job manage to compensate for the training cost. Then, when the match-quality of the job is observed, it may be optimal for the firm to retain this good draw by updating the associated technology. Note though that this labor-hoarding strategy is based on an ex-post information whereas the hiring decision is based on an ex-ante information: the quality of the match is unknown before the meeting date. Then, even if is optimal to renovate some high quality matches occupied by old workers, this does not imply that the capitalization effect is dominant: hiring decisions, and thus the magnitude of the capitalization effect, are based on the average match-quality distribution.

We try to take into account this result by introducing in the model a random idiosyncratic component ϵ in the match-specific productivity which becomes $x\epsilon$. ϵ is distributed according to a cumulative function $F(\epsilon)$ and its value is revealed once the worker and the firm meet. If the match breaks up this match-specific productivity component is lost and in the next job the worker may have a higher or a lower productivity.

Without a renovation opportunity and in the presence of rigid wages, the destruction age of a job occupied by an old worker equals $T^*(\epsilon) = \frac{\ln(x\epsilon)-\ln b}{g}$, for a given match-specific quality ϵ.[36] Note that $T^*(\epsilon) \geqslant 0$ for $\epsilon \geqslant \frac{b}{x}$.[37] Finally, these equations show that $\partial T^*(\epsilon)/\partial \epsilon > 0$ implying that firms keep high quality matches for a longer period of time. Moreover, Property 3a ($\partial T^*(\epsilon)/\partial g < 0$) and Property 1a ($\partial T^*(\epsilon)/\partial \lambda_o = 0$) still hold.

Implementing a new technology is the best option only if this horizon is lower than the scrapping time, $T_o^{R*}(\epsilon) < T^*(\epsilon)$. If firms have the opportunity of renovating, the updating horizon for old workers[38] (denoted $T_o^{R*}(\epsilon)$), solves

$$I = x\epsilon(1-\eta)\int_0^{T_o^{R*}(\epsilon)} [1 - e^{g(s-T_o^{R*})}]e^{-(r+\delta+\lambda_o)s}ds.$$

We conclude that $\partial T_o^{R*}(\epsilon)/\partial I > 0$, $\partial T_o^{R*}(\epsilon)/\partial \lambda_o > 0$ and $\partial T_o^{R*}(\epsilon)/\partial \epsilon < 0$, implying that the technology is updated more frequently in a good match (furthermore, the equilibrium value J_o^* increases with the quality level). Indeed a good match is a scarce resource that the firm tries to preserve: renovation insures that the quality of the match is maintained. Conversely,

[35] Data comes from the French Complementary Survey on Training 2001.

[36] If wages are flexible the scrapping time is given by $T_o^*(\epsilon) = \frac{\ln(x\epsilon)-\ln \omega(\theta_o)}{g}$.

[37] $\epsilon \geqslant \frac{\omega(\theta_o)}{x}$ for flexible wages.

[38] The renovation horizon for young workers, $T_y^{R*}(\epsilon)$, is given by:

$$I = x\epsilon(1-\eta)\int_0^{T_y^{R*}(\epsilon)} [1 - e^{g\left(s-T_y^{R*}\right)}]e^{-(r+\delta+\lambda_y)s}ds + \lambda_y\int_0^{T_y^{R*}(\epsilon)} \left[J_o^R(0,s) - e^{g\left(s-T_y^{R*}\right)}J_o^R(0,T_y^{R*})\right]e^{-(r+\delta+\lambda_y)s}ds.$$

for every new match the firm must draw a new match-specific productivity. This last option, implying layoffs, is preferred by the firm when its actual ϵ is low.[39]

Firms renovate only positions having a match-specific quality greater than a critical value ϵ_o^{MIN} solving:[40]

$$T_o^{R*}(\epsilon_o^{MIN}) = T^*(\epsilon_o^{MIN}) \Longleftrightarrow J_o(\epsilon_o^{MIN}) = J_o^R(\epsilon_o^{MIN})$$

Jobs having a quality level above ϵ_o^{MIN} constitute the set of renovated matches. Because $\partial T_o^{R*}(\epsilon)/\partial I > 0$ we have $\partial \epsilon_o^{MIN}/\partial I > 0$: a rise in the renovation cost is necessarily associated with an increase in the reservation quality ϵ_o^{MIN} so as to keep $T_o^{R*}(\epsilon_o^{MIN}) = T^*(\epsilon_o^{MIN})$. The set of renovated jobs then decreases. This result remains robust when assuming flexible wages.

