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SKILL DEMAND AND FACTOR SUBSTITUTION

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ABSTRACT

Skill Demand and Factor Substitution*

The aim of this paper is to empirically evaluate the relative importance of the various factors likely to have influenced the demand for skilled and unskilled labour in France, over the period 1962–89. Our approach is macroeconomic, and we essentially deal with technology choice, that is factor productivity over the long run. We estimate a system of three equations, with a dynamic formulation of the error correction type. The main aim is to estimate price elasticities, and direct and cross partial elasticities of substitution between different factors, especially those related to skilled and unskilled labour.

JEL Classification: E24, J23
Keywords: Shephard's lemma, exogenous technical progress, skill mismatch

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NON-TECHNICAL SUMMARY

The clear slowdown in economic growth over the last 20 years has not hit all social groups equally. The proportion of unskilled labour in total employment has decreased sharply in both the United States and Europe. Equally, in Europe at least, the upward trend in unemployment has hit unskilled workers much harder.

There are many causes for the relative rise in unskilled unemployment. One important cause is no doubt the inadequate adjustment of relative costs due to the non-competitive nature of the labour market. This can itself be caused or exacerbated by exogenous shocks to the relative demand for skilled/unskilled labour. Such shocks can reflect a change in demand across all sectors of the economy. They can also reflect a change in the relative weight of various sectors. The aim of this paper is to evaluate the relative importance of the various factors likely to have influenced the demand for skilled and unskilled labour in France, over the period 1962–89. We do not equate skill with non-manual work, but use instead a classification which corresponds better to the skill criterion. Skilled workers, for example, includes executives and foremen and technicians, whereas unskilled workers include some employees as well as manual labourers.

Two types of decisions can be distinguished in firms' production plans: those concerning the long term and those concerning the short term. The long-term decision relates to production technology, whereas the short-term decision relates to production levels, and how much of each factor the firm should use. In this paper we essentially deal with the firms' technological choice, that is factor productivity over the long run. The effective demand for each factor depends on the overall economic climate, and also on the adjustment costs. In the short run, therefore, we can expect divergence between technical and actual productivities.

We assume that four factors are used in production: unskilled labour, skilled labour, energy and fixed capital. Firms choose the production technology that minimizes costs. We thus obtain and estimate a system of three equations, with a dynamic formulation of the error correction type, in which the demand for each factor per unit of output is expressed in terms of real costs of the four factors, allowance also being made for exogenous technical progress. The main aim is to estimate price elasticities, and direct and cross partial elasticities of substitution between different factors, especially those related to skilled and unskilled labour. One interesting conclusion from the theoretical

model is that when the partial elasticities of substitution between skilled labour and energy and/or capital are not identical to those for unskilled labour, then the same change in relative skilled/unskilled wages has different consequences on the relative demand for skilled/unskilled labour demand, according to which category of wages is responsible for the change. Similarly, another conclusion is that a general increase in wage levels (with unchanged relative wages) has different effects on skilled and unskilled labour.

Our main conclusions are as follows. Over the last 30 years, exogenous technical progress has had a systematic negative effect on the demand for unskilled labour. Surprisingly, however, this negative influence is much less powerful after 1974. Skilled and unskilled labour are substitutes, but they are also substitutes with energy and capital. The partial elasticity of substitution between labour and capital is about the same for both categories of labour, but energy prices affect the demand for the two types of labour differently. Demand for both capital and energy have low own-price elasticities.

Finally, based on our estimated elasticities, and assuming a constant output level, we calculate that in order for the demand for unskilled labour to grow at the same rate as its supply over this period, the growth of unskilled real wage costs should have been limited to 0.92% per year instead of the actual 2.56%. The corresponding figures for skilled labour are 1.16% instead of 2.07%. Similar results are obtained when looking at relative unskilled/skilled employment, where variations in output level have no impact. For relative unskilled/skilled employment to have grown in line with relative supply, a 20% reduction in relative unskilled wages would have been necessary (i.e. a fall to the level of the mid-1960s). Social security contributions represent a significant part of wage costs. Their proportion has increased regularly over the last 20 years, from 40% in 1973 to more than 65% in 1989. We therefore underline the possibility of achieving the required reduction in wage costs, at least partly, by a change in the mode of financing the social security system.

Osterwald-Lenum, (1992), "Practitioners'Corner",*Oxford Bulletin of Economics and Statistics*, 54 (3), 461-472.

Risager, O., (1992), "Labour Substitution in Denmark", Discussion paper, Institute of Economics, University of Aarhus, Denmark.

Sneessens, H.R., (1993), "Courbe de Beveridge et demande de qualifications", IRES DP9319, Dpartement des Sciences Economiques, Universit Catholique de Louvain.

Sneessens, H.R., (1993), "Penurie de Main-D'oeuvre Qualifiée et Persistence du Chomage", Report submitted to the Commissariat Général au Plan in Paris, IRES, Dpartement des Sciences Economiques, Universit Catholique de Louvain.

SKILL DEMAND AND FACTOR SUBSTITUTION[1]

F. Shadman-Mehta and H.Sneessens

1. INTRODUCTION

A clear slowdown in economic growth has been the hallmark of the past twenty years. The average growth rate of GDP in the twelve member states of the European community has fallen from 4.8% per annum in real terms during the sixties to 2.3% during the eighties; the corresponding figures for the United States are 3.8% and 2.5% respectively. This slowdown has not hit all social groups equally, and less qualified workers have seen their relative situation deteriorate. The proportion of unskilled labour in total employment has decreased sharply both in the United States and in Europe. In the United States however, the change is accompanied by a drop in relative unskilled wages (see Levy-Murnane, 1992). The same process is generally not observed in Europe; moreover, the upward trend in unemployment which has accompanied the slowdown in growth, has hit unskilled workers much harder.

