Technological Bias and Unemployment:

A Macroeconomic Perspective

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Abstract

This paper focuses on the macroeconomic impact of introducing new technologies (among which information technologies) when the latter stimulate the relative demand for high-skilled labour. The fact that there is biased technical progress (or at least, that growth has asymmetric effects) is little disputed. Evaluating its effect on unemployment still remains a difficult task. This paper stresses the need to rely on a genuine structural analysis. To clarify some of these issues, we develop a simple analytical framework with two types of labour (high- and low-skilled). This framework is used to distinguish macroeconomic vs structural shocks, and to illustrate the interactions between macroeconomic and structural phenomena as well as their implications for the interpretation of simple mismatch indicators. The framework is next used as a reference setup wherein to evaluate and compare the empirical modelling approaches used by different authors and the results they obtain.

1 Introduction

This paper focuses on the macroeconomic impact of the introduction of new technologies (among which information technologies) when the latter stimulate the relative demand for high-skilled labour. To what extent the deterioration of the position of low-skilled workers (either in terms of employment perspectives or of real wages) should be seen as a consequence of such biased technological change? What are, in such a scenario, the consequences of relative wage rigidities, especially in Europe? Can such a phenomenon have contributed to the persistence of high aggregate unemployment rates? These are the main questions addressed in this paper. Our objective is obviously not to propose a definite and complete answer, but rather to try and explain the difficulties met in examining these questions, and by so doing to put available empirical results (sometimes contradictory) in better perspective.

The contrast between the US and the EU countries in terms of social insurance coverage, wage dispersion and unemployment rate changes over the last twenty years suggests that the poor employment performance of European economies may at least in part result from too little adjustment to structural changes. In part, but how much? Many studies downplay the role of structural factors. They stress the fact that both high- and low-skilled unemployment rates have increased, especially over the last ten years, while relative unemployment rates (high- and low-skilled rates compared to the aggregate rate) have decreased. The interpretation of raw data is far from easy though. As an example, Table 1 reports the 1995 values of the unemployment and non-employment rates across age and education groups for three countries: France, the United Kingdom and the United-States. Implicit participation rates are also indicated. A few clear conclusions can be drawn from this table. In all three countries, unemployment is decreasing with education, and middle-aged workers (30-44), especially the low-educated ones, appear better protected against unemployment (this is even more striking in terms of non-employment rates). The unemployment rate is larger in France than in the UK, and larger in the UK than in the US ($U_{Fr} > U_{UK} > U_{US}$), and this holds true for all education groups for workers aged 25-64. Workers aged 15-19 seem particularly vulnerable in France. The unemployment rate for low-educated young workers is 25%, a value similar to that of the other two countries; the non-employment rate however is likely to be much larger, if we compare the participation rates of male workers aged 15-24 (given between parentheses) in the three countries.

year 1995 (1992)	skill group	Group l: below upper-sec.			Group m: upper-secondary			Group h: tertiary		all educational attainm. levels		
	age group	15-19	30-44	25-64	20-24	30-44	25-64	30-44	25-64	15-19	30-44	25-64
			men			men		men			men	
Fr	unem.	25%	14%	14%	25%	7%	9%	4%	6%	24%	8%	10%
	non-em.		21%	48%		10%	25%	6%	16%	(48%)	11%	31%
	partic.	(37%)	92%	60%		97%	82%	98%	89%	(37%)	97%	76%
UK	unem.	28%	21%	12%	13%	8%	7%	3%	4%	17%	8%	7%
	non-em.		34%	46%		12%	24%	4%	12%	(19%)	14%	27%
	partic.	(77%)	83%	62%		95%	82%	99%	91%	77%)	93%	79%
US	unem.	20%	12%	10%	9%	5%	5%	2%	3%	17%	5%	5%
	non-em.		31%	46%		13%	25%	5%	13%	(25%)	13%	24%
	partic.	(70%)	78%	60%		92%	79%	97%	89%	(70%)	92%	80%

Table 1: Unemployment and non-employment rates

year 1995		Ratio U_l/U_h		Ratio U/U_h		Diff. $U_l - U_h$		Diff. $U - U_h$	
	age	30-44	25-64	30-44	25-64	30-44	25-64	30-44	25-64
	sex	M	M+F	M	M+F	M	M+F	M	M+F
France	unempl. rate	3.46	2.37	1.98	1.64	10%	8%	4%	4%
	non-em. rate	3.50	3.00	1.83	1.94	15%	32%	5%	15%
UK	unempl. rate	7.36	3.49	2.86	2.11	18%	9%	5%	4%
	non-em. rate	8.50	3.83	3.50	2.25	30%	34%	10%	15%
US	unempl. rate	6.32	4.00	2.63	1.88	10%	8%	3%	2%
	non-em. rate	6.20	3.54	2.60	1.85	26%	33%	8%	11%

Table 2: Comparison of different unemployment dispersion measures

It is not obvious though, on the basis of these simple figures, that there should be more skill mismatch in France than in the UK or the US. Table 1 reports standard measures of unemployment (and non-employment) dispersion, either in the form of relative unemployment rates or in the form of unemployment rate differences across educational groups. These measures are based on the data of Table 1. The first two columns give the ratio of the unemployment rates of low- and high-educated workers, for middle-aged workers (30-44) and for workers aged 25-64 respectively. The next two columns give the ratio of the total and the high-education unemployment rates for the same two age groups. The last four columns give similar informations in terms of differences rather than ratios. Except for the last

age group	15-24		25-54		55-64		65 and over		total	
year	1972	1992	1972	1992	1972	1992	1972	1992	1972	1992
France	58%	37%	97%	95%	73%	44%	18%	4%	87%	75%
UK	78%	77%	96%	94%	88%	66%	18%	9%	94%	85%
US	73%	70%	94%	93%	79%	67%	23%	16%	89%	88%

Table 3: Male participation rates. Source: R.Barrell et al., 1995, NIESR

column, all measures of dispersion give almost always the same ranking, whether in terms of unemployment or of non-employment. The UK comes first with the highest unemployment dispersion indicator, the US comes next; France has almost always the lowest coefficient. If one looks at the last column however, France and the UK seem to share very similar fates, with dispersion indicators substantially larger than in the US.

