Low-Skilled Unemployment, Capital-Skill Complementarity and Embodied Technical Progress

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Abstract

We construct an intertemporal general equilibrium model with two types of jobs and two types of workers. We allow for job competition between high- and low-skilled workers on the low-skilled segment of the labour market and for on-the -job search. Matching processes are represented by matching functions *à la* Pissarides. Workers search intensities are endogenous. The model is calibrated and simulated to evaluate the impact of various types of shocks. Biased technological change is introduced via embodied technical progress and a capital-skill complementarity. The model reproduces quite well the unemployment rate changes and the relative wage stability observed over the last two decades. It suggests strong interactions between biased technological change, discouragement effects and job competition.

Keywords: skill mismatch, equilibrium unemployment, ladder effect, macro dynamics

JEL classification: E24, J21, J23

1 Introduction

The unemployment rise observed in many EU countries over the last decades has been particularly strong among low-skilled workers. One possible interpretation of this uneven unemployment changes is in terms of biased technological change. If investment in new technologies raises the relative demand for skilled workers[1], there will be more low-skilled unemployment unless the change in relative demands is compensated by a change in the relative wages or in relative labour supplies. Bias technological change combined with relative wage rigidities may thus lead to "skill mismatch". More and more attention is now paid however to an alternative interpretation in terms of job competition. If high-skilled workers may compete with low-skilled ones for low-skilled jobs but not the opposite is not true, purely aggregate shocks may potentially have strong asymmetric unemployment effects by generating a so-called ladder effect. The interest for this alternative view has arisen from the observation that all unemployment rates have increased, while a a biased technological change should a priori decrease the unemployment rates for high-skilled workers, at least if wage-wage interactions are not too strong. In many OECD countries, investment in human capital (education) has significantly increased despite a stable wage premium (see for instance Muysken *e*t al. [24]. Youngsters invest more in human capital not because the relative wage for high-skilled on complex jobs has increased, but rather because a higher education level increases the number of job opportunities. Recent empirical works suggest that the proportion of "overqualified" workers is far from negligible although hard to evaluate[2].

Theoretical models have been constructed and calibrated to examine this issue. Gautier [14] develops a stylized partial equilibrium model with two types of jobs and two types of workers and wage bargaining. He focuses on the stationary state properties of the model and emphasizes the diversity of effects that can be obtained as a result of the externalities introduced

[1] There is ample evidence suggesting that technological progress may have substantially increased the relative demand for skilled workers (see for instance Autor *et al* [4], Berman *et al* [5], and Machin and Van Reenen [20]).

[2] Hartog [17] collects empirical results from various studies about the level of job competition ("overeducation") in several EU countries. Depending on the methodology used and the country surveyed, this overeducation is estimated to be in between 10% and 30% during the first half of the nineties. Moreover, it is also shown that overeducation increased over the last decades (except in UK).

via the matching function. Dolado *et al.* [11] use a similar approach (with a simpler albeit more realistic representation of wage determination) to provide a quantitative analysis of the Spanish case. They calibrate a stationary equilibrium model to evaluate the job competition effect triggered by the dramatic increase in the proportion of skilled workers that took place in the late eighties. Similar models also include Albrecht and Vroman [2] and Dolado *et al.* [12]. Collard *et al.* [10] provide a first attempt to include this type of quantitative analysis in a dynamic general equilibrium setup. Pierrard and Sneessens [27] use a similar setup with on-the-job search and endogenous search intensities for high-skilled workers so as to obtain a less mechanical job competition effect. Their model explains a significant part of the unemployment rise observed over the last twenty years by simply changing two parameters: the relative productivity of high-skilled workers and the proportion of high-skilled workers in the total labour force. They furthermore examine the interactions between "skill mismatch" and "job competition". Although the proportion of overqualified workers they obtain is relatively low, job competition contributes significantly to the overall increase in low-skilled unemployment.

One of the main difficulties in these models is to account for simultaneously for the three main stylized facts observed in many EU countries since the mid seventies: (i) the overall unemployment rate increase; (ii) the difference between high-skilled and low-skilled unemployment; (iii) the stability of relative wages[3]. This paper focuses on these issues. It builds on [27]. Our contribution is threefold. Instead of assuming that low-skilled wages are indexed on high-skilled ones, we allow separate wage bargaining for all workers. We also investigate the consequences of the discouragement effect on the part of low-skilled workers by endogenizing their search intensities. Finally, we introduce biased technological change as the result of embodied technical progress with a capital-skill complementarity. Many empirical studies (see Berman *et al* [5], Fitz Roy and Funke [13], Machin and Van Reenen [20], Krusell [19] and Moreno-Galbis [23]) point to the importance of the capital-skill complementarity. Technological progress seems also to have become more and more embodied (see Greenwood *et al.* [15]). The model reproduces correctly the three main stylized facts mentioned above. We furthermore obtain a significant discouragement

[3] In OECD [25], data (from 1979 to 1995) about the distribution of earnings (D9/D5 (ratio of the upper earnings limit of the ninth decile of workers to the upper limit of the fifth decile) and D5/D1) are provided for eleven EU countries. For all these countries (except in UK), these ratios remain fairly stable all over the period studied.

effect of low-skilled workers partly induced by an dpartly reinforcing the competition effect.

The paper is organized as follows. In section 2 we present the model. We describe labor market flows, workers and firms behaviors, and wage bargaining. In section 3 we calibrate the model on Belgian data for 1996. We examine the properties of the model by simulating its responses to various types of shocks. We next set the the technological and labour force composition variables to their 1976 values and check the ability of the model to reproduce the stylized facts. Section 4 concludes.

2 The Model

There are four types of agents: (*i*) intermediate firms (they use labor to produce intermediate goods), (*ii*) a representative final firm (it uses intermediate goods and capital to produce an homogeneous final goods that can be consumed or accumulated by the representative households) (*iii*) a representative high skilled household (it supplies labor to the intermediate firms and capital to the final firm) and (*iv*) a representative low skilled household (it supplies labor to the intermediate firms).

There are two types, defined by their task complexity as in Gautier [14], of intermediate firms: intermediate firms with a complex job (and they produce a complex intermediate goods) and intermediate firms with a simple job (and they produce a simple intermediate goods)[4]. There also are two types, defined by their qualification level, of labor: the high-skilled and the low-skilled. High-skilled workers can perform simple and complex tasks; low-skilled workers can only perform simple tasks. Moreover, the high-skilled working on a simple job can continue to search (on-the-job search) for a complex job. We thus have the same double heterogeneity (jobs and workers) and the same flexibility (for the high-skilled) as in Gautier [14].

There are three markets: labor, goods and capital. On the labor market, the double heterogeneity (jobs and workers) makes search and recruiting behaviors potentially sophisticated. For each type of job, we assume a standard matching function and an exogenous job destruction rate. Because they know that their application will always be turned down, low-skilled job seekers never apply for complex jobs. High-skilled job seekers may look for both types of jobs. On the goods

[4] We can think in terms of high-tech *vs.* low-tech industries (and services) and goods.

market, the prices of the intermediate goods adjust such that their supply by the intermediate firms are equal to their demand by the final firm. Finally, on the capital market, adjustment between the supply (by the representative household) and the demand (by the representative firm) is realized *via* the endogeneous interest rate.