There are certainly many causes for the relative fall in unskilled employment (and hence the relative rise in unskilled unemployment in Europe). Such a fall probably reflects the inadequate adjustment of relative costs due to the non-competitive nature of the labour market. This problem can itself be induced or exacerbated by exogenous shocks to the relative demand for skilled/unskilled labour. Two types of shocks can normally be distinguished. A change in the relative demand for skilled/unskilled labour at the aggregate level may reflect an identical change in each of the different sectors of the economy. On the other hand, it may result from a change in composition, that is a change in the relative weight of each sector. Examples of the first type of change include technical progress, and in the case of the manufacturing sector, the shifting of production to low wage countries; as for the second category, one can mention factors that cause structural change in final demand and

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in disindustrialisation.

The aim of this paper is to empirically evaluate the relative importance of the various factors likely to have influenced the demand for skilled and unskilled labour in France, over the period 1962-1989. Our approach will be macroeconomic. For want of a better reason, many aggregate studies have so far been based on a distinction between manual and non-manual workers. However, this distinction can only shed some light on the problem of skill mismatch at the aggregate level, insofar as the state of the manufacturing sector constitutes the most important element of the problem. Given the growing importance of the service sector however, one can envisage that the relative increase in non-manual labour may reflect a shift of labour from the secondary to the tertiary sector (the second category of factors mentioned above), just as much as it may reflect substitution within the manufacturing sector (first category). In this case, the interpretation of series such as the relative manual/non-manual wages is problematic; rather than reflecting a change in relative skilled/unskilled wages, a fall may be the result of the fact that at a given skill level, productivity and wages are lower in the service sector than in the manufacturing sector. To avoid these difficulties, and have a skilled/unskilled classification which corresponds better to the skill criterion, this study uses a classification of employment based on statistics on employment, unemployment and wages by professional occupation, published by INSEE. The skilled worker group corresponds to professional and managerial workers (categories 3 and 4 of the employment surveys): the unskilled group corresponds to employees and blue collar workers, plus farmers and craftmen (categories 1, 2, 5 and 6). Unemployed workers are grouped according to their previous occupation; those who never worked before are regarded as unskilled (for details see Sneessens(1993)).

The paper is organised as follows. The theoretical model is presented in section 2. Shephard's lemma is used to derive the demand for factors of production from a cost function. The underlying production function has four factors: unskilled labour, skilled labour, energy and capital. The form that we retain is close to that obtained from a trans-log cost function. The data and the results are described in sections 3 and 4 respectively. Section 5 summarises the main conclusions.

References

Clark, K., Freeman, R.B., (1980), "How Elastic is the Demand for Labour", *Review of Economics and Statistics*, 62, 509-20.

Engle, R.F. and C.W.J.Granger(1987), "Cointegration and Error Correction: Representation, Estimation, and Testing", *Econometrica*, 55, 2, 251-276.

Hamermesh, D.S., (1986), "The Demand for Labor in the Long Run", in Ashenfelter, O.C., Layard, R., eds, *Handbook of Labor Economics*, North-Holland.

Hendry, D.F.,(1989), "PC-GIVE: An Interactive Econometric Modelling System", Oxford Institute of Economics and Statistics, Oxford.

Johansen,S., (1988), "Statistical Analysis of Cointegration Vectors", *Journal of Economic Dynamics and Control*, 12, 2/3, 231-254.

Johansen,S., (1991), "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models", *Econometrica*, 54, 3, 383-397.

Johansen,S., Juselius, K., (1990), "Maximum Likelihood Estimation and Inference on Cointegration-With Applications to the Demand for Money", *Oxford Bulletin of Economics and Statistics*, 52, 2, 169-210.

Levy, Fr., Murname, R.J., (1992), "U.S. Earnings levels and Earnings Inequality: A Review of Recent Trends and Proposed Explanations", *Journal of Economic Literature*, XXX, 1333-1381.

MacKinnon, J.G., (1991), "Critical Values for Cointegration Tests", Chapter 13 in R.F.Engle and C.W.J.Granger(eds.),*Long Run Economic Relationships: Readings in Cointegration*, Oxford, Oxford University Press, 267-276.

Maillard, B., Sneessens, H.R., (1993), "Caractristiques de l'emploi et du chmage par PCS : France, 1962-1989", IRES DP9317, Dpartement des Sciences Economiques, Universit Catholique de Louvain .

Perron, P., (1989), "The Great Crash, The Oil Price Shock, and the Unit Root Hypothesis", *Econometrica* , 57 (6), 1361-1401.

Pfann, G., Palm, F., (1993), "Asymmetric Adjustment Costs in Non-Linear Labour Demand Models For the Netherlands and UK Manufacturing Sectors", *Review of Economic Studies*, forthcoming.

2- Skilled and unskilled labour are substitutes, but they are also substitutes with energy and capital. Their own-price elasticities are very similar and close to -0.50. Let us stress again these are elasticities <u>for a given output level</u>. The partial elasticity of substitution between the two types of labour is estimated at 0.88 (standard error=0.31). The elasticity of total employment to wages is much smaller. An overall 10% increase in the wage level, would reduce unskilled labour by 2.5% and skilled labour by 1.5%.

3- The partial elasticity of substitution between labour and capital is about the same (0.5) for both categories of labour. On the other hand, energy prices affect the demand for the two types of labour differently; skilled labour is basically unaffected, but there is a significant positive effect for unskilled labour (partial elasticity is 0.12, with a standard error of 0.02).

4- The own-price elasticity of demand for energy is rather low in absolute value, about 0.15. On the other hand, the partial cross elasticity with respect to unskilled wages is quite large, about 0.50.

5- The own-price elasticity of demand for capital is relatively low, between 0.2 and 0.3 in absolute value. An overall increase in wages has a significant positive effect; the sum of the two corresponding cross elasticities is near 0.40. The elasticity with respect to energy prices is negative (implying energy is a complement), about 0.15.