This exercice suggests at the very least that one should be very careful and avoid inferring too much from raw data and simple statistics. The danger of relying too much on simple unemployment dispersion indicators is illustrated in Figure 1. The figure shows the correlation across OECD countries between the aggregate unemployment rate and a measure of unemployment dispersion. In the left panel,dispersion is measured as the ratio of the low- and the high-skill unemployment rates; in the right panel, it is measured by unemployment rate differences. The correlation is nil in the first case, positive in the second.

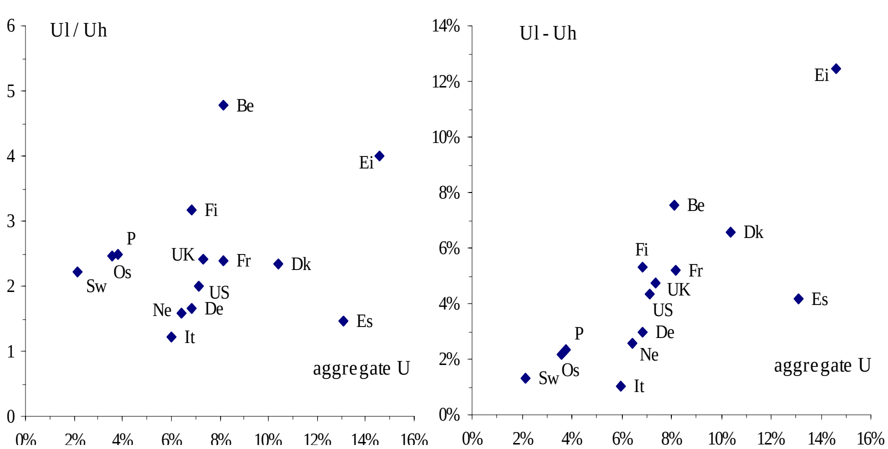

Figure 1: Relationship between unemployment rate level and dispersion
(dispersion measured by ratios -left- or differences -right-)

A conclusion about the role and importance of biased technical change and skill mismatch can obviously not be reached by such simple correlation exercises. Furthemore, comparisons as those made in Tables 1 and 1 may give different results for different years or different types of disaggregation. They fail to take into account trends observed over the recent past, both in terms of unemployment rates and participation rates. Table 3 illustrates how much participation rates may have changed from 1972 to 1992 for different age groups. There are striking cross-country differences, which surely should be accounted for and explained if one wants to understand cross-country similarities and differences. There is, at the OECD level, a clear negative correlation between unemployment and participation rates for youngsters aged 15-24 (see OECD, 1996, figure 3.6). A full understanding of the structural component of today's unemployment problem calls for a better understanding of all these aspects simultaneously.

The difficulties met in evaluating the macroeconomic impact of a biased technological change are at least in part due to the many dimensions of the problem (skills, age, sex, sectors) and the many interactions between them, the nature of which is influenced by labour market (implicit or explicit) institutions and rules. Macroeconomic and structural phenomena are strongly interrelated. Evaluating the macroeconomic consequences of asymmetric shocks like a biased technical progress cannot be done without a correct understanding of these interactions. A correct appraisal of the macroeconomic consequences of a biased technological change therefore goes through an adequate (i.e., realistic and workable) representation of these phenomena.

This paper's objective is to clarify some methodological issues and provide a key to interprete and compare results obtained by different researchers starting from different specifications and data sets. To this end, we first propose a simple and in many ways quite standard analytical framework (section 2). In section 3, this framework is used to distinguish macroeconomic vs structural shocks, and to illustrate the interactions between macroeconomic and structural phenomena as well as their implications for the interpretation of simple dispersion indicators like those mentioned above. We also discuss the limits of such a simple representation of the economy and suggest some extensions. Section 4 is then devoted to a discussion and comparison of a few empirical evaluations of the contribution of biased technological change to aggregate unemployment. Section 5 concludes.

2 Analytical Framework

We use a model of equilibrium unemployment extended to include structural features. The usual NAIRU model is extended to include two types of labour (low- and high-skilled labour) and the corresponding labour markets [1]. In line with the equilibrium unemployment literature, we focus on the price and wage formation behaviours and do not model explicitly the demand side of the economy.

There are various ways to introduce asymmetric effects of growth on the welfare (income or employment opportunities) of low- vs high-skilled workers. Capital accumulation as such may have asymmetric effects when the capital-labour substitution elasticities are different for the two groups of workers (see Krusell et al., 1997, e.g.). Globalization and changes in the structure of the economy provide another explanation. We focus here on a third possibility, biased technical progress [2].

Firm's Behaviour

Let us consider a setup with one type of goods (one sector) and monopolistically competitive firms. All firms have access to the same production technologies using three types of input: low- and high-skilled labour plus capital. For convenience, we assume a constant elasticity of σ substitution between low- and high-skilled employment (denoted N_l and N_h respectively) and neglect the capital stock. This simplification avoids technicalities and complications not essential for our purpose, which is to clarify a few key concepts and issues [3].

The firm's optimal price (output) and technology choices can then be summarized in the following two relationships:

$$\left\{ \sum_i (\alpha_i)^\sigma \left(e^{-\gamma_i t} w_i \right)^{(1-\sigma)} \right\}^{1/(1-\sigma)} = a_0 \,, \quad i \,\epsilon\, (l,h). \tag{1}$$

[1]This section is based on the first section of Sneessens (1994).

[2]These three "explanations" may of course be strongly interrelated, for example when there is embodied technical progress which facilitates communication and globalization.

[3]Neglecting the capital stock implicitly amounts to assuming that the two types of labour have the same elasticity of substitution with respect to capital, which may not be the case. High-skilled labour is usually considered to be less substitutable to capital. In such a case, higher real interest rates -as observed in Europe over the last ten or fifteen years- have a favourable effect on low-skilled employment opportunities, ceteris paribus.

$$\log N_l - \log N_h = -(1-\sigma)(\gamma_l - \gamma_h)\, t - \sigma(\log w_l - \log w_h) \ , \tag{2}$$

where w_l and w_h stand for the real wage cost of low- and high-skilled labour respectively, coefficients γ_l and γ_h represent asymmetric exogenous rates of technical progress, and a_0 reflects the effect of capital accumulation and unbiased technical progress at given markup rate [4]. Equation (1) is the factor price frontier determined by cost minimization and price behaviour; equation (2) determines the optimal low-to-high skilled labour ratio.

Wage Formation

To represent the wage formation process, we rely on a standard monopoly-union-right-to-manage argument and use the following two simple relationships:

$$\log w_l \ = \ \lambda_0 \ + \ \beta_l\, t \ - \ \chi_l \ \log u_l \ , \tag{3}$$

$$\log w_h \ = \ \eta_0 \ + \ \beta_h\, t \ - \ \chi_h \ \log u_h \ , \tag{4}$$

where the β's measure the trend in wage demands generated by technical progress.