At ϵ_o^{MIN} the firm is indifferent between renovating or destroying the job, implying that when g accelerates the creative destruction effect is actually dominant[41] for the marginal worker having a productivity level ϵ_o^{MIN}. If a higher growth leads to more destructions, this reduces the incentives to renovate the job: the reduction in the renovation horizon fostered by the rise in g is greater than that of the scrapping time. Consequently, the reservation quality ϵ_o^{MIN} increases in order to reestablish the equality $T_o^{R*}(\epsilon_o^{MIN}) = T^*(\epsilon_o^{MIN})$. The set of renovated jobs will fall.[42] The acceleration in the growth rate reduces the match quality heterogeneity of the set of jobs being renovated, since only the best quality matches survive.

8. Numerical simulations

Our empirical analysis (see Table 1) shows that an increase of one percentage point in the growth rate increases aggregate employment rate by 1.55 points and young's employment rate by 1.49 points, which is coherent with the empirical estimations of Pissarides and Vallanti (2007). In contrast, an increase of one percentage point in the growth rate does not seem to have a significant effect on the employment rate of old workers (see column 3 Table 1) and and it is rather the interacted variable between the TFP growth and the short horizon that arises as significant and equal to -3.08 (this elasticity remains robust when controlling for the interacted effect of institutions).

The theoretical analysis shows that there is an equilibrium such that an acceleration of the TFP growth can improve the employment rate of prime-age workers, and simultaneously discriminate against older workers. This equilibrium can support our empirical evidence. In this section, we propose numerical experiments in order to test the ability of the model to reproduce the variation in the employment rates estimated in the introduction. These experiments contribute to enriching the discussion on the capacity of the matching model to explain the impact of productivity changes on the employment rate.[43] We only report the outcome of computational experiments for the rigid wage case. Pissarides and Vallanti (2007) paper shows that this assumption improves the elasticity of the employment rate with respect to the TFP growth rate.

The numerical values of the parameters of our benchmark simulation are summarized in Table 5. The discount factor, the recruiting cost and the bargaining power are taken from Mortensen and Pissarides (1994). A matching function of the Cobb-Douglas form is assumed: $M = \phi u_i^{\alpha} v_i^{1-\alpha}$, for $i = y, o$, where α is the elasticity with respect to unemployment and it is assumed to be equal to 0.5 (see Petrongolo and Pissarides (2001)). Concerning the exogenous destruction rate, we employ the estimations provided by Gomez-Salvador et al. (2004) for France for the period from 1992 to 2000. The estimated annual job destruction rates[44] for the manufacturing sector are equal to 3.2%. The outside option $b = .4$ is chosen on the basis of the estimations made by Blanchard and Wolfers (2000) for France.

Given this standard set of parameter values, we choose the renovation cost I and the scale parameter of the matching function ϕ, so that to match both the employment rate and the unemployment duration of an European type economy (France). Our numerical simulations display, for an annual TFP growth rate equal to 2%, an equilibrium employment rate around 90% for the 20–54 year old workers (young workers) and an unemployment duration of around one year and a half. For 55–64 year old workers the employment rate[45] equals 39% and the unemployment duration is six years, which actually

[39] These results are robust to the introduction of a flexible wage.

[40] For young workers:

$$T_y^{R*}(\epsilon_y^{MIN}) = T^*(\epsilon_y^{MIN}) \Longleftrightarrow J_y(\epsilon_y^{MIN}) = J_y^R(\epsilon_y^{MIN}).$$

[41] Note that, it is not because it is in the interest of the firm to renovate a job, that the capitalization effect dominates.

[42] Numerical simulations show that this result is robust for a large set parameter values of the model. Available from the authors upon request.

[43] See Pissarides and Vallanti (2007) for the long-run relationship between TFP growth and employment, or Shimer (2005); Hall (2005); Mortensen and Nagypal (2007); Hagedorn and Manovskii (2008); Costain and Reiter (2008) or Pissarides (2009) for the short-run relationship between productivity shocks and employment fluctuations.

[44] As suggested in Pissarides and Vallanti (2007), we consider that, although a job may be "destroyed" on average after ten years in the sense of Davis et al. (1996) (for US) or OECD (1996) (for other western countries), the position is not necessarily closed down but brought back into use at a later date. In this case, the expected life of the job for discounting purposes will be the life of the position, not the job. This definition of "job destruction" is also employed by Gomez-Salvador et al. (2004) who consider a sample of continuing firms for 15 European countries for the period 1992-2000 (they do not include firms' closures).

[45] We consider that young workers enter the labor market at the age of 20, which implies neglecting all those workers that pursue their educational training until later. In order to compensate this overestimation, we consider as older workers all those going until the age of 64. We assume that the retirement age is equal to 60, as in the French economy. Then, the employment rate of the 55–59 years old workers is strictly positive. In contrast, the employment rate for the 60–64 years old workers is equal to zero. The employment rate of the 55–64 year old workers is then computed as the weighted average of these employment rates.

Table 5
Baseline parameters values.