6- Based on the estimated price elasticities, we can calculate that, in order for the demand for unskilled labour to grow at the same rate as its supply over the entire sample, the growth of unskilled real wage costs should have been limited to 0.92% per year instead of the actual 2.56%. The corresponding figures for skilled labour are 1.16% instead of 2.07%. This scenario therefore implies a gigantic decrease in real labour costs. Recall that this calculation is done assuming a constant output level. But it is worth adding that in the United States, average real wages have grown at a yearly rate of 0.6% since 1971. Variations in the level of output have no impact on relative employment. We can therefore treat the same calculations, but with relative wages, as more reliable. For relative unskilled/skilled employment to have grown in tune with relative supply, a 20% decrease in relative unskilled wages is necessary, that is going back to the levels prevalent in the mid-sixties.

2. THE THEORETICAL MODEL

Two types of decisions can be distinguished in firms' production plans: those concerning the long-term, and those concerning the short-term. The long-term decision is about the production technology itself; the short-term decision concerns the level of production and the quantity of inputs. The firm choses the production technology that minimises costs of production at given input prices. This choice determines the technical production coefficients, independently of the overall economic situation. Given this technological decision, the effective demand for each factor will then depend on the overall economic climate, and on adjustment costs (for example costs of hiring and firing). Such adjustment costs, together with the degree of utilisation of each factor, can in the short-run lead to divergence between technical and actual productivities. In this paper, we essentially deal with technological choice, that is factor productivity over the long-run. The theoretical model developed here, must therefore be viewed from that standpoint. We largely follow the model used by Risager(1992). But it should be added that this type of modelling based on minimising costs for a given level of output is also compatible with profit maximisation with variable (endogenous) output.

2.1 Cost minimisation and demand for factors of production: Shepard's lemma

We assume that production of goods requires the use of four factors denoted as follows:

$$L_u = \quad unskilled \quad labour(men/year)$$

$$L_s = \quad skilled \quad labour(men/year)$$

$$E = \quad energy$$

$$K = \quad fixed \quad capital$$

The nominal unit costs of these factors are denoted by W_u, W_s, P_e and V respectively. We assume constant returns to scale and denote the unit cost function (i.e. cost per unit produced) as $C(W_u, W_s, P_e, V)$. The function C is assumed to satisfy all necessary conditions to adequately represent a set of technological constraints: it is continuous, non-decreasing in each of its arguments, concave and homogeneous of degree one.

The firm choses its production technology so as to minimise its costs. Following Shepard's lemma, we know that the demand for each factor per unit of output is given by the corresponding first partial derivative of the cost function. Thus, the demand for unskilled labour for example, is obtained as follows:

$$\frac{L_u}{Y} = \frac{\partial C(.)}{\partial W_u} = a_u(W_u, W_s, P_e, V) \qquad (1)$$

Similar expressions hold for the other factors. Log-linearisation of the above expression leads to the following form:

$$log(\frac{L_u}{Y}) = cst + \eta_{uu} log(\frac{W_u}{P}) + \eta_{us} log(\frac{W_s}{P}) + \eta_{ue} log(\frac{P_e}{P}) + \eta_{uk} log(\frac{V}{P}) \qquad (2)$$

$$with \quad \eta_{uu} < 0 \quad and \quad \sum_j \eta_{uj} = 0 \quad for \quad homogeneity$$

where the η_{uj}'s, $j \in \{u, s, e, k\}$, are price elasticities for a given level of output. We have used homogeneity to rewrite (2) in terms of real rather than nominal costs. For a given level of output, there is a direct relationship between price elasticities and the partial elasticities of substitution denoted by σ_{uj}. $\eta_{uj} \equiv \sigma_{uj}.s_j$, where s_j is the share of input j in total output value (see Hammermesh(1986)). Similar expressions are derived from the demand functions of other factors. Two factors of production are called *p-substitutes*, if $\eta_{ij} > 0$ (and therefore $\sigma_{ij} > 0$), and *p-complements* if the inverse is true. Note that the matrix of the partial elasticities of substitution is symmetric ($\sigma_{ij} = \sigma_{ji}$), but that the matrix of price elasticities is not so in general (i.e. $\eta_{ij} \neq \eta_{ji}$ in general). Finally, note that the inputs can all be *p-substitutes*, but they cannot all be *p-complements*.

Adjustment costs obviously imply lags in adjustment, and we will allow for this by introducing an error correction mechanism in the empirical section[2]. We still need to deal with three other problems: technical progress, the cost of capital, and the use of expressions in terms of value-added rather than output.

[2]When there are adjustment costs, the question of the choice of technology through cost minimisation becomes an intertemporal problem. To be rigorous, one should therefore use the Euler conditions related to this problem, rather than the first order conditions of the static case, and allow for expectations of future costs (see for example Pfann-Palm(1993)). The extension of this approach to a model with four inputs remains for future research.

	$\Delta log S_u$	$\Delta log S_s$	$\Delta log S_e$
Constant	−0.6436 (0.2675)	−5.7199 (0.7738)	−4.5943 (0.8845)
ΔTS_{74}	−0.0385 (0.0092)	0.0115† (0.0152)	0.0050† (0.0150)
ΔDUM_{76}	-	−0.0481 (0.0120)	-
DUM_{76-1}	-	−0.0493 (0.0120)	-
ΔDUL	0.1479† (0.3614)	−0.4652 (0.1312)	-
DUL_{-1}	0.1479† (0.3614)	−0.4652 (0.1312)	-
$\Delta log \frac{W_u}{P_v}$	1-0.4222 (0.1714)	0.3863† (0.3243)	0.4945† (0.2906)
$\Delta log \frac{W_s}{P_v}$	0.3120 (0.1136)	1-0.7289 (0.1958)	0.6905 (0.2283)
$\Delta log \frac{P_e}{P_v}$	−0.0896 (0.0148)	−0.0641† (0.3780)	1-0.1378 (0.0270)
Error Correction Coefficient	0.3976 (0.1404)	1.6829 (0.1843)	0.6965 (0.1340)
R^2	0.84	0.88	0.99
DW	2.58	2.03	1.52
$SEE(\%)$	0.65	0.70	1.32
Residual S_u	1.00	-0.24	-0.20
Correlation S_s		1.00	+0.19
matrix S_e			1.00

†=not significantly different from zero.