Equilibrium Unemployment

Equations (1) to (4) can be solved for the two equilibrium unemployment rates.

We proceed in two steps. We first combine the factor price frontier (1) and the wage equations (3)-(4) to obtain the so-called *equilibrium unemployment frontier* (see Layard et al., 1991, p308). Log-linearization yields [5]:

$$\begin{array}{rccl} & \alpha\,\chi_l\, \log u_l & + & (1-\alpha)\,\chi_h\, \log u_h \\ = & \alpha_0 + \alpha\,\lambda_0 & + & (1-\alpha)\,\eta_0 \\ + & \alpha\,(\beta_l - \gamma_l)\, t & + & (1-\alpha)\,(\beta_h - \gamma_h)\, t \end{array} \tag{5}$$

where $\alpha_0 \equiv -\log a_0$. This equilibrium condition describes a negative relationship between the two unemployment rates. This relationship should be understood as follows. Ceteris

[4]More precisely, we write the production function as: $Y = \kappa \left\{ \alpha_l \left[e^{\gamma_l t} N_l \right]^{-\rho} + \alpha_h \left[e^{\gamma_h t} N_h \right]^{-\rho} \right\}^{-\beta/\rho}$, where $\beta \leq 1$ and $\alpha_l + \alpha_h = 1$. The substitution elasticity is equal to $\sigma = 1/(1+\rho)$. With this specification, it can be shown that $a_0 \equiv \frac{\beta\,\kappa}{1+\mu} \left(\frac{\kappa}{Y}\right)^{(1-\beta)/\beta}$, where μ is the markup rate.

[5]Parameter α is defined as: $\alpha \equiv \left\{ \alpha_l^{\sigma} (e^{-\gamma_l t} w_l)^{1-\sigma} \right\} \ / \ \left\{ \sum_j \alpha_j^{\sigma} (e^{-\gamma_j t} w_j)^{1-\sigma} \right\}$.

paribus, if one of the two types of labour experiences a lower unemployment rate and exerts pressure to receive a larger real wage, the other's wage must necessarily decrease (one moves along a given factor price frontier), which can be obtained only through an increase in the corresponding unemployment rate.

A second relationship between the two equilibrium unemployment rates is obtained by recasting the technological equation (2) in terms of unemployment rates. We first use the approximation $\log N_i - \log L_i = \log(1 - u_i) \approx -u_i$ where L_i stands for the labour force of type i, and next use equations (3) and (4) to eliminate the wage rates. We obtain the following *equilibrium technological constraint*:

$$\begin{aligned} & [u_l - u_h] + \sigma\,[\chi_l \log u_l - \chi_h \log u_h] \\ = f_0 \quad + & \quad \sigma\,\{ (\lambda_0 - \eta_0) + (\beta_l - \beta_h)\,t \} \\ + & \quad [\,(\phi_l - \phi_h) + (1-\sigma)\,(\gamma_l - \gamma_h)\,]\ t\ . \end{aligned} \tag{6}$$

Parameter ϕ_i stands for the growth rate of the labour force of type i; the value of the scale parameter f_0 depends on the aggregate labour force's initial composition. This equilibrium condition describes a positive relationship between the two unemployment rates. This relationship follows from the firms' optimal technology choices and can be understood as follows. If one of the two unemployment rates increases, the corresponding relative wage will decrease, which induces the firm to change technology and reduce its relative demand for the other type of labour, whose unemployment rate also increases as a result.

The equilibrium unemployment frontier (5) and the equilibrium technological constraint (6) determine together the equilibrium low- and high-skilled unemployment rates. This is illustrated in the left panel of Figure 2, in the $u_l - u_h$ space. The downward-sloping relationship corresponds to equation (5), the upward-sloping one to equation (6) . The equilibrium combination of unemployment rates is determined by their intersection. Technology, price and wage shocks may shift these curves up or down, thereby changing the equilibrium unemployment rate values.

3 Macroeconomic vs Structural Shocks

The analytical framework developed in the previous section allows one to distinguish two types of shocks. We shall call *macroeconomic shocks* all the shocks that have identical direct

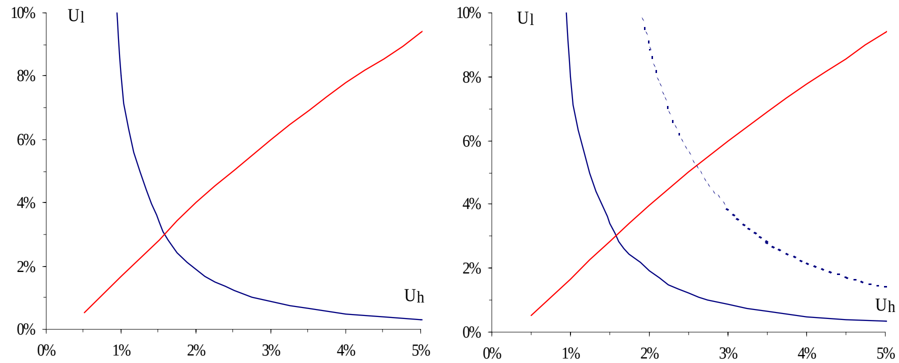

Figure 2: Determination of equilibrium unemployment rates (left) and effect of a macroeconomic shock (right)

impacts on the two labour markets [6]; we call *structural shocks* all the shocks that have different direct impacts. We discuss and illustrate the consequences of each type of shock in turn, next derive implications about the use of so-called mismatch indicators. We close the section with a few qualifications.

Macroeconomic Shocks

The macroeconomic shocks include all the shocks that affect the price equation (changes in a_0 reflecting global productivity shocks, e.g.), plus all the shocks that affect symmetrically the two wage equations (i.e., wage shocks such that $\Delta\lambda_0 = \Delta\eta_0$, or $\Delta\beta_l = \Delta\beta_h$), the two labour demands (technological shocks satisfying $\Delta\gamma_l = \Delta\gamma_h$), or the two labour supplies (labour force changes such that $\Delta\phi_l = \Delta\phi_h$). By definition, a macroeconomic shock will thus shift the downward-sloping equilibrium unemployment frontier but leave unchanged the upward-sloping equilibrium technological constraint (see right panel of Figure 2). A macroeconomic shock thus necessarily changes the two unemployment rates (low- and high-skilled) in the same direction, although the magnitude of the change may differ from one market to the next. In other words, symmetric shocks can have asymmetric effects. *A macroeconomic shock may thus change the dispersion of unemployment and wage rates.* The outcome depends on the

[6]It is worth stressing that there is no room for macroeconomic demand shocks in this model.

slope and position of the technological constraint schedule.