Job productivity	$x = 1$
Interest rate	$r = .04$
Matching elasticity	$\alpha = .5$
Recruiting cost	$c = .35$
Exogenous separation rate	$\delta = .032$
Bargaining power	$\eta = .5$
Outside option	$b = .4$
Young age duration	$1/\lambda_y = 36$ years
Old age duration	$1/\lambda_o = 4$ years

implies that a worker over 55 years old loosing her job does never go back into employment before retirement.[46] Our estimation of the scale parameter of the matching function equals 0.25 and the renovation cost is 0.6.

Table 6 reveals many interesting results. First of all, an increase of one percentage point in the TFP growth rate decreases the unemployment duration of young workers while increasing that of old workers. The capitalization effect is then dominant in the young segment whereas the creative destruction dominates in the old segment. Secondly, it is in the interest of the firms to renovate positions occupied by young and old workers ($T_i > T_i^R\ \forall i = y, o$).[47] The optimal renovation horizon is 13.49 years for young workers and 27.62 years for old workers. Given the short working horizon of old workers (the expected duration for a job occupied by an old worker is 4 years) these jobs are likely to have ended before the renovation date. In contrast, young workers can take advantage of economic growth since their working horizon equals 36 years. Finally, Table 6 shows that an increase of one percentage point in the growth rate increases the employment rate of young workers by 0.143 percentage points and decreases that of old workers by 0.016 percentage points, which remains far away from the empirical estimations[48] provided in Table 1. The low reactivity of the old-worker employment rate is due to the large impact of the horizon effect: the impact of the endogenous job destruction flows on the employment rate is small because *(i)* the proportion of the 55–59 age-group in the total population of 55–64 year old workers is one half, and *(ii)* there is a positive effect coming from the young labor segment where the employment rate increases.

8.1. Sensitivity analysis

In Pissarides and Vallanti (2007), the authors find that, in order to reproduce the estimated elasticity of unemployment with respect to growth, $r + \delta$ should equal 0.05. This implies adopting completely unrealistic values for r or for δ. Similar to Pissarides and Vallanti (2007) or Shimer (2005), we can check the robustness of the results with respect to our parameter choice.

First, Table 7 displays, for different parameter values, the change in the employment rate of young and senior workers, as well as the change in their unemployment duration, when growth increases from 2% to 3%. We modify sequentially (i) the values of r and δ, such that $r + \delta = 0.05$, (ii) the value of the working horizon, λ_y and λ_o, (iii) the generosity of the unemployment system, b, (iv) the elasticity of the matching process with respect to unemployment α, and (v) the renovation cost, I. In all cases, we adjust the value of the matching efficiency ϕ, so as to reproduce an employment rate of young workers of 90%, an average unemployment duration of 1,5 years for young workers and an employment rate of 39% for old workers. This exercise allows us to identify the parameters yielding major changes in the employment rate of senior and young workers when growth accelerates.

Second, in Table 8 we interact the effect of various changes. As suggested in the empirical investigation of the paper (Tables 1 and 3), institutions (and the interactions between them), are likely to account for a non-negligible part of the progression in the employment rate when growth accelerates. Our numerical exercise aims at evaluating the impact of these combined effects on the employment rate of both senior and young workers, so as to identify the driving parameters of the employment rate on each segment.

Let us start with part A of Table 7. As in Pissarides and Vallanti (2007), we first consider the case where firms discount the revenues from new jobs over an infinite horizon. However, contrary to Pissarides and Vallanti (2007) we consider the existence of embodied technological progress. We observe that the employment rate of young workers increases considerably more than in the benchmark, but the resulting unemployment duration is somewhat high (above three years). Moreover, since these young workers become old, there is a mechanical effect on the old segment yielding a rise in the employment rate in spite of the decrease in the labor market tension of this segment. Both the numerical results and the

[46] This is in accordance with the French experience because French workers above 56 being unemployed are allowed to stop searching for a job while receiving the unemployment benefit.

[47] As in Pissarides and Vallanti (2007), the calculated scrapping times are very high, above 45 years for $g = 2\%$ and above 30 years for $g = 3\%$.

[48] Note that, to reproduce the impact of growth on the aggregate unemployment rate, Pissarides and Vallanti (2007) are obliged to assume that there is no embodied technological progress (no creative destruction), that wages are rigid and that firms discount the revenues from new jobs over an infinite horizon. In our case, wages are rigid, however we account for creative destruction and we also consider that firms discount the revenues from new jobs over a finite horizon.

Table 6
The impact of growth on the main macroeconomic variables.

	n_y (%)	n_o (%)	T_y	T_y^R	T_o	T_o^R	$1/p(\theta_y)$	$1/p(\theta_o)$
$g = 2\%$	90.14	38.74	45.81	13.49	45.81	27.62	1.83	6.29
$g = 3\%$	90.29	38.72	30.54	10.69	30.54	19.53	1.80	6.45

hypothesis of an infinite discounting horizon seem unrealistic to us. We rather focus on alternative, but more reasonable, values of the model's parameters.