2.1 Labor Market Flows

Let N_t^c and N_t^s represent the total number of complex and simple jobs respectively. Simple jobs can be occupied by high- (N_t^{sh}) or low-skilled (N_t^{sl}) workers, so that $N_t^s = N_t^{sh} + N_t^{sl}$. Normalizing the total labor force to one and denoting α the (exogenous) proportion of high-skilled workers yields the following accounting identities:

$$N_t^c + N_t^{sh} + U_t^h = \alpha, \qquad \text{and} \qquad N_t^{sl} + U_t^l = 1 - \alpha, \tag{1}$$

where U_t^h and U_t^l denote the number of high- and low-skilled unemployed job-seekers respectively. Let the number of complex and simple job matches be denoted by M_t^c and M_t^s respectively. We assume that the number of such matches is a function of the number of corresponding job vacancies (V_t^c and V_t^s) and effective job seekers (number of job seekers corrected by search efficiencies), that is, we use the following two matching functions:

$$M_t^c = M^c\left(V_t^c\ ,\ sc_t\, U_t^h + o_t\, N_t^{sh}\right) \qquad \text{and} \qquad M_t^s = M^s\left(V_t^s\ ,\ ss_t\, U_t^h + sl_t\, U_t^l\right). \tag{2}$$

Both functions are assumed to be linear homogeneous. Given the conditions on the labor market (wages, probabilities to find jobs, ...), a high-skilled unemployed splits its time (normalized to 1) between searching for a complex job ($0 \leq eu_t \leq 1$) and searching for a simple job ($0 \leq 1 - eu_t \leq 1$). In the same way, a high-skilled working on a simple job spends a fraction ($0 \leq eo_t \leq 1$) of its leisure (normalized to 1) to search for a complex job. Besides, a low skilled unemployed splits its time (also normalized to 1) between searching for a job in the simple segment ($0 \leq el_t \leq 1$) and staying at home doing domestic activities ($0 \leq 1 - el_t \leq 1$). Search efficiencies, sc_t, ss_t, o_t and sl_t are increasing on the search efforts, eu_t, $1 - eu_t$, eo_t and el_t, respectively.

We denote labor market tensions by θ_t^c and θ_t^s respectively, where:

$$\theta_t^c \equiv \frac{V_t^c}{sc_t\, U_t^h + o_t\, N_t^{sh}} \qquad \text{and} \qquad \theta_t^s \equiv \frac{V_t^s}{ss_t\, U_t^h + sl_t\, U_t^l}. \tag{3}$$

With linear homogeneous matching functions, the probabilities of finding a complex or a simple job per unit of search intensity can be respectively written as follows:

$$p_t^c = \frac{M_t^c}{sc_t\, U_t^h + o_t\, N_t^{sh}} = p^c\left(\theta_t^c\right) \qquad \text{and} \qquad p_t^s = \frac{M_t^s}{ss_t\, U_t^h + sl_t\, U_t^l} = p^s\left(\theta_t^s\right). \tag{4}$$

The probabilities of filling a complex and a simple job vacancy are similarly given by:

$$q_t^c = \frac{M_t^c}{V_t^c} = q^c\left(\frac{1}{\theta_t^c}\right) \qquad \text{and} \qquad q_t^s = \frac{M_t^s}{V_t^s} = q^s\left(\frac{1}{\theta_t^s}\right). \tag{5}$$

The probability that a simple job is filled is the sum of the probabilities of hiring a high-skilled worker and a low-skilled worker:

$$q_t^{sh} = \frac{ss_t\, U_t^h}{ss_t\, U_t^h + sl_t\, U_t^l}\, q_t^s \qquad \text{and} \qquad q_t^{sl} = \frac{sl_t\, U_t^l}{ss_t\, U_t^h + sl_t\, U_t^l}\, q_t^s. \tag{6}$$

Finally, we assume two exogenous job destruction rates ψ (for the complex jobs) and χ (for the simple jobs), implying for each type of job and worker the following employment dynamics (in terms of vacancies and job-seekers' search effort respectively):

$$\begin{aligned} N_{t+1}^c &= (1-\psi)\, N_t^c + q_t^c\, V_t^c, && \text{(7-a)} \\ &= (1-\psi)\, N_t^c + p_t^c\left[sc_t\, U_t^h + o_t\, N_t^{sh}\right]. && \text{(7-b)} \end{aligned}$$

$$\begin{aligned} N_{t+1}^{sh} &= (1-\chi-o_t\, p_t^c)\, N_t^{sh} + q_t^{sh}\, V_t^s, && \text{(8-a)} \\ &= (1-\chi-o_t\, p_t^c)\, N_t^{sh} + p_t^s\, ss_t U_t^h. && \text{(8-b)} \end{aligned}$$

$$\begin{aligned} N_{t+1}^{sl} &= (1-\chi)\, N_t^{sl} + q_t^{sl}\, V_t^s, && \text{(9-a)} \\ &= (1-\chi)\, N_t^{sl} + p_t^s\, sl_t U_t^l. && \text{(9-b)} \end{aligned}$$

Figure 1 summarizes these labor market flows and transition probabilities. Armed with these definitions and notations, we can now describe firms and household behaviors.

2.2 Intermediate Firms

Intermediate firms are of the type one-job-one firm, therefore, an intermediate firm can open only a complex (VC) or a simple (VS) vacancy. A complex vacancy can be either filled by a

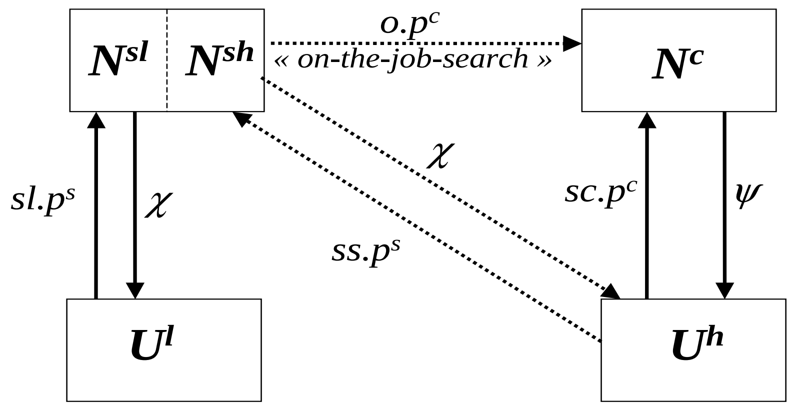

Figure 1: Labor market flows and transition probabilities

high skilled worker (FC) or remain unfilled (VC). While a simple vacancy can be filled either by a high skilled worker (FSH), a low skilled worker (FSL) or remain unfilled (VS). We can then distinguish five possible states, $i \in \{VC, VS, FC, FSH, FSL\}$, and to each one of them we can associate a value function W_t^i.