To illustrate the consequences of a macroeconomic shock, let us consider the case of *a global productivity slowdown* ($\Delta a_0 < 0$). We start with the particular case where low- and high-skilled wage rates are equally sensitive to their own unemployment rate (i.e., $\chi_l = \chi_h = \chi$). This particular case is unlikely to be most realistic for countries with official or *de facto* minimum wage rules, but it may serve as a useful starting point. Using this assumption and simplifying the notation yields the following expressions for the equilibrium unemployment frontier and the equilibrium technological constraint respectively:

$$\alpha \log u_l + (1-\alpha) \log u_h = m_0 \ , \tag{7}$$

$$[u_l - u_h] + \sigma\, \chi \, [\log u_l - \log u_h] = s_0 \ , \tag{8}$$

where m_0 and s_0 summarize all the terms on the right-hand side of the original equations. A productivity slowdown corresponds to an increase in m_0 at fixed s_0, as illustrated in the right panel of Figure 2. Such a shock increases both unemployment rates. It can easily be checked by differentiating the second equation that the productivity slowdown will have asymmetric effects when the high- and low-skilled unemployment rates have different initial values. More precisely, an increase in m_0 implies $\Delta u_l \geq \Delta u_h$ when the initial unemployment rate values satisfy $u_l \geq u_h$, i.e., the macroeconomic shock exacerbates the initial differences between the two unemployment rates. The same equation also implies that the *ratio* of the low- and high-skilled unemployment rates decreases and comes closer to one (this is also apparent in the right panel of Figure 2), which implies a lower variance of the relative unemployment rates [7]. This decrease is larger the larger the initial discrepancy between the two unemployment rates.

We briefly consider the other extreme case, where the two wage rates have totally different sensitivities to their own unemployment rate. Let us assume for instance that low-skilled wages are totally insensitive to unemployment ($\chi_h > \chi_l = 0$). It can then easily be checked that a productivity slowdown increases the difference between the two unemployment rates, but may increase or decrease their relative value and the variance of relative unemployment rates.

This example illustrates how a macroeconomic shock can have structural effects, i.e., change

[7] The variance of the relative unemployment rates is proportional to $(u_l - u_h)/u$, where the aggregate unemployment rate u is given by $u = \alpha\, u_l + (1-\alpha)\, u_h$.

the difference and/or the ratio between the two unemployment rates. Whether the dispersion of unemployment rates (either in levels or in relative terms) is increased or decreased crucially depends on initial conditions and on wage rigidities (sensitivity to own unemployment rate) [8].

Structural Shocks

Structural shocks include all types of asymmetric shocks: asymmetric shocks on wages, technical progress and labour force. At variance with a macroeconomic shock, a structural shock does shift the equilibrium technological constraint schedule (equ.(6)). Simultaneously, it may or may not shift the equilibrium unemployment frontier (as the macroeconomic shock does), depending on the type of structural shock considered. Because they may affect both the unemployment frontier and the technological constraint, structural shocks may have all kinds of effects on the constellation of equilibrium unemployment rates. By way of example, we briefly discuss three specific cases : labour force composition change, asymmetric wage shock, and biased technological progress.

Labour force composition changes ($\Delta f_0 \neq 0$ or $\Delta\phi_l \neq \Delta\phi_h$) shift only the technological constraint and thus have an opposite effect on the two equilibrium unemployment rates (see left panel of Figure 3). All other types of structural shocks shift both the unemployment frontier and the technological constraint.

An exogenous increase in low-skilled wage claims (higher minimum wages e.g., represented here by $\Delta\lambda_0 > 0$) will shift both curves upwards (u_l is measured along the vertical axis) and may thus increase both the low- and the high-skilled equilibrium unemployment rates (see right panel of Figure 3).

A biased technological progress unfavourable to low-skilled workers (either $\gamma_l \geq \gamma_h$ when $\sigma \leq 1$, or $\gamma_l \leq \gamma_h$ when $\sigma \geq 1$) moves the technological constraint upwards and the unemployment frontier inwards; ceteris paribus (in particular, at unchanged minimum wage and unchanged β_l and β_h), the high-skilled unemployment rate will certainly decrease, the low-skilled and the aggregate unemployment rates may increase or decrease. This analysis is of course partial and fails to take into account induced the effects that biased technical progress may have

[8]Allowing different elasticities of substitution between labour and capital for the two types of skill would introduce yet another channel by which macroeconomic shocks -a change in the capital usage cost e.g.- could have structural implications.

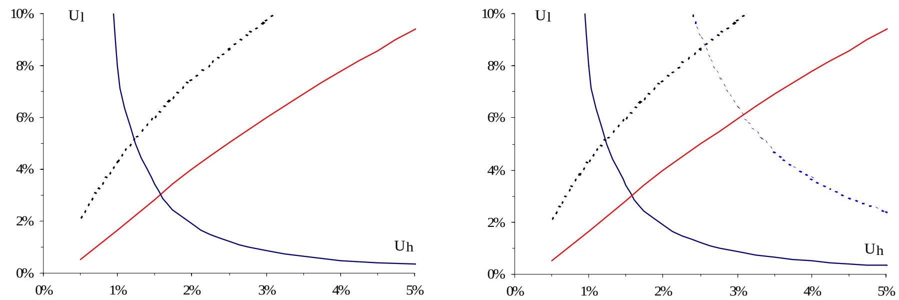

Figure 3: Effect of changes in labour force composition (left) or minimum wage (right)

on wage demand behaviours (represented by coefficients β_l and β_h). When such effects are allowed for, biased technological change may well have no effect at all on unemployment.