Additional instruments (in logs): UR_{ut-1}, UR_{st-1}, $\Delta log XW_t$ and $log XW_{t-1}$.

Table 10:Estimated coefficients under hypothesis (ii).

least a 2.5% per year to stabilise unskilled employment (the observed average rate since 1973 is 2.4%). However, the negative influence of technical progress appears much less powerful after 1974,than during the twelve years before. This result strikes as surprising *a priori*, given that it is after 1974 that we observe successive increases in unskilled unemployment rate. But we may interpret it as follows: The estimated effects of technical progress in fact cover two types of exogenous shock mentioned in the introduction, technical progress strictly speaking, and effects due to composition. There has been a sharp increase in the relative importance of the tertiary sector since 1974, which may explain the slowdown in observed average productivity.

therefore treat the implications of a similar type of calculation as far as relative unskilled/skilled wages are concerned as more robust and reliable. For the relative unskilled/skilled employment to have evolved at the same rate as relative supply, the relative wage of unskilled workers ought to have been 20% below its present level, that is back to the level in the mid-sixties.

8- Social security contributions represent a significant part of wage costs. Their proportion has increased regularly over the last twenty years, going from about 40% in 1973 to more than 65% in 1989. This remark underlines on the one hand, the importance of a good control of social security expenditures, and on the other, the possibilty of achieving the required decrease in wages at least partly by a change in the mode of financing the social security system.

(vi)<u>Dynamic parameters and the quality of adjustment</u>

Table 10 gives the estimated values of the dynamic parameters, so far unmentioned, as well as the usual adjustment statistics. The representation of the short-run coefficient associated to changes in factor costs, takes into account the direct pure accounting effect of a change in a given factor cost on the corresponding factor share. One remark regarding the error correction coefficients is called for. We have an error correction coefficient larger than 1 in the case of skilled labour. We obtain the same result with the alternative specification discussed earlier (with input/output ratios rather than factor shares as endogenous variables). It also holds in the unrestricted case, and is therefore unrelated to the introduction of constraints such as symmetry, etc ... It may be related to anomalies in the data mentioned in section 3, and which are not taken care of sufficiently by the use of the dummy variable $DUM76$. The other important source of the problem could be, as mentioned before, the misspecification of the maximal lag length at 1.

5. CONCLUSIONS

We can summarise our main results as follows:

1- Over the last thirty years, exogenous technical progress has had a systematic negative effect on the demand for unskilled labour. This result confirms that of previous studies (see Levy-Murnane, 1992, for example). Moreover, other things being equal, today we would need a growth rate of output of at

2.2 Exogenous technical progress

Exogenous technical progress can have a different effect on productivity and hence the demand for various factors of production. Let us allow for this by writing the quantity-price relations such as (2) above, in terms of efficient units. For example, we replace L_u and W_u by $\tilde{L}_u \equiv e^{\tilde{\gamma}_u t}.L_u$ and $\tilde{W}_u \equiv e^{-\tilde{\gamma}_u t}.W_u$ respectively, where $\tilde{\gamma}_u$ is the exogenous rate of growth of the productivity of unskilled labour, and so on for the other factors. Some rearrangement of terms leads to the following complete system of equations:

$$log(\frac{L_u}{Y}) = cst - \gamma_u t + \eta_{uu} log(\frac{W_u}{P}) + \eta_{us} log(\frac{W_s}{P}) + \eta_{ue} log(\frac{P_e}{P}) + \eta_{uk} log(\frac{V}{P}) \quad (3a)$$

$$log(\frac{L_s}{Y}) = cst - \gamma_s t + \eta_{su} log(\frac{W_u}{P}) + \eta_{ss} log(\frac{W_s}{P}) + \eta_{se} log(\frac{P_e}{P}) + \eta_{sk} log(\frac{V}{P}) \quad (3b)$$

$$log(\frac{E}{Y}) = cst - \gamma_e t + \eta_{eu} log(\frac{W_u}{P}) + \eta_{es} log(\frac{W_s}{P}) + \eta_{ee} log(\frac{P_e}{P}) + \eta_{ek} log(\frac{V}{P}) \quad (3c)$$

$$log(\frac{K}{Y}) = cst - \gamma_k t + \eta_{ku} log(\frac{W_u}{P}) + \eta_{ks} log(\frac{W_s}{P}) + \eta_{ke} log(\frac{P_e}{P}) + \eta_{kk} log(\frac{V}{P}) \quad (3d)$$

Again $\eta_{ii} < 0$ and $\sum_j \eta_{ij} = 0$ (homegeneity), and $\eta_{ij} \equiv \sigma_{ij} s_j$ and $\sigma_{ij} = \sigma_{ji}, \forall i,j$ (symmetry). It is easily verified that the coefficients of technical progress γ_i in equations (3) are themselves combinations of the initial coefficients $\tilde{\gamma}_i$.