$$W_t^{VC} = -a + \mathrm{E}_t \left[q_t^c \, \frac{W_{t+1}^{FC}}{1+r_{t+1}} + (1-q_t^c) \, \frac{W_{t+1}^{VC}}{1+r_{t+1}} \right], \tag{10}$$

$$W_t^{VS} = -b + \mathrm{E}_t \left[q_t^{sh} \, \frac{W_{t+1}^{FSH}}{1+r_{t+1}} + q_t^{sl} \, \frac{W_{t+1}^{FSL}}{1+r_{t+1}} + (1-q_t^{sh}-q_t^{sl}) \, \frac{W_{t+1}^{VS}}{1+r_{t+1}} \right], \tag{11}$$

$$W_t^{FC} = 1 \, c_t^c - w_t^c + \mathrm{E}_t \left[(1-\psi) \, \frac{W_{t+1}^{FC}}{1+r_{t+1}} + \psi \, \frac{W_{t+1}^{VC}}{1+r_{t+1}} \right], \tag{12}$$

$$W_t^{FSH} = 1 \, c_t^s - w_t^{sh} + \mathrm{E}_t \left[(1-\chi-p_t^c \, o_t) \, \frac{W_{t+1}^{FSH}}{1+r_{t+1}} + (\chi + p_t^c \, o_t) \, \frac{W_{t+1}^{VS}}{1+r_{t+1}} \right], \tag{13}$$

$$W_t^{FSL} = \nu \, c_t^s - w_t^{sl} + \mathrm{E}_t \left[(1-\chi) \, \frac{W_{t+1}^{FSL}}{1+r_{t+1}} + \chi \, \frac{W_{t+1}^{VS}}{1+r_{t+1}} \right]. \tag{14}$$

We assume that the cost of opening a complex (resp. simple) vacancy is a (resp. b). Marginal productivity of jobs is normalized to unity, so that, an skilled worker in a complex job produces one unit of complex intermediate good that will be sold at the price of c_t^c per unit. In the

same way a high (low) skilled worker in a simple job produces one unit (ν units[5]) of simple intermediate good that will be sold at the price of c_t^s per unit. Finally, workers on complex jobs receive a wage w_t^c while workers in simple job receive w_t^{sh} if skilled and w_t^{sl} if unskilled.
At the equilibrium, we impose (free entry conditions): $W_t^{VC} = W_t^{VS} = 0$.

2.3 Final Firm

The representative final firm uses capital, complex goods and simple goods in order to produce a final goods *via* a linear homogeneous production function $F(\, . \, , \, . \, , \, . \,)$. Let denote W_t^F as the final firm's value function. Then it satisfies the following Bellmann equation:

$$\max_{K_t,\, Q_t^c,\, Q_t^s} F\big(K_t, Q_t^c, Q_t^s\big) - c_t^c Q_t^c - c_t^s Q_t^s - (r_t + \delta) K_t \tag{15}$$

where r_t is the interest rate. The first optimality conditions can be then written as follows:

$$F_{K_t} = r_t + \delta, \tag{16}$$

$$F_{Q_t^c} = c_t^c, \tag{17}$$

$$F_{Q_t^s} = c_t^s, \tag{18}$$

where, in general, Y_{X_t} is the first derivative of Y with respect to X_t.
The production process is represented *via* a two levels Cobb-Douglas production function. Since marginal productivity of labor in the intermediate firm has been normalized to one, we can replace, for explanatory purposes, the notation of intermediate complex (Q_t^c) and simple (Q_t^s) goods by N_t^c and $N_t^{sh} + \nu * N_t^{sl}$, respectively.

$$Y_t = z * (K_t)^{1-\mu} * ((N_t^c)^{\theta_t^1} * (N_t^{sh} + \nu * N_t^{sl})^{\theta_t^2})^{\mu} \tag{19}$$

K_t is the capital stock, z total factor productivity, μ the share of labor in the production process and θ_1 the share of complex jobs in the labor aggregate. This specification of the production function respects the constancy of the share of capital in the production process, which is an accepted stylized fact. Two important aspects must be remarked in this production function:

[5] *A priori*, ν could be lower or higher than 1. In other words, a low-skilled could be less or more productive than a high-skilled on a simple job.

1. Based on the empirical evidence, many studies (see Berman *et al* [5], Fitz Roy and Funke [13], Machin and Van Reenen [20] and Moreno-Galbis [23]) conclude on the importance of the capital skill complementarity relationship in determining the changes of labor demand composition over the last decades. To take into account this fact, θ_1 and θ_2 are endogenized making the relative share of complex jobs increasing with capital accumulation and innovation capacity of the economy:

$$\frac{\theta_t^1}{\theta_t^2} = a_0 * K_t^{a_1\,\lambda} \tag{20}$$

   where $a0, a1, \lambda$ are positive constants, and the last one is related with de capacity of innovation of the economy.

2. The increasing importance given by the literature (see Greenwood *et al.* [15] and Boucekkine *et al.* [6]) to the distinction between *disembodied technological progress* (which affects all factors) and *embodied technological progress* (which affects only new equipment), leads us to distinguish between both types of technical change. The first one is considered as exogenous, and affects all factors productivity. The second is endogenous and takes place through a learning-by-doing (LBD) process based on capital accumulation (see [6]). Let us denote embodied technological progress as q_t, so that the process of LBD will be given by:

$$K_{t+1} - K_t = q_t * I_t - \delta * K_t \tag{21}$$

$$q_t = q_0 * K_t^{\lambda} \tag{22}$$

   where I represents investment, $\delta > 0$ the exogenous depreciation rate of capital, $\lambda > 0$ the exogenous intensity of the LBD process, q_0 is a positive constant and q_t is bigger than one. The learning process takes place as follows: the presence of embodied technological process permits to obtain from one unit of investment more than one unit of capital, which, at its time, will stimulate embodied technical change. The bigger is this one, the more capital the economy is able to obtain from one unit of investment.

2.4 The household behavior

We distinguish two types of households, high- and low-skilled ones. To keep the model tractable, we assume that low-skilled consumption is equal to their current income. Distinguishing two types of households is crucial for the analysis of search and wage behaviors.