To illustrate this point, let us first define *exogenous mismatch* (EMI) as the *net* exogenous relative labour demand change induced by a biased technological progress. This net change is measured by the last bracketed term on the right-hand side of equation (6), i.e. :

$$EMI \equiv (\phi_l - \phi_h) + (1-\sigma)(\gamma_l - \gamma_h) \ . \tag{9}$$

When $EMI = 0$, the effect of biased technical progress is matched by labour force composition changes (which we also took as exogenous). A net exogenous relative labour demand shift ($EMI > 0$) leaves all unemployment rates unchanged if and only if two "neutrality conditions" are simultaneously satisfied. The first neutrality condition is that average wage growth be compatible with average labour productivity growth, that is:

$$\alpha\,\beta_l + (1-\alpha)\,\beta_h = \alpha\,\gamma_l + (1-\alpha)\,\gamma_h \,. \tag{10}$$

With this condition satisfied, the unemployment frontier (5) keeps the same position (the tradeof between the two unemployment rates remains unaffected). The second neutrality condition is that the imbalance between skill demands and supplies generated by $EMI > 0$ be compensated by relative wage changes. From equation (6), it can be seen that the wage growth coefficients must then satisfy :

$$\beta_l = \beta_h - \frac{EMI}{\sigma} \leq \beta_h. \tag{11}$$

When this second neutrality condition is satisfied, biased technical progress leaves the position of the equilibrium technological constraint (6) unaffected. Combining the two conditions yields:

$$\beta_l = \alpha\,\gamma_l + (1-\alpha)\,\gamma_h - (1-\alpha)\,\frac{EMI}{\sigma}\,,$$

$$\beta_h = \alpha\,\gamma_l + (1-\alpha)\,\gamma_h + \alpha\,\frac{EMI}{\sigma}\,.$$

In other words, when EMI is different from zero, the stabilization of all unemployment rates is achieved at the cost of a growing wage dispersion.

An alternative scenario is the one where, although EMI is positive, the high- and low-skilled wages grow at the same rate, compatible with total exogenous productivity gains, so that only the first neutrality condition (10) remains satisfied. With $\beta_l = \beta_h$ and $EMI > 0$, the technological constraint (6) shifts upwards; the two unemployment rates change and move in opposite directions. Ceteris paribus, the relative wage of low-skilled workers decreases by an amount determined by the unemployment rate sensitivity of individual wages (equations (3) and (4)). Compensating this effect by minimum wage increases ($\Delta\lambda_0 > 0$) would however break the first neutrality condition as well and shift out the unemployment frontier, which could eventually yield an increase in both unemployment rates. The fact that we actually observed a rise in both the low- and the high-skilled unemployment rates should thus not be interpreted as a proof that biased technological progress has not contributed to the rise and persistence of aggregate unemployment in EU countries.

Pursuing an objective of stable relative wages in the face of an exogenous, technology-induced net labour demand shift is thus bound to have macroeconomic effects, the size of which will depend on many parameters of the model (sensitivity of wages to unemployment and minimum wage rules a.o.), plus other propagation mechanisms that we have so far neglected, like labour supply behaviours, or the government budget constraint and its impact on labour taxes and wage costs in a context of growing unemployment.

Mismatch Indicators

Can we find a simple aggregate indicator that would measure the contribution of structural shocks to observed aggregate unemployment changes? The answer is (most probably) negative. This comes from the fact that macroeconomic and structural phenomena are intimately interrelated phenomena.

Because symmetric shocks can have asymmetric effects, mismatch indices cannot give information on the nature of the shocks. Observed changes in the difference or the relative value of the low- and the high-skilled unemployment rates may a priori be the result of either macroeconomic or structural shocks. Furthemore, the propagation mechanism started by a structural shock may well lead to substantial aggregate unemployment changes with little apparent structural imbalances (at least in terms of unemployment rate dispersion), as in the case illustrated by the right panel of Figure 3. Hence, unchanged unemployment dispersion does not mean that there has been no structural shock and no structural problem.

"Mismatch indicators" may of course be designed for more specific and less ambitious objectives. For instance, Layard et al. (1991) use the variance of relative unemployment rates *not* to measure the contribution of structural shocks to observed aggregate unemployment changes, but rather more simply to "assess how the structure of unemployment is related to its average level (*both of course being endogenous*)." (Layard et al., 1991, p307; my emphasis). In the particular case where the elasticity of wage claims to unemployment is identical for both groups of workers ($\chi_l = \chi_h = \chi$), the variance of relative unemployment rates measures by how much the aggregate unemployment rate could be decreased by moving *along a given unemployment frontier* towards the point where all unemployment rates are equal[9]. It says of course nothing about the nature of the shocks that produced the observed unemployment dispersion; it says also nothing about the nature of the shocks that pushed the unemployment frontier in its current position. A shift of the unemployment frontier and a movement alongside it may be two sides of the same phenomenon.

[9] The result is obtained by adding and subtracting the log of aggregate unemployment in the unemployment frontier equation, under the assumption $\chi_l = \chi_h = \chi$. The equilibrium unemployment frontier can then be written as:

$$\log u = \alpha_0^{'} - \left\{ \alpha \log\left(\frac{u_l}{u}\right) + (1-\alpha)\log\left(\frac{u_h}{u}\right) \right\} \approx \alpha_0^{'} - \frac{1}{2}\,\text{var}\left(\frac{u_i}{u}\right) .$$

.

There exists also (in our framework) a conceptually simple and natural indicator to measure the importance of biased technological shocks. It is the exogenous mismatch indicator EMI defined in equation (9). This is essentially the mismatch indicator used in Manacorda-Petrongolo (1996) and Manacorda-Manning (1997). This indicator measures the size of the shock, not its effect on unemployment rates, which depends on induced wage changes (see above discussion).

Qualifications and Extensions

Our representation of the way structural phenomena interact with macroeconomic phenomena remains extremely stylized. Structural phenomena are multidimensional. We focused here on one particular dimension (skills) because the available empirical evidence suggest that biased technological progress (or more generally, a biased growth process) may have had profound implications on the wage and employment opportunities of the various skill groups in all sectors of the economy. Still, one should keep in mind that, even if biased technological process were the sole structural shock, the existence of other structural dimensions (sectors, age, sex) may considerably affect the propagation mechanism and the final outcome of a biased technological shock, both at the aggregated and the disaggregated levels. For reasons related to institutions and bargaining power, some groups are better protected than others (typically middle-aged workers), and this asymmetry like the others may have macroeconomic effects. De-industrialization may also interact with biased technological change, especially if there are wage rigidities and if moving from the manufacturing to the service sector implies relatively larger wage losses for low-skilled workers[10].