Part B of Table 7 focuses on the working horizon. As observed, whereas the elasticity of the employment rate with respect to growth is slightly modified when we change the working horizon of young workers, it strongly reacts to any modification of the working horizon of seniors. This result is not surprising. Modifying by 2 or 4 years the working horizon of someone that has still a working horizon of 36 years, will necessarily have a less important effect than modifying by 2 or 4 years the working horizon of someone having only 4 more years to work. The relative size of the shock is not the same.

Part C considers the consequences of a change in the generosity of the unemployment system. The elasticity of the employment rate with respect to growth of both, senior and young workers, is very reactive to any change in b. Particularly, the increase in the generosity of the unemployment benefit system, rises (in absolute terms) to 3.54 the elasticity of the employment rate with respect to growth for senior workers, which is even above our empirical estimations.

Part D focuses on the elasticity of the matching process with respect to the number of unemployed, α. For low values of α, the probability of filling a vacancy ($q(\theta) = m_0\theta^{-\alpha}$) is reduced. So when growth accelerates, if firms want to benefit from the increased profit they will have to post more vacancies. This boosts the labor market, as it increases the probability of finding a job and reduces unemployment duration. Thus for $\alpha = 0.3$ we observe that an increase of one percentage point in growth improves the employment rate of both young and senior workers.

Finally, part E considers a variation in the renovation cost. The elasticity of the employment rate of young workers with respect to growth seems more sensitive to this cost than the elasticity of senior workers.

In sum, if we leave aside the infinite discounting horizon assumption proposed by Pissarides and Vallanti (2007), and focus instead on alternative (more reasonable) parameter values for our model, we can conclude that: (*i*) the working horizon has a major influence on the elasticity of senior employment with respect to growth, while the influence is minor for the young workers' case; (*ii*) the generosity of the unemployment benefit system plays a major role in the progression of the young and old employment rates when growth accelerates; finally (*iii*) a modification in the elasticity of the matching process with respect to unemployment or a modification of the renovation cost foster a larger variation in the young employment rate than in the senior employment rate.

Table 8 presents the impact of an acceleration in growth on the employment rate in the presence of various institutions. For the young segment, we combine a weakly reactive labor market with respect to the number of unemployed (low α) with a lower renovation cost. The former assumption is easily justified on the basis of the European experience (most European countries suffer from high young unemployment rates that are difficult to absorb). The reduced renovation cost, corresponds to the fact that young workers have more updated skills. We choose these two parameters since the employment rate of young workers is particularly sensitive to them (see Table 7). The newly estimated elasticity in the young segment equals 1.13, which better fits our empirical estimation than the benchmark result presented in Table 6.

For senior workers, we distinguish between two driving factors that also arise as major determinants of employment in the empirical estimations presented in Tables 1 and 3: the unemployment benefit (b) and the length of the working horizon

Table 7
Sensitivity analysis when growth increases by one percentage point (from 2% to 3%).

	$\Delta n_y/\Delta g$	$\Delta n_o/\Delta g$	$\Delta[1/p(\theta_y)]/\Delta g$	$\Delta[1/p(\theta_o)]/\Delta g$
A	*Discounting horizon*			
$r + \delta = 0.05$	0.5545	0.1809	−0.2422	0.4541
B	*Working horizon*			
$\lambda_y = 1/40$	0.1691	−0.0142	−0.0359	0.1623
$\lambda_y = 1/32$	0.1088	−0.0183	−0.0215	0.1623
$\lambda_o = 1/6$	0.1488	−0.0896	−0.0304	0.1562
$\lambda_o = 1/2$	0.1247	−1.5342	−0.0259	0.1448
$\lambda_y = 1/40$ and $\lambda_o = 1/2$	0.1545	−2.9346	−0.0331	0.1448
C	*Generosity of the unemployment system*			
$b = 0.6$	−0.8925	−3.5378	0.1830	0.3241
$b = 0.2$	0.4358	0.0895	−0.0874	0.0541
D	*Elasticity of the matching process*			
$\alpha = 0.6$	0.0922	−0.0178	−0.0188	0.0684
$\alpha = 0.3$	0.3446	0.0789	−0.0714	2.1053
E	*Renovation cost*			
$I = 0.3$	0.4787	0.0807	−0.0968	0.1292
$I = 0.8$	−0.0622	−0.0693	0.0129	0.1642

Table 8
Sensitivity analysis in the presence of various institutions when growth increases from 2% to 3%.