The representative high-skilled household

The representative high skilled household supplies labor to the intermediate firm and capital to the final firm. It will have to decide both, about its optimal consumption (and thus optimal saving) and about its search effort on the labor market (eu_t, eo_t). Its value function[6] is represented by:

$$W_t^{Hh} = W^{Hh}\left(K_t, N_t^c, N_t^{sh}\right). \tag{23}$$

The value function satisfies the following Bellmann equation:

$$W_t^{Hh} = \max_{C_t^h,\, eu_t,\, eo_t} \left\{\mathcal{U}\left(C_t^h\right) - \mathcal{D}\left(eo_t\right) N_t^{sh} + \beta\, \mathrm{E}_t\left[W_{t+1}^{Hh}\right]\right\}, \tag{24}$$

where the optimization is subject to constraints (1), (7-b), (8-b) and the flow budget constraint (income = expenditure):

$$w_t^c N_t^c + w_t^{sh} N_t^{sh} + w_t^u U_t^h + (r_t + \delta)K_t + \Pi_t = \frac{1}{q_t}\left(K_{t+1} - (1-\delta)K_t\right) + C_t^h + T_t. \tag{25}$$

C_t^h is the consumption of the high skilled household, $\frac{1}{q_t}\left(K_{t+1} - (1-\delta)K_t\right)$ is the investment (equation (21)), $\mathcal{U}(.)$ is an increasing and concave utility function, $\mathcal{D}(.)$ is an increasing and convex desutility function, β is the psychological discount factor. Moreover, w_t^u stands for the unemployment benefits, Π_t stands for the profits (value added net of labor and vacancy costs) redistributed by the intermediate firms and T_t stands for the taxes (lump sum taxes levied to finance the unemployment benefits). The first-order optimality conditions can then be written

[6] As usual in this type of literature, we assume a perfect insurance mechanism between the members of the household.

as follows:

$$\mathcal{U}_{C_t^h} = \beta \, \mathrm{E}_t \left[q_t \left(\delta + r_{t+1} + \frac{1}{q_{t+1}} \left(1 - \delta \right) \right) \mathcal{U}_{C_{t+1}^h} \right], \tag{26}$$

$$0 = \mathrm{E}_t \left[p_t^c \, sc_{eu_t} \, W^{Hh}_{N^c_{t+1}} - p_t^s \, ss_{1-eu_t} \, W^{H}_{N^{sh}_{t+1}} \right], \tag{27}$$

$$\mathcal{D}_{eo_t} = \beta \, p_t^c \, o_{eo_t} \, \mathrm{E}_t \left[W^{Hh}_{N^c_{t+1}} - W^{Hh}_{N^{sh}_{t+1}} \right]. \tag{28}$$

From the envelope theorem, we have the following additional dynamic relationships:

$$\begin{aligned} W^{Hh}_{N^c_t} &= \mathcal{U}_{C_t^h} \left(w_t^c - w_t^u \right) \\ &\quad + \beta \left(1 - \psi - p_t^c \, sc_t \right) \mathrm{E}_t \Big[W^{Hh}_{N^c_{t+1}} \Big] - \beta \, p_t^s \, ss_t \, \mathrm{E}_t \Big[W^{Hh}_{N^{sh}_{t+1}} \Big], \end{aligned} \tag{29}$$

$$\begin{aligned} W^{Hh}_{N^{sh}_t} &= \mathcal{U}_{C_t^h} \left(w_t^{sh} - w_t^u \right) - \mathcal{D} \left(eo_t \right) \\ &\quad + \beta \, p_t^c \left(o_t - sc_t \right) \mathrm{E}_t \Big[W^{Hh}_{N^c_{t+1}} \Big] + \beta \left(1 - \chi - o_t \, p_t^c - p_t^s \, ss_t \right) \mathrm{E}_t \Big[W^{Hh}_{N^{sh}_{t+1}} \Big] \end{aligned} \tag{30}$$

The representative low skilled household

The low skilled representative household supplies labor to the intermediate firm, but it is assumed to have zero savings. Therefore, the consumption of the household will be equal to its revenue, and the only decision the household has to make concerns the search effort on the labor market (el_t). Its value function is represented by:

$$W_t^{Hl} = W^{Hl} \left(N_t^{sl} \right). \tag{31}$$

The value function satisfies the following Bellmann equation:

$$W_t^{Hl} = \max_{el_t} \left\{ \mathcal{U} \left(C_t^l \right) + \beta \, \mathrm{E}_t \left[W^{Hl}_{t+1} \right] \right\}, \tag{32}$$

where the optimization is subject to the constraint (9-b) and the flow budget constraint (consumption = revenue):

$$C_t^l = w_t^{sl} N_t^{sl} + U_t^l \; (\; w_t^u + (1 - el_t) \; f(Y_t^D)) \tag{33}$$

C_t^l is the consumption of the low skilled household, which is not only determined by the revenue obtained when employed but also by the unemployment benefit and "home production" obtained when unemployed. Indeed, the unemployed worker spends $1 - el_t$ of its time on domestic production, represented by the function $f(Y_t^D)$. This is on increasing linear function of the average product:

$$f(Y_t^D) = \zeta\, Y_t^D, \tag{34}$$

$$Y_t^D = \frac{Y}{N_t^c + N_t^s} \tag{35}$$

where $\zeta > 0$.

The first order optimality condition can be written as follows:

$$\mathcal{U}_{C_t^l} = \frac{1}{f(Y_t^D)}\, \beta\, \mathrm{E}_t \left[p_t^s \; sl_{el_t} \; W^{Hl}_{N^{sl}_{t+1}} \right] \tag{36}$$

The following dynamic relationship is obtained from the envelope theorem:

$$W^{Hl}_{N^{sl}_t} = \mathcal{U}_{C_t^l} \left[\, w_t^{sl} - \left(w_t^u + (1 - el_t)\; f(Y_t^D) \right) \right] + \beta\, \mathrm{E}_t \left[\left(1 - \chi - p_t^s \; sl_t \right) W^{Hl}_{N^{sl}_{t+1}} \right] \tag{37}$$

2.5 Wages Determination

As specified in section 2.2, we distinguish between three types of matching: a complex job occupied by a high skilled worker (NC), a simple job occupied by a low skilled worker (NSL) and a simple job occupied by a high skilled worker (NSH). Every period, for each match, a wage is determined through a negotiation between the intermediate firm and the households. The wage is actually fixed by a fairly standard Nash product problem (see Cahuc and Zylberberg [8]) where the firm and the household share the surplus obtained from the match. Since the surplus obtained from a match between simple job and a high skilled worker differs from that obtained when the match concerns a low skilled worker, wages will also differ.

2.5.1 Complex jobs

A complex job can only be occupied by a high skilled worker. The Nash bargaining problem is given by:

$$\max_{w_t^c} \left(\frac{W^{Hh}_{N_t^c}}{\mathcal{U}_{C_t^h}} \right)^{\eta_1} \left(W_t^{FC} - W_t^{VC} \right)^{(1-\eta_1)}, \tag{38}$$

where η_1 represents the skilled household's bargaining power. The first order optimality condition is obtained applying the free entry condition:

$$W^{Hh}_{N_t^c} = \eta_1 \left(W^{Hh}_{N_t^c} + \mathcal{U}_{C_t^h} W_t^{FC} \right) \tag{39}$$

2.5.2 Low skilled workers in simple jobs

In the case that the simple vacancy is filled by a low skilled worker, the Nash bargaining problem is represented by:

$$\max_{w_t^{sl}} \left(\frac{W_{N_t^{sl}}^{Hl}}{\mathcal{U}_{C_t^l}} \right)^{\eta_2} \left(W_t^{FSL} - W_t^{VS} \right)^{(1-\eta_2)} \tag{40}$$

where η_2, represents the low skilled bargaining power. The first order condition is obtained applying the free entry condition:

$$W_{N_t^{sl}}^{Hl} = \eta_2 \left(W_{N_t^{sl}}^{Hl} + \mathcal{U}_{C_t^l} W_t^{FSL} \right) \tag{41}$$