Another limitation of our simple framework deserves special attention too. We proceeded so far as if neither macroeconomic nor structural shocks had any *induced* effect on the labour force composition. There are serious reasons to believe that this is not the case. For instance, in the face of a biased technological shock unfavourable to low-skilled workers, public and private reactions can modify the composition of the labour force, either by changing the participation rates (early retirement programmes, longer compulsory education, discouragement effects) or by changing the composition of the population of working age (acquisition of skills by low-skilled workers). Macroeconomic shocks may also induce (genuine or appar-

[10] The change in aggregate unemployment is positively correlated to industrial employment losses in OECD countries over the period 1983-1993. See OECD (1997, p.36).

ent) changes in the composition of the labour force, either by the de-skilling of long-term unemployed workers, or by the so-called "ladder effect", when high-skilled workers take the job of low-skilled ones. Observed changes in the composition of the labour force should thus be decomposed into population of working age and participation rate changes. This means replacing in equation (6) the trend coefficients $(\phi_l - \phi_h)$ by $(\phi_l - \phi_h) \equiv (\psi_l - \psi_h) + (\pi_l - \pi_h)$, where ψ_i and π_i stand for trend changes respectively in the population of working age and in the participation rate of group $i \in (l, h)$, which then allows one to examine separately the determinant of each variable.

Yet another "missing link" is the absence of relationship between the technical progress parameters and the wage demand parameters. The way workers' claims adjust in reaction to a (biased or unbiased) technological change is crucial and reflects the characteristics of the institutional environment as well as the nature of the prevailing "social consensus" about income distribution and wage inequalities. The effect of exogenous productivity growth on wage claims depends on strategic interactions across sectors or segments of the labour market; it also depends on the bargaining power of the various groups of workers (skill, age, sex, sectors) and on efficiency wage considerations (to determine the share accruing to wages rather than profits)[11].

4 Empirical Models

Simple as it is, the model of the previous section provides useful insights and helps understand why evaluating the contribution of structural factors to the rise and persistence of unemployment in EU countries may be a difficult task. It also provides a nice reference setup to compare the empirical modelling approaches used by different authors and the results they obtain.

Because simple measures of unemployment dispersion cannot provide reliable measures of the size of structural shocks, the empirical evaluation of the macroeconomic consequences of biased technological shocks necessarily goes through a genuine structural analysis. The latter involves at least two types of information, first about changes in net labour demands (the last bracketed term in equation (6)); second about the determinants of real wages (especially their trend increase and their sensitivity to unemployment; see equation (5)). Some studies focus

[11] Agénor and Aizenman (1997) provide an interesting analysis of such interactions and their implications.

on one of these two issues; others look at both issues simultaneously and draw conclusions about the factors that may explain unemployment. We briefly review a few of them.

Evidence on Biased Technological Progress

There exits a number of empirical studies aiming to test the biased technological progress hypothesis via the estimation of production or labour demand functions (see synthesis in table 4). These studies may differ by the specification of the production function and/or by the nature of the data and the definition of the skill groups. The type of a priori restrictions used to identify the parameters may also play a substantial role.

Authors	Data Description						Production Model				
				Skill Groups							
	Period	Country	Sector	Criterion	# of cat.	N_l/N_h (beg.-end)	Specification	Number of inputs	Measure bias.techn. progress	Subst. elast. σ_{lh}	Sources of asymmetric empl. growth
Shadman-Sneessens,1995	62-89	France	macro	occupat.	2	5 - 2.2	log-linearis. dem.f.	skill cat. $+ K$,M	piecewise lin.trend	0.5	bias. tech. prog.
Draper-Manders, 1996	72-93	Netherl.	shelt. & non-sh.	educat.	2	3 - 1	SGM cost f.	skill cat. $+ K$	quadratic trend	3 1.5	bias. tech. prog. +asym.K-Nsubst.
Krusell et al., 1997	63-92	US	macro	educ	2	(2 - 1)	CES (nested)	skill cat. $+ K_s$, K_e	-	1.5	asym.K-Nsubst. (emb.tech.progr)
Card et al., 1996	82&89	US, Can. and Fr.	micro	educ. & age/sex	> 5 > 6	-	CES	skill cat.	computer use	≈ 0	bias. tech. prog.
Machin et al., 1996	70-90	US, UK, Dk., Sw.	16 man. indust.	non-prod. vs prod.	2	3 - 2	translog cost f.	skill cat. $+ K$	R&D/Y	> 0	bias. tech. prog. +asym.K-Nsubst.
Manacorda-Petrongolo,96	m.70's - e.90's	pool 10 OECD c.	macro	educat.	2	3 - 1	CES (var.weight)	skill cat.	lin.trend (coun.sp.)	1	bias. tech. prog.

Table 4: Estimates of technological bias in production models with different skill levels

Shadman-Mehta and Sneessens (1995) estimate the parameters of a four-input production function (low- and high-skilled labour, capital and energy) with exogenous labour-augmenting technical progress. The model allows a structural break in the exogenous rates of technical progress in 1974. The parameters are estimated on French annual aggregate data over the period 1962-1989. Skills are defined by occupation. A simplified version of the model is used in Sneessens and Shadman-Mehta (1995). The elasticities of substitution between capital and the two types of skills are not significantly different; the elasticity of substitution between low- and high-skilled workers is estimated at around 0.50. There is strong evidence though of asymmetric technical progress unfavourable to the low-skilled (i.e., given $\sigma < 1$, they find $(\gamma_l - \gamma_h) > 0$). It is worth stressing that this asymmetry is reduced by 50% after 1974 $((1-\sigma)(\gamma_l - \gamma_h) = 0.0480$ before 1974, 0.0245 afterwards$)$. The trend in the relative labour supply observed during the same periods are respectively $(\phi_l - \phi_h) = -0.045$ before 1974,and -0.023 afterwards. This implies a *positive but decreasing* exogenous net labour demand shift in favour of high-skilled labour, equal to $(4.80 - 4.50) = 0.30$ percentage points per annum before 1974, $(2.45 - 2.30) = 0.15$ afterwards.

Draper-Manders (1996) use a flexible functional form (the Symmetric Generalized McFadden cost function) to estimate why low-skilled employment has decreased relatively to high-skilled employment in the Netherlands over the period 1972-1993. Most of the change is explained by biased technological change.