	$\Delta n_y/\Delta g$	$\Delta n_o/\Delta g$	$\Delta[1/p(\theta_y)]/\Delta g$	$\Delta[1/p(\theta_o)]/\Delta g$
Young workers				
$b = 0.4$, $\alpha = 0.3$, $I = 0.3$	1.1325	0.3769	−0.2297	1.8307
Old workers				
$b = 0.6$, $\alpha = 0.5$, $I = 0.6$, $\lambda_o = 1/4$	−0.8925	−3.5378	0.1830	0.3241
$b = 0.6$, $\alpha = 0.3$, $I = 0.6$, $\lambda_o = 1/2$	−2.4096	−2.9812	0.5044	4.7054

(λ_o). Concerning the unemployment benefit, in accordance with the French legislation, unemployment compensation is more generous for older workers (see Hairault et al. (2010)). Consistent with this legislation, we add a premium on the unemployment benefit for old workers which is set to $b = 0.6$. The result is already reported in part C, Table 7. When unemployment benefits are more generous, a one percentage point increase of in growth decreases the senior's employment rate by 3.54 points, which is much closer to our empirical estimations than the numerical results obtained with the standard calibration (see Table 6).

When combining this generous unemployment benefit with a shorter working horizon[49] and a less sensitive matching process (as in the young segment), an increase by one percentage point in the growth rate decreases the employment rate of seniors by 2.99 points, which corresponds well to the empirical estimations provided in the introduction. With this new calibration, most exits from employment come from retirement (which is not affected by growth), since the scrapping time remains too high with respect to the working horizon of seniors to significantly affect the destruction flows. The only impact of growth comes from the entry side, since growth reduces the labor market tightness and hence the probability of finding a job.

To conclude, a standard calibration of our model allows us to reproduce the estimated positive relationship between growth and the employment rate of young workers, as well as the negative relationship between growth and the employment rate of senior workers. However, with this standard calibration, the model is unable to reproduce the estimated size of the elasticity of employment with respect to growth. Institutional specificities associated with each market segment (young and old) must be taken into account. In the young segment, the low elasticity of the matching process with respect to the number of young unemployed together with the reduced cost of updating a technology explain the increase in the young employment rate by more than one percentage point when growth increases from 2 to 3%. In the old segment, policies combining a reduction in the working horizon with a more generous unemployment compensation, allow to understand why there is a drastic decrease in the senior's employment rate when growth accelerates.

9. Conclusions

Recent studies on the link between growth and unemployment concur on the existence of a negative relationship between both variables, suggesting that, in case of an acceleration in the growth rate, the capitalization effect dominates the creative destruction effect (see Blanchard and Wolfers (2000); Pissarides and Vallanti (2007) or Tripier (2007)). However, one of the main drawbacks of these studies is that, by considering homogeneous agents, they are ignoring the heterogenous effects that growth may have on different population segments. This paper analyzes the effects of growth on the employment rate of individuals having heterogeneous working horizons. More precisely, while very young workers (having a high turnover rate) or old workers (approaching retirement) have a short working horizon, young and middle-aged workers still have a long working horizon. Does growth affect the employment rate of these workers in an homogenous way?

We present some empirical facts showing that the link between economic growth and the employment rate depends on the working horizon of the considered population. In OECD countries, economic growth discriminates against older workers (short working horizon workers), whereas it leads to more employment for prime-age workers (long working horizon workers). In order to explain these empirical results, we introduce in a standard Mortensen and Pissarides (1998) heterogenous workers in terms of their working horizon. In the aim of simplicity we consider 2 types of individuals: young workers having a long working horizon and old workers with a short working horizon. Life-cycle features introduce a comparative advantage for young workers: when a worker is young, the time horizon during which a firm can recoup the updating cost of renovating an existing technology is longer than for a senior.

Contrary to Pissarides and Vallanti (2007), our results suggest that the creative destruction effect is a useful concept in order to explain the link between economic growth and the employment rate when considering heterogeneous workers in terms of their working horizon. Moreover, whereas the capitalization effect applies for the young segment when growth accelerates, the creative destruction effect is dominant in the old segment.

Our computational experiments confirm this theoretical result. Using a standard calibration, our model manages to reproduce the positive relationship between growth and the employment rate of long working horizon workers (young workers), and the negative relationship between growth and the employment rate of short working horizon workers (old workers). However, the simulated variations remain far removed from their empirical counterparts. Institutional specificities

[49] In France, from the age of 57, workers loosing their job are not forced to search for a job in order to be eligible for the unemployment benefit first, and for the retirement pension, from the age of 60.

associated with each labor market segment (young and old) must be taken into account to reproduce the estimated size of the variation in the employment rates when growth accelerates.