2.3 Cost of capital

Capital poses a particular problem. Its cost is not a market price and is therefore not observable. One can of course use a real interest rate as an approximation, but the quality of this kind of approximation is hard to evaluate. It is probably quite poor, and likely to cause significant bias in estimation (see for example Clark-Freeman(1980)). There is, however, an alternative approach which blends naturally with a long-term viewpoint. In this approach, we assume profit margins to be constant (or even zero) in the long-term, so that the value of output is proportional to the total cost of production:

$$P.Y = cst.(W_u.L_u + W_s.L_s + P_e.E + V.K) \quad (4)$$

Using this accounting identity, we can establish a link between the real cost of capital and the real cost of other inputs. Taking the total differential of equation (4) expressed in logarithms, and solving it for the real cost of capital, we get:

$$s_k\Delta log\frac{V}{P} = -\{s_u\Delta log\frac{W_u}{P} + s_s\Delta log\frac{W_s}{P} + s_e\Delta log\frac{P_e}{P}\}$$
$$- \{s_u\Delta log\frac{L_u}{Y} + s_s\Delta log\frac{L_s}{Y} + s_e\Delta log\frac{E}{Y} + s_k\Delta log\frac{K}{Y}\} \quad (5)$$

where s_j is the share of factor j in total output value, and $\sum_j s_j = 1$. Substituting the expressions (3) for technical coefficients in (5), and using the homogeneity constraint, we get:

$$s_k\Delta log\frac{V}{P} = s_k.\gamma_k + s_u[\gamma_u - \Delta log\frac{W_u}{P}] + s_s[\gamma_s - \Delta log\frac{W_s}{P}] + s_e[\gamma_e - \Delta log\frac{P_e}{P}] \quad (6)$$

If we assume that all price elasticities in (3) are constant, we can reparameterise the coefficients, by using $\eta_{ij} \equiv \sigma_{ij}.s_j$, and setting the s_j's at their sample means $\bar{s}_j$. All the tests of hypothesis reported later(symmetry, etc ...), will therefore be based on the corresponding σ_{ij}'s. Substituting (6) (in levels) in (3), we get:

$$log\frac{L_u}{Y} = cst - \gamma_u.t + (\sigma_{uu} - \sigma_{uk})\bar{s}_u log\frac{W_u}{P} + (\sigma_{us} - \sigma_{uk})\bar{s}_s log\frac{W_s}{P} + (\sigma_{ue} - \sigma_{uk})\bar{s}_e log\frac{P_e}{P} \quad (7a)$$
$$log\frac{L_s}{Y} = cst - \gamma_s.t + (\sigma_{su} - \sigma_{sk})\bar{s}_u log\frac{W_u}{P} + (\sigma_{ss} - \sigma_{sk})\bar{s}_s log\frac{W_s}{P} + (\sigma_{se} - \sigma_{sk})\bar{s}_e log\frac{P_e}{P} \quad (7b)$$
$$log\frac{E}{Y} = cst - \gamma_e.t + (\sigma_{eu} - \sigma_{ek})\bar{s}_u log\frac{W_u}{P} + (\sigma_{es} - \sigma_{ek})\bar{s}_s log\frac{W_s}{P} + (\sigma_{ee} - \sigma_{ek})\bar{s}_e log\frac{P_e}{P} \quad (7c)$$
$$log\frac{K}{Y} = cst - \gamma_k.t + (\sigma_{ku} - \sigma_{kk})\bar{s}_u log\frac{W_u}{P} + (\sigma_{ks} - \sigma_{kk})\bar{s}_s log\frac{W_s}{P} + (\sigma_{ke} - \sigma_{kk})\bar{s}_e log\frac{P_e}{P} \quad (7d)$$

Note that the definition of the coefficients of technical progress γ_i is once again modified. Homogeneity implies that the sum of the coefficients in each equation $i \in \{u, s, e, k\}$ is now equal to $-\sigma_{ik}$. The coefficient of a term such as the real wage $log\frac{W_u}{P}$ for example, takes into account two different effects of a wage change: a direct effect σ_{uu}, and an indirect effect coming from prices σ_{uk}(see equation (4)). The latter reflects the movements in the cost of capital.

2.4 Output and value-added

The relations derived above are expressed in terms of the price and quantity of output P and Y. Available macroeconomic data however relate to value-added, i.e. P_v and Y_v. Ignoring this difference and its consequences can lead to misleading interpretation of the empirical results.

of energy have had little effect on skilled employment, whereas the increase in the real cost of energy since 1973 has had a beneficial effect on unskilled employment.

4- Comparing the long term evolution of supply and demand, we note that over the whole sample period, there is a 0.128% average rate of growth of the supply of unskilled labour, whereas demand grows at an average rate of -0.444%, thus a cumulated employment deficit of 15.44%. As far as skilled labour is concerned, the corresponding figures are 3.284% and 3.396%. This difference is probably negligible, due to estimation standard errors.

5- Comparing the observed and the calculated long term variation in employment, it appears that a non-negligible part of the losses in unskilled employment are still to materialise: an extra 4.37% loss of employment that would be added to the present (1989) deficit in actual employment of 11.1%.

6- What growth rate of wages would have been required, *ceteris paribus*, to maintain the same growth rate of supply and demand, for both categories of labour? The estimated price elasticities suggest that the growth of real unskilled wages should have been limited to 0.92% instead of the actual 2.56%, and for skilled wages, the growth rate should have been 1.16% instead of the actual 2.07%. This scenario therefore implies a gigantic drop in the real cost of labour: -44% for unskilled labour, and -25% for skilled labour, i.e. more or less a return to the end of the 1960's. This is a dramatic result indeed. Let us recall however, that the calculations are done for a given output level. It is a partial calculation and hence truncated; only direct effects are taken into account. Clearly, an exogenous wage moderation would alter the unemployment rate, and this initial change would in turn set in motion a whole series of other reactions (prices, wages and employment). To evaluate the total effect, one would need a complete model which contains not only equations relating to technical coefficients, but also to output, employment, prices and wages. As mentioned before (see footnote 9), when we take output effects into account, we could easily end up with elasticities which are 5 to 10 times larger in absolute value, thus reduce the necessary decrease in real wages by the same order of magnitude. Let us also recall that the rate of growth of average real wages in the United States has been of the order of 0.6% per annum since 1971[11] ...

7- Relative employment on the other hand, is totally unaffected by changes in output. We can

[11]Source: European Economy.