Krusell et al. (1997) estimate a four-input nested-CES production function on US data. High- and low-skilled labour inputs are measured in efficiency units. Each of the two labour input indices is defined as a productivity-weigthed sum of all hours worked by individuals in different age-sex-education cells. The high-skilled worker group includes all individuals with education attainment level at least equal to college completion. The (normalized) relative value of the low-skilled labour input index decreases from 2 to 1 over the period covered by the analysis. The authors find evidence of a biased, unfavourable effect of growth on the demand for low-skilled labour. This effect however does not come trough an exogenous trend technical progress, but rather through the process of capital accumulation itself, because low- and high-skilled labour have different elasticities of substitution vis-à-vis the capital stock once the latter is decomposed into structures and equipment. Their results suggest that nearly all the increased wage inequality could be the consequence of economic growth driven by the introduction of new technologies embodied in capital equipment.

Card et al. (1996) estimate CES employment equations (together with labour supply equations and wage flexibility parameters; see below) on micro data from three different countries: US, Canada and France. The micro data are aggregated in age-education cells (skill is thus proxied by educational attainment); two observations are available for each cell: one in the late 70's-early 80's, the other in the late 80's. Measures of exogenous labour supply changes (population of working-age changes) are directly available from the data. The bias in technical progress is proxied by the proportion of workers using computers in each group towards the end of the eighties, assuming that the progression of this ratio has been similar in all three countries during the period considered. The model performs well at least for men aged between 25-54. The coefficient associated to the biased technical progress indicator is correctly signed and statistically different from zero; the estimated elasticity of substitution is however extremely low (0.16), implying that relative wages should have little impact on relative employment. The difficulty may come from the representation of wage determination and/or labour supply behaviours included in the model.

Machin et al. (1996) estimate a translog cost function on panel data covering 16 manufacturing industries and four countries (US, UK, Denmark, Sweden). Four productive factors are distinguished: low- and high-skilled labour, physical capital and R&D (in percentage points of value-added). The R&D variable is meant to capture the effects of investment in new technologies. Skills are defined by production vs non-production status, but the authors checked the robustness of their findings on US and UK data by using an education criterion. As in Krusell et al. (1997), the authors find evidence of important skill-capital and skill-technology complementarities. This implies biased technological progress, not large enough however to explain the observed changes in the skill structure in the US and the UK. The authors give some evidence that institutional factors (giving better protection to low-skilled workers) rather than international trade can explain these differences. These findings stress again the need to try and take simultaneously into account the several dimensions of macroeconomic and structural interactions.

Manacorda-Petrongolo (1996) estimate a CES relative employment function on annual data from ten OECD countries (US, Canada, Australia plus seven EU countries including France, Italy, Spain and the UK). Skill is here proxied by educational attainment. Due to a lack of data on relative wages, the number of observations may vary considerably from country to country. By pooling all the countries' observations and imposing the same elasticity of substitution in all countries, it is possible to estimate a country-specific coefficient of biased exogenous technical progress (corresponding to $(1-\sigma)(\gamma_l - \gamma_h)$ in equation (6))[12]. The estimated elasticity of substitution is not significantly different from one. In all countries the technical progress coefficient is positive (technical progress is unfavourable to the low-skilled); it varies from 0.051 in Australia to 0.076 in the UK. These estimates are next compared to the trend change in labour force composition $(\phi_l - \phi_h)$. The proportion of low-skilled (i.e. low educational attainment) workers has decreased everywhere; the estimated net labour demand shift however remains positive, hence unfavourable to the low-skilled, in all countries but one (the Netherlands). The net shift appears to have been much higher in the US than in France during the eighties $((4.92 - 3.21) = 1.71$ percentage points per annum in the US, against $(6.54 - 6.09) = 0.45$ in France), despite a lower biased technical progress effect in the US. In the US, the net shift *increases* from -0.82 in the seventies to 1.71 in the eighties, an increase mainly due to a reduction in the relative rate of growth of high-skilled labour supply.

Manacorda-Manning (1997) build on this previous work by taking into account explicitly that educational attainment may be an imperfect measure of skill. To this end, they have to start with a continuum of skill levels and next aggregate in two or more groups. Assuming a unitary elasticity of substitution between skills (Cobb-Douglas production function), they are able to obtain yearly estimates of exogenous net labour shifts for the US and five EU countries. There is again in all countries evidence of shifts unfavourable to the low-skilled. In four EU countries (France, Germany, Italy and the UK), the shift keeps the same value throughout the eighties; it is decreasing in the Netherlands, increasing in the US.

It seems fair to conclude that there is fairly strong evidence of biased technological change unfavourable to the low-skilled[13]. In almost all countries, the composition of the labour force did not change rapidly enough to compensate this bias, which means that the relative wage cost of the low-skilled had to decrease to stabilize the difference in unemployment rates. There are only a few studies that examine how this net demand shift may have changed over time. A tentative conclusion is that the net demand shift has remained stable or even decreased in France and has increased in the US. It is worth recalling though that taking

[12] The authors estimate $(1-\sigma)(\gamma_l - \gamma_h)$ as one coefficient, without imposing that it be equal to zero when σ is one. This amounts to using a Cobb-Douglas function with changing wage share coefficients.

[13] Estimates of biased "technological change" relying on unexplained trend coefficients may well of course pick up the effects of factors others than technical progress, like international trade and globalization or changes in the structure of the economy.

observed changes in the labour force composition as given, as if they were exogenous, may be misleading, especially when there are early retirement programmes and when changes in the compulsory schooling age reduces the participation rates of older and younger workers. In such a case, the calculated net demand shifts may seriously underestimate the true magnitude of the shock[14].

The relative wage adjustment needed to offset a net demand shift of course depends on the size of the elasticity of substitution. There is not much consensus (to say the least) about the latter. The estimates reported here vary from almost zero to three[15].

Evidence on Wage Rigidities

A biased technological change may leave relative employment unchanged if relative wage costs are suitably adjusted. Whether this will occur or not depends on many factors, including a.o. the sensitivity of wages to unemployment rate changes, the existence of insider-outsider effects, wage rivalry, etc...

Cohen (1997), comparing France and the US, obtains that bargaining power on the various segments of the labour market is similar in the two countries, except for workers with no diploma,where the bargaining power is 20% higher in France. In Sneessens and Shadman (1995), the French low-skilled wage rate appears to be insensitive to unemployment rate changes, while the skilled wage rate is sensitive to changes in its own unemployment rate. Card et al. (1996) obtain a larger wage rigidity in all age-education cells in France, compared to the US. There is a single coefficient measuring wage flexibility, which broadly corresponds to the ratio between the realized wage adjustment and the one that would be needed to restore full-employment. If the adjustment needed to restore full employment is larger on the low-skilled labour market segment (which seems a most plausible assumption in situations of biased technical progress unfavourable to the low-skilled), their result implies a larger non-adjustment of low-skilled wages.