2.5.3 High skilled workers in simple jobs

When the simple vacancy is filled by a high skilled worker, the Nash bargaining process is represented by:

$$\max_{w_t^{sh}} \left(\frac{W_{N_t^{sh}}^{Hh}}{\mathcal{U}_{C_t^h}} \right)^{\eta_3} \left(W_t^{FSH} - W_t^{VS} \right)^{(1-\eta_3)} \tag{42}$$

where η_3 represents the high skilled workers bargaining power in simple jobs. Applying the free entry condition, we obtain the first order optimality condition:

$$W_{N_t^{sh}}^{Hh} = \eta_3 \left(W_{N_t^{sh}}^{Hl} + \mathcal{U}_{C_t^h} W_t^{FSH} \right) \tag{43}$$

3 Model Calibration and Simulations

In this section we calibrate the model and use deterministic simulation exercises to illustrate the properties of the model and gain insights on the effects of various types of shocks. The focus is on search intensities, unemployment rate differences (across skill groups) and the size of the ladder effect.

3.1 Calibration

We use the following specific functions:

$$M_t^c = m_0^c \left(V_t^c\right)^{\lambda^c} \left(sc_t\, U_t^h + o_t\, N_t^{sh}\right)^{1-\lambda^c} \qquad \text{matching function (complex jobs)} \tag{44}$$

$$M_t^s = m_0^s \left(V_t^s\right)^{\lambda^s} \left(ss_t\, U_t^h + sl_t\, U_t^l\right)^{1-\lambda^s} \qquad \text{matching function (simple jobs)} \tag{45}$$

$$F_t = z\ (K_t)^{\mu} \left(N_t^c\right)_1^{\theta} \left(N_t^{sh} + \nu\, N_t^{sl}\right)^{\theta_2} \qquad \text{production function} \tag{46}$$

$$\frac{\theta_1}{\theta_2} = a_0\ (K_t)^{a_1\ \lambda_3} \qquad \text{factor share's evolution} \tag{47}$$

$$q_t = q_0\ (K_t)_3^{\lambda} \qquad \text{embodied technological progress} \tag{48}$$

$$\mathcal{U}_t = \ln C_t \qquad \text{instantaneous utility function} \tag{49}$$

$$\mathcal{D}_t = \tau\ eo_t \qquad \text{instantaneous desutility function} \tag{50}$$

$$sc_t = \phi_0^{sc} + \phi_1^{sc} \sqrt{eu_t} \qquad \text{search efficiency (i)} \tag{51}$$

$$ss_t = \phi_0^{ss} + \phi_1^{ss} \sqrt{1 - eu_t} \qquad \text{search efficiency (ii)} \tag{52}$$

$$o_t = \phi_0^{o} + \phi_1^{o} \sqrt{eo_t} \qquad \text{search efficiency (iii)} \tag{53}$$

$$sl_t = \phi_0^{sl} + \phi_1^{sl} \sqrt{el_t} \qquad \text{search efficiency (iv)} \tag{54}$$

Our model is in quarterly data (1 period = 1 quarter). We retake the calibrations used by Pierrard and Sneessens [27]. The psychological discount factor (β) is set to 0.99; q_0 and λ are set to obtain an embodied technological change (q_t) to 1.178. The values of β and q_t imply a steady state real interest rate of 0.005 (annual real interest rate of 0.02). In the absence of embodied technological progress ($q_t = 0$) the steady state real interest becomes 0.01 (annual interest rate of 0.04). The capital depreciation rate (δ) is set to 0.025. The production function is a two levels Cobb-Douglas[7] with μ (elasticity of output with respect to the labor aggregate) set to 0.66. Since the elasticity of output with respect to capital is given by $1 - \mu$ we have a steady state ratio between capital stock and output of 10. The relative efficiency of low-skilled workers on simple jobs is measured by ν (the efficiency of high-skilled workers on simple jobs is normalized to 1) and such that a firm usually (in the steady state) prefers to fill a simple job vacancy with a high-skilled (more formally: $W^{FSH} > W^{FSL}$)[8]. Setting $\nu = 0.75$ satisfies this constraint.

[7] Manacorda and Petrongolo [21] estimate such a production model (with two types of labor) for several OECD countries and conclude that the Cobb-Douglas hypothesis cannot be rejected.

[8] Even if we don't have explicit data about this, it seems a realistic assumption and reflects the interest of

The skilled household bargaining power on complex job (η_1) is set equal to 0.6, and bigger than the bargaining power of workers, skilled or unskilled, in simple jobs. Furthermore, since it is difficult to determine whether skilled workers in simple jobs have a larger or a smaller bargaining power than unskilled, it is assumed that $\eta_2 = \eta_3 = 0.4$. The total cost of opening vacancies is usually estimated to be small. From a representative sample of French establishments in 1992, Abowd and Kramarz [1] estimate an hiring cost per hired (excluding training cost) representing 3.3% of the total labor cost. With our calibration for a and b, the hiring costs in the economy (vacancy costs) amounts around 4% of the labor costs (or to about 2.6% of the output), which seems reasonable enough. We moreover make the plausible assumption that $a > b$: it is costlier (recruiting costs) to a firm to open a complex vacancy rather than a simple vacancy. We use a logarithmic utility function and a linear desutility function (limit case of a convex function), as often in the RBC literature. Search efficiencies are concave and represented as linear functions of the search intensities square roots.

Most of the remaining parameters are calibrated on Belgian data for, whenever it is possible, the mid 90's[9]. The proportion of high-skilled workers in the total labor force (parameter α) has substantially increased over time, at least if the skill level is measured by the educational attainment level. For calibration purposes, we define the high-skill group by an educational attainment level at least equal to a upper-secondary degree and set $\alpha = 0.66$, the 1996 value reported by Sneessens and Shadman [29] for Belgium. Capital skill complementarity is measured by changes in the Cobb-Douglas labour production function coefficients. Using the 1995 estimates reported in [29], we fix a_0 and a_1 in equation (20) so that to obtain the elasticity of output with respect to complex jobs equal to 0.5. The ratio of simple to complex wages resulting from the bargaining process is systematically around 0.6. This value is close to the D1/D9 value reported by the OECD [25] for Belgium. Using 1997 Belgian data, Van der Linden and Dor [31] estimate a replacement ratio of 0.34. We fix the unemployment benefit so as to equal 35% of the average wage of the economy, which seems quite reasonable. The same authors estimate a lower bound for the job destruction rate (or transition rate from employment to unemployment) equal

firms with simple jobs for the high-skilled. This calibration has nevertheless only few incidence on the simulation results.

[9] Some data and estimations are available for this period. Moreover, the Belgian economy was neither in a recession (as at the beginning of the 90's) nor in a boom (as at the end of the 90's).

to 0.013 (monthly data). Simple jobs being typically more precarious than complex jobs, we impose the complex jobs destruction rate ψ to be lower than the simple jobs destruction rate χ. Using the Van der Linden and Dor [31] lower-bound estimate as a reference, we set the complex and simple job destruction rates at $\psi = 0.03$ and $\chi = 0.05$ respectively (quarterly data). The elasticity of job matches with respect to vacancies is usually estimated to be in between 0.4 and 0.6. We set it to 0.5 for complex vacancies (λ_c) and to 0.6 for simple vacancies (λ_s).