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Appendix A. Data sources, variables and robustness tests

- Group-specific employment rates: employed workers as share of the corresponding population group, in %. Source: OECD, Database on Labor Force Statistics. Data adjustments: missing observations are obtained by linear interpolation when possible.
- Implicit tax on continuing activity: weighted average of implicit tax rates on continued work between age 55 and 60 in early retirement pathways (50%) and between age 60 and 65 in both early retirement pathways (25%) and old-age pension schemes (25%). This variable can be interpreted as a summary measure of retirement incentives facing the age group 55–64. Source: Duval (2004).
- Total Factor Productivity (TFP) is computed assuming a Cobb-Douglas production function. More precisely, the AMECO database (OECD) contains information on the gross domestic product, the capital stock and the employment level for the period 1960–2008. Assuming a capital share in the production function equal to $\alpha = 0.35$, we compute TFP as: $A = \frac{Y}{L^{1-\alpha}K^{\alpha}}$. We use the HP-filter component of the TFP growth rate so as to capture the long-run path.
- Output gap: gap between actual and potential output as a percentage of potential output. Source: OECD, Economic Outlook 76, December 2004.
- Product market regulation: OECD summary indicator of regulatory impediments to product market competition in seven non-manufacturing industries. Source: OECD Economics Department.
- Average replacement rate: average unemployment benefit replacement rate across two income situations (100% and 67% of APW earnings), three family situations (single, with dependent spouse, with spouse in work) and three different unemployment durations (1st year, 2nd and 3rd years, and 4th and 5th years of unemployment). Source: OECD, Benefits and Wages Database.
- Tax wedge: combined labor and consumption tax rate derived from National Accounts. Source: OECD Revenue Statistics and OECD National Accounts (see Bassanini Duval (2007) for more details).
- Employment protection for regular contracts: OECD summary indicator of the stringency of Employment Protection Legislation. Source: OECD, Employment Outlook 2004.
- Union density: trade union density rate, i.e. the share of workers affiliated to a trade union, in %. Source: OECD, Employment Outlook 2004.
- Union coverage: Collective bargaining coverage rate, i.e. the share of workers covered by a collective agreement, in %. Source: OECD, Employment Outlook 2004.

Appendix B. Proofs

Property 1a. *The equilibrium optimal age of job destruction is the solution to the problems defined on the right hand side of Eqs. (14) and (15). Concerning the first order condition of Eq. (14) we find:*

$$(1-\eta)(x - e^{gT_y^*}b) + \lambda_y J_o(0, T_y^*) = 0$$

$$\text{where} \quad J_o(0, T_y^*) = (1-\eta)x \int_{T_y^*}^{T_o^*} (1 - e^{g(s-T_o^*)}) e^{-(r+\delta+\lambda_o)(s-T_y^*)} ds$$

$$e^{gT_y^*} = \frac{x}{b}\left[1 + \lambda_y \int_{T_y^*}^{T_o^*} (1 - e^{g(s-T_o^*)}) e^{-(r+\delta+\lambda_o)(s-T_y^*)} ds\right] \tag{29}$$

The first order condition associated with (15) is:

$$e^{gT_o^*} = \frac{x}{b} \tag{30}$$

Evaluating at T_y^* a job occupied by an old worker, $J_o(0, T_y^*)$, has no sense if the job is already destroyed, that is, T_y^* cannot be larger than T_o^* in this context. Similarly, in order to find $T_y^* < T_o^*$ we need the integral term, $\int_{T_y^*}^{T_o^*} (1 - e^{g(s-T_o^*)}) e^{-(r+\delta+\lambda_o)(s-T_y^*)} ds$, to be negative, which cannot be the case if $T_y^* < T_o^*$. Hence, there is only one possible solution: $T_y^* = T_o^* \equiv T^*$. This yields the following expression for the scrapping time:

$$T^* = \frac{\ln x - \ln b}{g} \quad (31)$$

which does not depend on the age of the workers.

Property 1b. *If $\lambda_y = \lambda_o$, Eqs. (18) and (19) clearly show that $J_y^* > J_o^*$. When $\lambda_y \to 0$, we also deduce from (18) and (19) that $J_y^* > J_o^*$. Then, by monotonicity, $\forall \lambda_y \in [0;\lambda_o]$, we have $J_y^* > J_o^*$. Because we assume that $\lambda_y < \lambda_o$, property 1b always holds. Because the job creation curve (Eq. 16) is an increasing relation between θ_i and J_i, we deduce that $\theta_y > \theta_o$.*

Property 2a. *Concerning (i), we easily deduce from Eq. (17) that $\frac{\partial T^*}{\partial g} < 0$. Concerning (ii), the job creation curve is not affected in none of the segments. The only observed shift in the (θ, J) space (for a constant scrapping time, $T = const$) corresponds to the job destruction curve which moves downwards:*

- In the old segment:

$$\frac{\partial J_o}{\partial g}|_{T=const} = \int_0^T (-se^{gs}b)e^{-(r+\delta+\lambda_o)s}ds < 0 \quad (32)$$

- In the young segment:

$$\frac{\partial J_y}{\partial g}|_{T=const} = \int_0^T (-se^{gs}b)e^{-(r+\delta+\lambda_y)s}ds + \lambda_y \int_0^T \frac{\partial J_o(0,s)}{\partial g} e^{-(r+\delta+\lambda_y)s}ds < 0 \quad (33)$$

Because faster growth shifts down the horizontal job destruction curves and does not affect the positive relation between θ_i and J_i defined by the job creation curves, both the equilibrium value of the match surplus and the labor market tightness decline with growth, *i.e.* $\frac{\partial J_i}{\partial g} < 0$ and $\frac{\partial \theta_i}{\partial g} < 0$ for $i = y, o$.