Variable	Period	Annual Growth Rate (in %): Observed Supply (1)	Observed Employment (2)	Long-term Employment (3)	Decomposition of long-term determinants of employment: Y (a)	Tech.Prog. and $\frac{Y}{P_v}$ (b)	Total Effect (a)+(b)	$\frac{W_u}{P_v}$ (c)	$\frac{W_s}{P_v}$ (d)	$\frac{P_e}{P_v}$ (e)	Total Effect (c) to (e)	Difference in growth rates of Supply and Demand (1)-(3)
L_u	1962-73	+0.241	+0.096	-0.290	(5.326)	-4.439	0.887	-0.939	-0.079	-0.259	-1.177	+0.531
	1973-89	+0.049	-0.542	-0.589	(2.433)	-2.576	-0.133	-0.503	-0.127	0.217	-0.456	+0.638
	1962-89	+0.128	-0.282	-0.444	(3.612)	-3.332	0.280	-0.640	-0.107	0.023	-0.724	+0.572
L_s	1962-73	+4.690	+4.637	+4.700	(5.326)	-0.249	5.077	-0.511	0.180	-0.043	-0.377	-0.010
	1973-89	+2.318	+2.173	+2.488	(2.433)	+0.052	2.485	-0.322	0.289	0.036	0.003	-0.170
	1962-89	+3.284	+3.177	+3.396	(3.612)	-0.072	3.540	-0.392	0.244	0.004	-0.114	-0.112
$\frac{L_u}{L_s}$	1962-73	-4.449	-4.541	-4.990	0	-4.190	-4.190	-0.325	-0.259	-0.216	-0.800	+0.541
	1973-89	-2.269	-2.715	-3.077	0	-2.628	-2.618	-0.181	-0.416	0.181	-0.459	+0.808
	1962-89	-3.156	-3.459	-3.840	0	-3.260	-3.260	-0.248	-0.351	0.019	-0.580	+0.684

Table 9:Long-term determinants of skilled and unskilled employment. Estimated coefficients under hypothesis (ii).

The simplest approach *a priori*, would be to reinterprete equations (7), using the following two assumptions:

(i) The ratio of value-added to output is a positive function of the relative price of energy:

$$log\frac{Y_v}{Y} = cst - technical \quad progress + \alpha log\frac{P_e}{P_v}$$

(ii) Movements in the price of output reflect the combined changes in the prices of value-added and of energy in such a way that we can use the following approximation:

$$logP = cst - technical \quad progress + (1 - s_e)logP_v + s_e logP_e$$

i.e. an approach similar to the one used for the cost of capital.

With these two assumptions[3] we can now replace Y and P with Y_v and P_v respectively. The input demand functions retain the same form, but the coefficient of the real price of energy now signifies something different: it becomes $(\sigma_{je}.s_e - \alpha, \forall j)$, and the structural parameters σ_{ij} are not identified.

We rather prefer using an alternative approach, which consists of first transforming the left-hand terms in equations (7), to obtain each factor's share S_i in total output; we then replace output price by price of value-added on the right-hand side, using assumption (ii) above. We thus obtain:

$$logS_u = cst - \gamma_u.t + [1 + (\sigma_{uu} - \sigma_{uk})\bar{s}_u]log\frac{W_u}{P_v} + (\sigma_{us} - \sigma_{uk})\bar{s}_s log\frac{W_s}{P_v} + (\sigma_{ue} - 1)\bar{s}_e log\frac{P_e}{P_v} \quad (8a)$$

$$logS_s = cst - \gamma_s.t + (\sigma_{su} - \sigma_{sk})\bar{s}_u log\frac{W_u}{P_v} + [1 + (\sigma_{ss} - \sigma_{sk})\bar{s}_s]log\frac{W_s}{P_v} + (\sigma_{se} - 1)\bar{s}_e log\frac{P_e}{P_v} \quad (8b)$$

$$logS_e = cst - \gamma_e.t + (\sigma_{eu} - \sigma_{ek})\bar{s}_u log\frac{W_u}{P_v} + (\sigma_{es} - \sigma_{ek})\bar{s}_s log\frac{W_s}{P_v} + [1 + (\sigma_{ee} - 1)\bar{s}_e]log\frac{P_e}{P_v} \quad (8c)$$

where $S_u = \frac{W_u.L_u}{P.Y}$ and so on for the other inputs[4]. The exact definition of the coefficients of technical progress is once again modified. This has no importance by itself, but the initial parameters γ_i are

[3]Note that these two assumptions are implicitly equivalent to postulating the existence of a production function for the value-added. This is not necessarily compatible with the basic formulation in terms of four inputs.

[4]Note the distinction between S_i (actual factor share), and $\bar{s}_i$ (mean factor share). Very similar formulae would be obtained if we used a translog cost function. The only differences are: (i) the log-linearisation of the left-hand term $dlogS_i = \frac{dS_i}{s_i}$; and (ii) the hypothesis of the long-term relation between average cost and price, which removes any difference between a factor's share in total costs and its share in the value of ouput, so that we have for example $dlogS_u = dlog\frac{L_u}{Y} + dlog\frac{W_u}{P}$

no longer identifiable, and we won't be able to use equation (6), to calculate an *ex-post* series for the cost of capital. Homogeneity implies that in each equation the sum of the coefficients is equal to $(1-s_e).(1-\sigma_{ik}), \forall i \in \{u,s,e\}$. Since these equations must satisfy the accounting identity $\sum_i S_i = 1$, the equation for capital is obtained by taking the difference.

We still need to calculate the shares in output S_i. We will start with the accounting identity:

$$P.Y \equiv P_v.Y_v + P_e.E$$

Writing in terms of the share of value-added in total output, we obtain an inverse relationship with the share of energy in total value-added ($S_{ev} \equiv \frac{P_e.E}{P_v.Y_v}$):

$$\frac{P_v.Y_v}{P.Y.} = \frac{1}{1+\frac{P_e.E}{P_v.Y_v}} = \frac{1}{1+S_{ev}}$$

This enables us to write each input's share in total output value as a function of its share in value-added, by dividing by $(1+S_{ev})$. For unskilled labour, for example, we have:

$$S_u = \frac{W_u.L_u}{P_v.Y_v}\frac{P_v.Y_v}{P.Y} = \frac{S_{uv}}{1+S_{ev}} \quad (9)$$

Similar results hold for the other factors, and $S_i = \frac{S_{iv}}{(1+S_{ev})}$, $\forall i$.