We still have to fix the following eleven parameters: matching efficiencies m_o^c and m_o^s, search efficiencies parameters ϕ_i^x and the desutility parameter τ. We choose the values of these parameters so as to satisfy the following eight steady state conditions: a steady state low-skilled unemployment rate of about 0.20; a steady state high-skilled unemployment rate around 0.07; a steady state low- to high-skilled employment ratio of about 0.50; the ratio between low and high skilled wages must be around 0.6 whether we simulate the model for 1976 or 1996 (relative wage rigidity); effective probabilities to find a complex job and a simple job of $p^c = 0.4$ and $p^s = 0.2$, respectively; and equal probabilities (of about 0.5) to fill complex or simple vacancies. The figures on employment and unemployment are based on data reported in Sneessens and Shadman [29] (Belgian data for 1996 (employment) and 1994 (unemployment)). The estimates of the probabilities to find a job are based on Cockx and Dejemeppe [9]. From Belgian data for the first half of the nineties, they compute the probabilities (by level of education) to find a job during the first unemployment duration (the first three months) and these probabilities are respectively of 0.64 (higher education), 0.39 (upper secondary education), 0.30 (lower secondary education) and 0.28 (secondary school or no education). Since these probabilities fall when the unemployment duration increases, these first trimester values may be considered as an upper bound and we roughly estimate the probability to find a complex job (resp. simple job) at 0.4 (resp. 0.2). Eventually, the estimates of the probabilities to fill a vacancy are based on Delmotte *et al* [30]. They report that, in 2000, 52% of the total vacancies were easily filled (within 3 months), 25% were filled with difficulty (vacancies open more than 3 months) and 33% were never filled. Moreover, if we carefully look for which types of jobs are not easy to filled, it is difficult to discriminate between complex jobs and simple jobs. We therefore approximate the probabilities to fill a vacancy (either complex or simple) by 0.5, suggesting that half of the job vacancies are filled within the first three months, independently of the nature of the job. This calibration is summarized in table 1.

Symbol	Value	Symbol	Value
Labor force composition			
α	0.66		
Job destruction rates			
ψ	0.03	χ	0.05
Matching functions			
m_0^c	0.42	λ^c	0.5
m_0^s	0.46	λ^s	0.6
Production function and domestic production			
μ	0.66	a_0	0.38
ν	0.75	z	1
a_1	7.10	q_0	0.88
λ	0.10	ζ	0.20
Desutility function			
τ	0.27		
Search efficiencies			
ϕ_0^{sc}	0.50	ϕ_1^{sc}	0.08
ϕ_0^{ss}	0.25	ϕ_1^{ss}	0.25
ϕ_0^{o}	0.25	ϕ_1^{o}	0.06
ϕ_0^{sl}	0.45	ϕ_1^{sl}	0.90
Vacancy costs			
a	0.80	b	0.20
Wages determination			
η_1	0.60	η_2	0.40
w^u	0.35	η_3	0.40
Psychological discount and capital depreciation			
β	0.99	δ	0.025

Table 1: Numerical parameter values

A result of these calibration exercise is that the proportion of high-skilled workers on simple jobs (or ladder effect or job competion or overeducation) must be around 13.1% (see table 2). This job competition may look rather small, if compared to the estimates reported in Delmotte *et al* [30] and Cockx and Dejemeppe [9]. Delmotte *et al* [30] used survey questionnaires with business firms to compare the skill requirements of job vacancies and the skill characteristics of the workers who filled these vacancies. A worker is overeducated when its education level is superior to that demanded by the firm when opening the vacancy. Delmotte *et al* [30] obtain that in 2000, 24% of all hired workers were overeducated. This figure may however overestimate the true number of overeducated workers if for instance the education level indicated by firm when opening a vacancy is meant to give a lower bound rather than a strict requirement. Cockx and Dejemeppe [9] use panel data on unemployment outflows in Wallonia over the years 1989-1994 and they obtain that the average proportion of overeducated workers is 43%. But one should keep in mind though that by distinguishing only two categories of workers (instead of four in Cockx and Dejemeppe [9]) we neglect the competition that may take place within each skill group. Moreover, the Walloon labor market, with an unemployment rate around 15%, is of course itself atypical; and the data used in the analysis are limited to male workers who became unemployed after loosing a job, which may not be representative of the aggregate labour market. The estimate for job competition, of about 13.1%, that we obtain for Belgium is thus not unrealistic.

3.2 Comparing steady states

One of the main merits of the present model with respect to previous ones of the same type, is that, by interiorizing search intensities of both types of workers, by taking into account capital skill complementarity relationship and by distinguishing between embodied and disembodied technological progress, we are able to reproduce the huge increase in low skilled unemployment over the last twenty five years.

The table bellow summarizes the main variables:

Economic variable	1996	1976
U^h/α	7.5%	5.5%
$U^l/(1-\alpha)$	20.4%	7.5%
N^{sh}/Ns	13.1%	3.1%
w^{sl}/w^c	60%	62%

The model seems then to perform well when representing the evolution of low and high skilled unemployment. Notice that its ability to represent the relative wage rigidity is mainly due to the presence of endogenous search intensities and domestic production for low skilled workers, whose reservation wage increases with the standards of living of the economy (represented through a fraction of the average product).

The satisfactory capacity of the model to represent the economic behavior between 1976 and 1996 suggests the possibility of using it in order to predict the consequences of different economic policy measures or of different exogenous shocks. This exercise is implemented in the following section.

3.3 Steady state simulations

We first examine the steady state effects of eight different types of shocks: two labor force composition changes (in α and in early retirements), three different types of productivity shock (aggregate technological shock (z), embodied technical shock (biased in favor to complex jobs λ) and exogenous increase in low-skilled workers relative productivity (ν)), three types of wage shock (increase in the bargaining power of workers on simple jobs (η_1 and η_2), an increase in the unemployment benefits (which amounts to an exogenous increase in w^u) and a subsidy over low skilled wages). The results for the long run effects are summarized in table 2[10]. We briefly comment each exercise.

Labor force composition

A rise in α (the proportion of high-skilled workers in the total labor force) increases the probability to fill a complex job, and thus stimulates complex employment (it nevertheless reduces the productivity of the complex jobs). The increased employment on complex jobs increases the marginal productivity of simple jobs. This stimulates w_t^{sh}, w_t^{sl} and the search effort of low skilled workers (el_t). The demand for simple jobs is - strongly - stimulated. The one for capital too, which *via* capital skill complementarity will raise again the demand for complex jobs.