Part *(iii)* can be deduced from (32) and (33). Indeed, at the limit, we have $\lambda_y = \lambda_o$: in this case, $\left|\frac{\partial J_o}{\partial g}|_{T=const}\right| < \left|\frac{\partial J_y}{\partial g}|_{T=const}\right|$. When $\lambda_y \to 0$ the inequality still holds: $\left|\frac{\partial J_o}{\partial g}|_{T=const}\right| < \left|\frac{\partial J_y}{\partial g}|_{T=const}\right|$. For $\lambda_y \in [0,\lambda_o]$, the impact of an increase in the growth rate of technical progress is greater for young workers. Because we assume $\lambda_y < \lambda_o$, the inequality $\left|\frac{\partial J_o}{\partial g}|_{T=const}\right| < \left|\frac{\partial J_y}{\partial g}|_{T=const}\right|$ always holds.

Appendix C. The unemployment rate of senior workers

At each time t, the flow of young workers employed in a vintage τ becoming old is defined by:

$$n_o^y(\tau,t) = \lambda_y u_y(\tau,t)p(\theta_y(\tau,t))e^{-(\delta+\lambda_y)(t-\tau)}$$

where $u_y p(\theta_y)e^{-(\delta+\lambda_y)(t-\tau)}$ is the number of young people who got jobs $(t-\tau)$ periods ago $(p(\theta_y(\tau, t))u_y(\tau, t))$ times the probability that they had not become old nor become exogenously unemployed during those $(t-\tau)$ years $(e^{-(\delta+\lambda_y)(t-\tau)})$. The dynamics of employment for old workers is then given by

$$\dot{n}_o(t) = \underbrace{-(\delta+\lambda_o)n_o(t)}_{Exo.des.} - \underbrace{n_o(t-T_o,t)}_{Endo.des.} + \underbrace{\int_{t-T_o}^t n_o^y(\tau,s)ds}_{Youngbecomingold} + \underbrace{u_o p(\theta_o)}_{Hirings}$$

where

$$n_o(t-T_o,t) = u_o p(\theta_o)e^{-(\delta+\lambda_o)T_o}$$

$$\int_{t-T_o}^t n_o^y(\tau,s)ds = \int_{t-T_o}^t \lambda_y u_y(\tau,s)p(\theta_y(\tau,s))e^{-(\delta+\lambda_y)(s-t)}ds$$

At steady state, we have $u_y(\tau, t) = u_y$ and $p(\theta_y(\tau, t)) = p(\theta_y)$ which leads to:

$$\int_0^{T_o} n_o^y(s)d\tau = \lambda_y u_y p(\theta_y) \int_0^{T_o} e^{-(\delta+\lambda_y)s}ds = \lambda_y u_y p(\theta_y)\frac{1-e^{-(\delta+\lambda_y)T_o}}{\delta+\lambda_y}$$

At the steady state entries to employment must equal exits, so that $\dot{n}_o(t) = 0$:

$$(\delta + \lambda_o)n_o + u_o p(\theta_o)e^{-(\delta+\lambda_o)T_o} = u_o p(\theta_o) + \lambda_y u_y p(\theta_y)\frac{1 - e^{-(\delta+\lambda_y)T_o}}{\delta + \lambda_y}$$

Since $P_o = \frac{\lambda_o}{\lambda_y}, u_o^R = \frac{u_o}{P_o}$ and $n_o = P_o - u_o$, the unemployment rate of seniors can be rewritten as follows:

$$u_o^R = \frac{\delta + \lambda_o - \lambda_o u_y p(\theta_y)(\frac{1-e^{-(\delta+\lambda_y)T_o}}{\delta+\lambda_y})}{\delta + \lambda_o + p(\theta_o)(1 - e^{-(\delta+\lambda_o)T_o})}$$

References

Aghion, P., Howitt, P., 1994. Growth and unemployment. Review of Economic Studies 61 (3), 477–496.

Aubert, P., Caroli, E., Roger, M., 2006. New technologies, workplace organization and the age structure of the workforce: firm-level evidence. Economic Journal 116, 73–93.