2.5 Substitution between skilled and unskilled labour

Subtracting equation (8b) from (8a), we obtain the ratio of unskilled to skilled labour demand in terms of real factor prices, that is:

$$log\frac{L_u}{L_s} = cst - (\gamma_u - \gamma_s).t + [(\sigma_{uu}-\sigma_{us})-(\sigma_{uk}-\sigma_{sk})]s_u log\frac{W_u}{P_v} \quad (10)$$
$$- [(\sigma_{ss}-\sigma_{us})-(\sigma_{sk}-\sigma_{uk})]s_s log\frac{W_s}{P_v} + (\sigma_{ue}-\sigma_{se})s_e log\frac{P_e}{P_v}$$

One simple but interesting special case is when capital and energy are separable from labour inputs. Here, the elasticity of substitution between unskilled labour and other inputs (capital and energy), is the same as for skilled labour (i.e. $\sigma_{uk}=\sigma_{sk}$ and $\sigma_{ue}=\sigma_{se}$). Given homogeneity ($\sum_j s_j.\sigma_{ij} = 0, \forall i$), it is easily shown that the absolute value of the coefficients of skilled and unskilled wages in the above equation are equal, so that the relative unskilled/skilled labour demand can be expressed as only a

labour, and of the price of energy. More precisely, we have:

$$\Delta log X_i = \Delta log Y - \left\{\gamma_i + \sigma_{ik}\left[s_u \Delta log\frac{W_u}{P_v} + s_s \Delta log\frac{W_s}{P_v}\right]\right\} \quad (16)$$
$$+ (\eta_{iu}+\eta_{is})\Delta log\frac{W_u}{P_v} - \eta_{is}\Delta log\frac{W_u}{W_s} + \eta_{ie}\Delta log\frac{P_e}{P_v}$$

for $i \in \{u,s,e\}$. The term inside the braces represents the combined effects of technical progress and the user cost of capital. We reproduce in table 9, the various elements of this decomposition for unskilled and skilled employment, as well as their relative employment (i.e. the difference between the first two). We have used the estimated values for price elasticities and rate of technical progress obtained under hypothesis (ii). The rate of growth of output is approximated by the rate of growth of value-added (this can bias the results). The calculation covers the whole period of 1962-1989, as well as two subperiods before and after 1973. We compare the calculated rates of growth of employment to the corresponding rates of growth of labour supply. To complete the available information, we have also added the rate of growth of observed employment in each category. It is possible to interpret the difference between observed employment and calculated employment as reflecting the difference between price effects already and not yet realised; this interpretation is particularly applicable when the period considered is rather short. We can draw the following conclusions from table 9:

1- Contrary to the empirical evidence for skilled labour, the effects of the growth of output on unskilled employment are almost totally cancelled out by the negative impact of technical progress and the user cost of capital. This is particularly the case over the most recent period (1973-89), where the beneficial effect of the slowdown in technical progress is dominated by the negative effect of the overall slowdown in economic activity. After 1973, a 2.5% growth rate in output is the minimum necessary to stabilise unskilled employment *at unchanged factor costs*.

2- To these effects of technical progress and user cost of capital are added those of the upward trend in all wages, as well as the increase in the relative wage of the unskilled. The upward trend in wages has a negative effect on both types of employment, but unskilled labour is affected most.

3- Energy prices have little effect over the whole sample. The decrease of the years 1962-73 are compensated by the increase thereafter. On the other hand, we note that the changes in the real price with the relative decline in the secondary sector (see figure 5). As far as demand for skilled labour is concerned, technical progress has no significant effect either before or after 1974, under the more likely hypothesis (ii). We observe no significant break in productivity gains related to the use of energy. These values imply an increasing trend in the use of capital, given output and factor costs.

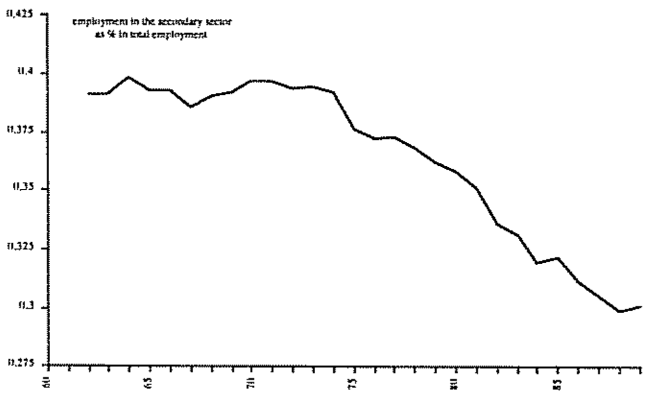

Figure 5:Proportion out of total employment of employment in secondary sector (source:employment surveys)

(v) <u>The long term determinants of observed employment</u>

We can calculate the long term effects of technical progress and of the observed changes in input prices over the period 1962 to 1989, based on our estimates of price elasticities and the coefficients of technical progress. We will start from the following definitions of the share S_i and real price $\frac{P_i}{P}$ of factor X_i:

$$\Delta log S_i = \Delta log X_i - \Delta log Y + \Delta log \frac{P_i}{P} \qquad (14)$$

$$\Delta log \frac{P_i}{P} \equiv \Delta log \frac{P_i}{P_v} - \Delta log \frac{P}{P_v}, \qquad (15)$$
$$\cong \Delta log \frac{P_i}{P_v} - s_e \Delta log \frac{P_e}{P_v}$$