The effect on the demand for workers on simple jobs is amplified by the increase in the probability of hiring high-skilled workers on a simple job, which stimulates their search effort on the

[10] For the variables expressed in percentage, deviations from the benchmark are absolute deviations; for the variables expressed in level, deviations from the benchmark are relative deviations.

	sl	U^h/α	$U^l/(1-\alpha)$	U^h+U^l	w^c	w^{sh}	w^{sl}	y	N^{sh}/N^s
benchmark	0.5%	7.5%	20.4%	12.0%	1.336	0.969	0.806	1.616	13.1%
$\alpha : 0.66 \to 0.7$	+5.2%	-0.7%	-4.4%	-2.3%	+0.6%	+1.8%	+1.7%	+4.5%	+4.7%
$erl : 0.00 \to 0.05$	+5.0%	-0.7%	-7.0%	-2.9%	-1.0%	+1.2%	+1.6%	-2.2%	-5.1%
$z : 1.00 \to 1.05$	8.1%	-0.5%	-2.5%	-1.2%	+11.8%	+6.4%	+3.1%	+11.1%	-1.8%
$\lambda : 0.1 \to 0.105$	-1.3%	+0.3%	+3.3%	+1.3%	+4.4%	+1.2%	-0.3%	+2.4%	-2.4%
$\nu : 0.75 \to 0.90$	+12.7%	0.1%	-1.9%	-0.6%	+5.2%	-4.1%	+5.1%	+5.8%	-3.0%
$\eta_2 = \eta_3 : 0.4 \to 0.44$	+1.4%	+0.1%	+0.5%	+0.2%	-0.2%	+1.2%	+0.6%	-0.2%	-0.0%
$w^u : 0.40 \to 0.44$	-5.0%	+0.4%	+2.6%	+1.1%	-1.0%	+1.9%	+3.1%	-1.2%	+0.2%
$txs : 0.00 \to 0.1$	+13.0%	-0.4%	-4.3%	-1.7%	+1.9%	-1.5%	+4.9%	+1.7%	-0.1%

Table 2: Steady state effects (deviations from the benchmark)

simple segment. Despite this increased competition for simple jobs (the size of the ladder effect increases), the low-skilled unemployment rate decreases. The high-skilled one also decreases.

Early retirements

Early retirement of low skilled workers turns out to be a bad policy measure in the sense that it implies a fall in output. As the size of the low skilled labor force is reduced, the low skilled unemployment rates fall. However, the amount of simple jobs also decreases. This has a negative impact over the marginal productivity of complex jobs and capital stock, resulting in a downturn in the demand of these factors as well as in complex wages. The reduction in the number of simple jobs leads to an increase in their marginal productivity and wages (w_t^{sl} and w_t^{sh}). This stimulates the search effort in the simple segment of the labor market of both, low and high skilled workers, increasing in this way the ladder effect. Actually, the fall in high skilled unemployment is completely due to the rise in the number of skilled workers in simple jobs.

Aggregate technological shock

A positive disembodied technological shock (5% increase in z in our example) raises marginal productivity of all factors. As capital cumulates, marginal productivity of simple and, particularly, complex jobs (*via* capital skill complementarity (θ_1)) is stimulated. Demand for both types of jobs increases in spite of the higher negotiated wages. The opening of more complex vacancies as well as the rise in complex wages stimulates the search effort of high skilled unemployed in the complex segment of the labor market (eu_t) and on the job search (eo_t). Low skilled unemployed are also encourage to increase their search intensity by the higher wages and the opening of more simple vacancies. All unemployment rates decrease.

Biased technological shock

We now consider the effects of an embodied technological shock. The increase in λ results not only in an upturn of the share of complex jobs in the production function but also in a downturn in real interest rate. This decrease stimulates capital accumulation, which *via* capital skill complementarity stimulates the demand of complex jobs. This fact, together with the rise of complex wages explains the upturn in the search effort of skilled unemployed (eu_t) and employed (eo_t) on the complex segment of the labor market. The increased employment in complex jobs and capital stock raises productivity of simple jobs, however demand for this type of jobs falls due to the increased wages negotiated by workers occupying these positions as the standard of living grows (el_t falls). Since both, skilled and unskilled workers benefit from simple jobs, a downturn in its demand increases skilled and unskilled unemployment. This explains the rise in skilled unemployment despite increased demand for complex jobs.

Relative low-skilled worker productivity

An increase in the parameter ν does not only stimulate the productivity of low skilled workers, but also the marginal productivity of complex jobs and capital, due to the increase in the amount of simple jobs. This results in an upturn in the demand of complex jobs and capital stock. The only drawback related to the improvement in relative low-skilled worker productivity concerns high skilled workers, whose demand suffers a downturn, due to the decrease in the marginal value that the firm obtains from hiring them. The rise in high skilled unemployment is explained by the reduction of the ladder effect. Low skilled unemployment decreases.

Bargaining power of simple jobs

On increase in the bargaining power of workers in simple jobs translates into a rise of their wages (w_l^{sh}, w_t^{sl}) and, thus, a fall in both, the number of simple vacancies opened and the demand of simple jobs. The reduced employment in simple positions, has a negative impact on marginal productivity of complex jobs and capital, leading to a reduction in the demand of both factors. All unemployment rates increase. Due to the increased wages on the simple segment of the job market the high and low skilled unemployed search more intensively for a simple job, despite the fall in the number of simple vacancies. But this increase in the simple wage reduces the intensity of the on-the-job search. All in all, the size of the ladder effect decreases.

Replacement ratio

An increase in the replacement ratio will mainly affect low skilled workers, whose consumption is constrained by its revenue. In this sense, an increase in the replacement ratio, represents a rise in their outside option and hence, in their reservation wage (el_t falls). This pushes up wages of low skilled workers and then decreases in the supply of simple vacancies. As the amount of simple jobs falls, their marginal productivity increases, which stimulates the demand of high skilled workers in simple jobs, as their wage increases in a lower amount. In any case, simple job employment decreases, which has a negative impact in marginal productivity of complex jobs and thus in complex wages and complex vacancies. This explains the reduction of the search effort in the complex segment and of on the job search. All unemployment rates increase.

Subsidy to low skilled wages

A target policy giving a subsidy to low skilled wages (w_t^{sl}) turns out to be beneficial for both, high and low skilled workers, in terms of unemployment reductions. Indeed, the subsidy increases the marginal value the firm obtains from low skilled workers, which will stimulate the opening of simple vacancies and a reduction of the ladder effect. As simple jobs increase, productivity of complex jobs improves, leading to an increase in the demand of this type of job. Finally, search efforts of skilled unemployed on the complex segment and unskilled unemployed in the simple segment increase. On the job search is also stimulated.

4 Conclusions

Over the last twenty five years low skilled unemployment rates have increased more than average unemployment rates. Two reasons have traditionally being put forward to explain this rise: (*i*) the adoption of new technologies being more skilled labor demanding (skilled biased technological progress) has favored changes in the labor demand composition. The rigidity of relative wages over the time has then led to a rise in low skilled unemployment rates due to the appearance of skill mismatch effects; (*ii*) aggregate technological shocks implying a decrease of the total labor demand have led to the crowding out of lower educated workers by higher educated (job competition). To analyze these explanations in an intertemporal general equilibrium model we need a double heterogeneity: low *vs* high skilled workers and simple *vs* complex jobs. We allow for the possibility that a simple job is occupied by a high skilled worker (*ladder effect*), so that we take into account job competition effects. On the job search is allowed for high skilled workers on simple jobs. Search intensities of both types of workers are endogenous. This permits to consider the discouragement effects which seem to be important in the case of low skilled unemployed.