Bartel, A., Sichermann, N., 1993. Technological change and retirement decisions of older workers. Journal of Labor Economics 11 (1), 162–182.

Bassanini, A., Duval, R., 2006. Employment patterns in OECD countries: reassessing the role of policies and institutions. Social Employment and Migration Working Papers, no. 35.

Berman, E., Bound, J., Griliches, Z., 1994. Changes in the demand for skilled labor within U.S. manufacturing: evidence from the annual survey of manufacturers. Quarterly Journal of Economics 109, 367–397.

Binmore, K., Rubinstein, A., Wolinsky, A., 1986. The nash bargaining solution in economic modelling. Rand Journal of Economics 17 (2), 176–188.

Blanchard, O., Wolfers, J., 2000. The role of shocks and institutions in the rise of European unemployment: the aggregate evidence. The Economic Journal 110 (462), 1–33.

Castaneda, A., Diaz-Gimenez, J., Rios-Rull, V., 2003. Accounting for earnings and wealth inequality. Journal of Political Economy 111 (4), 818–857.

Cheron, A., Hairault, J.-O., Langot, F., 2007. Job Creation and job destruction over the life cycle: the older workers in the spotlight. IZA Discussion Paper, no. 2597.

Costain, J., Reiter, M., 2008. Business cycles, unemployment insurance, and the calibration of matching models. Journal of Economic Dynamics and Control 32, 1120–1155.

Davis, S.J., Haltiwanger, J.C., Schuh, S., 1996. Job Creation and Destruction. MIT Press.

Duval, R., 2004. Retirement behaviour in OECD countries: impact of old-age pension schemes and other social transfer programmes. OECD Economic Studies (37).

Gomez-Salvador, R., Messina, J., Vallanti, G., 2004. Gross job flows and institutions in Europe. Labour Economics 11 (4), 469–485.

Gruber, G., Wise, D., 1999. Social Security and Retirement around the World. The Chicago University Press.

Hagedorn, M, Manovskii, I, 2008. The cyclical behaviour of equilibrium unemployment and vacancies revisited. American Economic Review 98 (4), 1692–1706.

Hairault, J.O., Langot, F., Sopraseuth, T., 2010. Distance to retirement and older workers employment: the case for delaying the retirement age. Journal of the European Economic Association 8 (5).

Hall, R., 2005. Employment fluctuations with equilibrium wage stickiness. American Economic Review 95 (1), 50–65.

Hall, R., Milgrom, P., 2008. The limited influence of unemployment on the wage bargain. American Economic Review 98 (4), 1653–1674.

Hornstein, A., Krusell, P., Violante, G., 2007. Technology-policy interaction in frictional labor markets. Review of Economic Studies 74 (4), 1089–1124.

Ljunqvist, J., Sargent, T., 2008. Two questions about European unemployment. Econometrica 76, 1–29.

Machin, S., Van Reenen, J., 1998. Technology and changes in skill structure: evidence from seven OECD countries. Quarterly Journal of Economics 113, 1215–1244.

Moreno-Galbis, E., Sneessens, H., Unemployment, 2007. capital-skill complementarity and embodied technological progress. Louvain Economic Review 73, 241–272.

Mortensen, D., Nagypal, E., 2007. More on unemployment and vacancy fluctuations. Review of Economic Dynamics 10 (3), 327–347.

Mortensen, D., Pissarides, C.A., 1994. Job creation and job destruction in the theory of unemployment. Review of Economic Studies 61, 397–415.

Mortensen, D., Pissarides, C., 1998. Technological progress, job creation and job destruction. Review of Economic Dynamics 1, 733–753.

Nagypal, E., 2007. Labor Market Fluctuations. On-the-Job Search and the Acceptance Curse. Mimeo.

OECD, 1996. Job Creation and loss: analysis, policy and data development. OECD.

Petrongolo, B., Pissarides, C., 2001. Looking back into the black box: a survey of the matching function. Journal of Economic Literature 39, 390–431.

Pissarides, C., 1990. Equilibrium Unemployment Theory. MIT Press, Cambridge, Massachusetts.

Pissarides, C., 2009. The unemployment volatility puzzle: is wage stickiness the answer? Econometrica 77 (5), 1339–1369.

Pissarides, C., Vallanti, G., 2007. The impact of TFP growth on steady-state unemployment. International Economic Review 48, 607–640.

Postel-Vinay, F., 2002. The dynamics of technological unemployment. International Economic Review 43 (3), 737–760.

Saint-Paul, G., 2009. Does the welfare state make older workers unemployable. IDEI Working Paper, no. 569.

Shimer, R., 2005. The dyclical behavior of equilibrium unemployment and vacancies. American Economic Review 95 (1), 25–49.

Tripier, F., 2007. The long run relationship between growth and unemployment. A Transatlantic Perspective, Mimeo.