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[14] In Card et al. (1996), participation rates are endogenous, but solely a function of the real wage rate. Part of the difficulty however is avoided when focusing on men aged 25-54, whose participation rates have been more stable.

[15] See also for instance Bound-Johnson (1992), who report a value larger than 2. Values of σ larger than one are typically associated to negative values of $\gamma_l - \gamma_h$, so that the relative wage implications remain essentially unchanged.

Manacorda-Petrongolo (1996) impose the same elasticity of wages to unemployment across skill groups, and obtain similar values for the UK and the US (around -0.03). They allow however from trend effects similar to those of equations (3)-(4) (our coefficients β_l and βh) and obtain striking differences between the two countries. The trends are positive and similar for low- and high-skilled workers in the UK (a case similar to the "second scenario" discussed in the previous section) ; they are negative in the US, especially for low-skilled workers (twice larger -in absolute value- for low-skilled workers; this case is similar to the "first scenario" discussed in the previous section).

Risager (1992) develops and estimate on Danish data (1951-1987) a model with two types of skills and wage rivalry. For both types of labour, own-unemployment wage elasticities are not significantly different from zero; there are however significant insider-outsider effects on the low-skilled segment of the labour market (highly significant negative lagged employment effects). The model implies a fairly constant long-run relative wage.

A fair conclusion seems to be that there is more wage rigidity in Europe than in the US, and more wage rigidity at the low end of the wage spectrum. Simultaneously, we should recognize that our understanding of the many dimensions of the wage formation process remains limited . Wage-wage interactions in particular remain poorly understood and taken into account, which certainly limits our ability to evaluate correctly the link between biased technical progress (or structural shocks in general) and aggregate unemployment.

This difficulty may contribute to explain the controversy about the effect of minimum wages. Whether minimum wage laws have significant macroeconomic implications remains a debated issue. Empirical work based on fairly aggregated data (see for instance Bazen-Martin, 1991) suggested that minimum wages might have little employment consequences. More recent studies based on micro data (Di Nardo et al., 1996; Abowd et al., 1996) suggest however that an increase in the minimum wage implies a dramatic reduction in employment opportunities for workers paid at the minimum wage. One easy way of reconciling the two results is to consider that the proportion of workers paid the minimum wage is quite small, so that aggregate effects are almost negligeable. This argument of course neglects the impact of wage-wage interactions.

Biased Technological Change and Unemployment

There is thus fairly convincing evidence of exogenous net labour demand shifs and of wage rigidities, especially for low wages. This suggests that exogenous net relative labour demand changes induced by biased technological progress must have contributed to observed unemployment changes. As suggested before, quantifying this contribution may turn out to be a difficult task, given in particular the many interactions between macroeconomic and structural phenomena. Not all the author do the exercise.

In Card et al. (1996), relative wage rigidities have almost no impact on relative employment because the elasticity of substitution σ is close to zero. The authors conclude that stronger relative wage rigidities in France can therefore not be held responsible for low-skilled unemployment.

Sneessens and Shadman-Mehta (1995) reach a different conclusion. Biased technical progress together with minimum wage changes play a dominant role. The two factors together explain five out of the eight percentage point unemployment increase observed in France between 1962 and 1989. As for the UK, Manacorda-Petrongolo (1996) conclude for that exogenous net labour demand shifts account for half the increase observed in aggregate unemployment between 1975 and 1992 (three percentage points out of six), the rest being accounted for by increased wage pressure (the trend terms in the wage equations). In the US, exogenous net labour demand shifts, although stronger, have been fully offset by relative (and absolute) wage changes.

5 Conclusions

The fact that there is biased technical progress (or at least, that growth has asymmetric effects) is little disputed. Evaluating its effect on unemployment still remains a difficult task. We first stressed the danger of working with simple measures of unemployment dispersion because they cannot provide reliable measures of the size of structural shocks. We emphasized instead the need to have a genuine structural analysis. The latter involves at least two types of information, first about net exogenous changes in relative labour demands, second about the determinants of real wages (especially their trend increase and their sensitivity to unemployment).

To clarify these issues, we developed a simple analytical framework with two types of labour (high- and low-skilled) and examined its implications. It was shown in this setup that pursuing an objective of stable relative wages in the face of exogenous, technology-induced net relative labour demand shifts is bound to have macroeconomic effects, the size of which will depend on many parameters like the sensitivity of wages to unemployment and labour supply behaviours, plus other propagation mechanisms like the government budget constraint and its impact on labour taxes and wage costs in a context of growing unemployment. The fact that we actually observed a rise in both the high- and the low-skilled unemployment rates should thus not too quickly be interpreted as a proof that biased technological progress has not contributed to the rise and persistence of aggregate unemployment in EU countries. We next used the model as a reference setup wherein to compare the empirical modelling approaches used by different authors and the results they obtain.

Existing empirical evaluations of the impact of biased technical progress and of structural shocks in general still fail to take into account a certain number of important factors and mechanisms. One key difficulty is to distinguish endogenous and exogenous changes in the labour force composition. The sharp reduction in the participation rates of younger and older workers in many EU countries is probably an endogenous rather than an exogenous phenomenon. The failure to take it into acount probably leads to the underestimation of the effect of biased technological progress.

Biased technical progress has probably been at work for a long time. A most relevant question in this perspective is why it should lead today to structural imbalances, while it was compatible in the past with full-employment and reduced inequalities. Existing empirical models with structural features allow too few interactions between macroeconomic and structural phenomena, and between different types of structural shocks (deindustrialisation vs technical progress, e.g.). The former may lead to overestimating the importance of structural shocks (by ignoring the structural implications of macro shocks, especially the so-called "ladder effect"); the latter may lead to its underestimation (by neglecting the amplifying effects of structural interactions).

Ignoring macroeconomic and structural interactions may be a serious shortcoming. Drèze (1997) shows that when there are real rigidities similar to those considered here (relative real wage rigidities), pessimistic self-fulfilling demand expectations can make the "size" of the economy arbitrarily small, via capital scrapping and persistent unemployment. Such a macroeconomic evolution can clearly have structural implications, especially if high-skilled workers can reduce their own unemployment risk by moving to the low-skilled labour market and taking the job of low-skilled workers (ladder effect). It may explain our difficulty to disentangle the effects of macroeconomic and of structural shocks. More work on these issues should be most welcome.

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