The skill biased technological progress is introduced through a two levels Cobb-Douglas production function where the relative share of complex jobs increases with capital accumulation and the innovation capacity for the economy. Furthermore, we distinguish between disembodied technological progress (it affects all factors and it varies exogenously) and embodied technological progress (it affects only new equipment and it varies endogenously).

Finally, wages in both, complex and simple jobs, are determined through a normal Nash bargaining problem. The rigidity of relative wages resulting from these negotiations is due to the fact that low skilled workers take as reference the average standard of living in the economy(average product) when making their wage demands. This rigidity in the skill premium seems to have play a role in low skilled unemployment rise, therefore, the capacity to reproduce it turns out to be a nice property of the model.

The model explains the labor market degradation (mainly for the less qualified) and the job competition increase that the EU has known over the last decades by simply considering changes in the population composition and biased technological shock. An aggregate negative technological shock decreasing labor demand is not required.

We then analyze the long run effects predicted by the model of eight exogenous shocks (some of which can be interpreted as policy measures): (*i*) change in the labor force composition (increase of the high-skilled *vs.* low-skilled ratio), (*ii*) early retirements for low skilled workers, (*iii*) positive aggregate technological shock, (*iv*) positive embodied technological shock (biased in favor of the high-skilled workers), (*v*) increase in the productivity of the low-skilled workers, (*vi*) increase in the bargaining power of workers in simple jobs, (*vii*) increase in the unemployment benefits and (*viii*) a subsidy on low skilled wages. When analyzing the outcomes of these shocks, we especially focus on high- *vs.* low-skilled unemployment difference and the ladder effect (proportion of simple jobs occupied by high-skilled workers).

References

[1] Abowd, J. and F. Kramarz, The costs of hiring and separations, 2003, CREST Working Paper 9543, revised, Labour Economics, forthcoming.

[2] Albrecht, J. and S. Vroman, A matching Model with Endogenous Skill Requirements, *International Economic Review*, 43 (2002), 283-305.

[3] Andolfatto, D., Business Cycles and Labour-Market Search, *American Economic Review* 86-1 (1996) 112-132.

[4] Autor D.H., L.F. Katz and A.B. Krueger, Computing inequality: Have computers changed the labour market?, *Quarterly Journal of Economics*, 113 (1998), 1169-1213.

[5] Berman E., J. Bound and S. Machin, Implications of skill-biased technological change: international evidence, *Quarterly Journal of Economics*, 113 (1998), 1245-1279.

[6] Boucekkine, R., F. del Rio and O. Licandro, Embodied Technological Progress, Learning and the Productivity Slowdown, *Scandinavian Journal of Economics*, forthcoming.

[7] Cahuc, P and E. Wasmer, Does Intrafirm Bargaining Matter in the Large Firm's Matching Model?, *Macroeconomic Dynamics*, 5 (2001).

[8] Cahuc, P and A. Zylberberg, Le Marché du Travail, *De Boeck Université*, 2001.

[9] Cockx, B. and M. Dejemeppe, Do the Higher Educated Unemployed Crowd out the Lower Educated Ones in a Competition for Jobs?, IRES Discussion Paper, 2002-20, Université catholique de Louvain.

[10] Collard, F., R. Fonseca and R. Munoz, "Spanish Unemployment Persistence and the Ladder Effect", Centre for Economic Performance, London School of Economics and Political Science, 2002.

[11] Dolado, J., F. Felgueroso and J. Jimeno, Youth labour markets in Spain: Education, training and crowding-out, *European Economic Review*, 44 (2000) 943-956.

[12] Dolado, J., M. Jansen and J. Jimeno, A Matching Model of Crowding-Out and On-the-Job Search (with an Application to Spain), 2002, CEPR DP3466.

[13] Fitz Roy, F. and M. Funke, Capital Skill Complementarity in West German Manufacturing, *Empirical Economics*, 20 (1995) 651-665.

[14] Gautier, P.A., Unemployment and Search Externalities in a Model with Heterogeneous Jobs and Heterogeneous Workers, *Economica*, 81 (1997) 342-362.

[15] Greenwood, J., Z. Hercowitz and P. Krussel, Long-Run Implications of Investment-Specific Technological Change, *American Economic Review*, 69 (2002) 21-40.

[16] Green, F., S. McIntosh, and A. Vignoles, “Overeducation and skills - Clarifying the concepts”, Centre for Economic Performance, London School of Economics and Political Science, 1999.

[17] Hartog, J., Over-education and earnings: where are we, where should we go?, *Economics of Education Review*, 19 (2000), 131-147.

[18] Hosios, A.J., On the efficiency of matching and related models of search and unemployment, *Review of Economic Studies*, 57 (1990), 279-298.

[19] Krusell,P., L.Ohanian, J.V.Rios-Rull, and F.Violante, ”Capital-Skill Complementarity and Inequality”, *Econometrica*, 68(5) (2001) 1029-53.

[20] Machin, S. and J. Van Reenen, Technology and changes in skill structure: Evidence from seven OECD countries, Quarterly Journal of Economics, 113 (1998), 1215-1244.

[21] Manacorda, M., and B. Petrongolo, ”Skill Mismatch and Unemployment in OECD countries”, *Economica*, 66 (1999) 181-207.

[22] Merz, M., Search in the labour market and the real business cycle, *Journal of Monetary Economics*, 36 (1995) 269-300.

[23] Moreno-Galbis, E., Causes of the Change in the Skill Structure of the Labour Force: An Empirical Application to the Spanish case, IRES Dicussion Paper No.2002-35, Universit Catolique de Louvain.

[24] Muysken,J. and B. ter Weel, “Overeducation, Job Competition and Unemployment”, MERIT DP 99032, Maastricht University, 1999.

[25] OECD, Employment Outlook, Chapter 3, July 1996.

[26] ONSS, Rapport annuel, Office National de sécurité Sociale.

[27] Pierrard, O. and H. Sneessens, Low Skilled Unemployment, Biased Technological Change and Job Competition, mimeo, IRES, Universit Catolique de Louvain, 2002.

[28] Pissarides, C., Equilibrium Unemployment Theory, 1990, Oxford, Basil Blackwell.

[29] Sneessens, H. and F. Shadman, Analyse macro-économique des effets de réductions ciblées des charges sociales, *Revue belge de sécurité sociale*, 3 (2000) 613-630.

[30] Delmotte J., G. Van Hootegem and J. Dejonckheere, Les entreprises et le recrutement en Belgique en 2000, 2001, HIVA, Katholieke Universiteit Leuven, and UPEDI.

[31] Van der Linden, B. and E. Dor, Labor market policies and equilibrium employment: Theory and application for Belgium, IRES Discussion Paper 2001-05, Université catholique de Louvain.