Together with equations (8), we can obtain the path of the employment of factor X_i in terms of the rate of growth of output Y, of technical progress and the user cost of capital (the latter two effects cannot be separated[10]), of the upward trend in wages, of the increase in the relative cost of unskilled

[10]See our previous remark, section 2

function of relative wages[5]:

$$log \frac{L_u}{L_s} = cst - (\gamma_u - \gamma_s).t - \sigma log \frac{W_u}{W_s}. \qquad (10')$$
$$with \quad \sigma = (\sigma_{us} - \sigma_{uu}).s_u = (\sigma_{us} - \sigma_{ss}).s_s$$

where the elasticity of substitution σ is constant. Note the close relationship between the direct and cross elasticities of substitution implied by the definition of σ:

$$\sigma_{ss} = \sigma_{uu} + \left(\frac{s_u}{s_s} - 1\right)(\sigma_{uu} - \sigma_{us}) \qquad (11)$$

Note that $\sigma \neq \sigma_{us}$ in general, and that σ_{us} can *a priori* be positive or negative. We get the *CES* formulation (with $\sigma = \sigma_{us} > 0$) only in two situations:(i) when the cross partial elasticities of substitution are all equal ($\sigma_{us} = \sigma_{ue} = \sigma_{uk} = \sigma$); (ii) when there are only two inputs ($s_e = s_k = 0$).

We can draw interesting conclusions by comparing equations (10) and (10'). When the partial elasticities of substitution between skilled labour and energy and/or capital are not identical to those for unskilled labour (i.e. $\sigma_{ue} \neq \sigma_{se}$ and/or $\sigma_{uk} \neq \sigma_{sk}$), the same change in relative skilled/unskilled wages will have different consequences on the relative skilled/unskilled labour demand, according to which category of wages is the source of the change. Similarly, a general increase in wage levels (with relative wages unchanged) will have different effects on skilled and unskilled labour.

Finally, if equation (10') is not rejected by the data, it is of particular interest for the following reason. It can be obtained directly by substracting (3b) from (3a), with the added assumption that $\sigma_{ue} = \sigma_{se}$ and $\sigma_{uk} = \sigma_{sk}$. It is neither necessary to use the various approximations for evaluating the cost of capital, nor to use the expressions in terms of value added in place of expressions in terms of output. Hence, the formulation (10)-(10') is more robust than (8a)-(8b).

[5]In our formulation, homogeneity implies:

$$s_u.\sigma_{uu} + s_s.\sigma_{us} = -(s_e.\sigma_{ue} + s_k.\sigma_{uk}),$$
$$s_u.\sigma_{su} + s_s.\sigma_{ss} = -(s_e.\sigma_{se} + s_k.\sigma_{sk}) = -(s_e.\sigma_{ue} + s_k.\sigma_{uk}),$$

if $\sigma_{ue} = \sigma_{se}$ and $\sigma_{uk} = \sigma_{sk}$. Hence, the coefficients of real unskilled and skilled wages can be written respectively as:

$$(\sigma_{uu} - \sigma_{us}).s_u = -(s_e.\sigma_{ue} + s_k.\sigma_{uk}) - (s_u + s_s)\sigma_{us} = -\sigma,$$
$$(\sigma_{ss} - \sigma_{us}).s_s = -(s_e.\sigma_{ue} + s_k.\sigma_{uk}) - (s_u + s_s)\sigma_{us} = -\sigma.$$

3. THE DATA

We will try to estimate the equations (8) and (10)-(10'), assuming that the coefficients are constant. We use French data covering the period 1962-1989. The data on skilled and unskilled (un)employment are taken from the employment surveys of the INSEE (*Enquêtes sur l'emploi*), and those on skilled and unskilled wage rates from the "Annual Declarations of Social Statistics" (DADS, *Déclarations Annuelles de Données Sociales*), also published by the INSEE. The distinction between skilled and unskilled labour (levels of L_u and L_s) is based on professional occupations. Skilled workers are basically professional and managerial workers (including foremen and technicians); unskilled workers are other categories, mostly employees and blue-collar workers[6] The wage data in the annual declarations are on net wages; to transform to labour costs, we have applied for each year the corresponding rates of social security contributions applicable to non-manual and manual workers respectively.

3.1 Historical observations

Figures 1 and 2 show the evolution of employment per unit of output and of the real costs for both skilled and unskilled labour. We observe a downward trend in unskilled employment (relative to GDP), with a clear break in the trend in 1974. Skilled employment relative to GDP on the other hand, remains rather stable; if there exists a downward trend, it is not very evident. A transitory decrease is observed in the latter series, from 1976 to 1982. This however, is more likely the result of a statistical problem related to the evaluation of employment and active population amongst intermediary professionals (see Sneessens(1993)). The relative cost of unskilled labour rises almost continuously between 1968 and 1986. The increase over this period is of the order of 25%; over the same period, the decrease in employment of unskilled workers relative to that of skilled workers is of the order of 67% ($\Delta logL_u = \Delta logL_s - 0.67$). These raw figures suggest an elasticity of substitution larger than 2, which is relatively high. However, one also needs to take into account the effects of technical progress, and of the real price of energy, to correctly evaluate how much of the decrease in unskilled employment

[6]Details are given in chapters 1 and 2 of Sneessens(1993).

5- The own price elasticity of *the demand for energy* is relatively low in absolute value, about 0.15. On the other hand, the cross-elasticity with respect to unskilled wages appears more significant; it is about 0.50 in the case of (ii).

6- The own price elasticity of *the demand for capital* is relatively low, about 0.2 to 0.3 in absolute value[9]. An overall increase in the wage levels has a relatively important positive effect; the sum of the corresponding two cross elasticities is in the region of 0.40, irrespective of the hypothesis ((ii) or (iii)). The elasticity with respect to the price of energy is negative, about -0.15, implying complementarity of the two factors.

(iv) Effects of technical progress.

Rate of Exogenous Technical Progress	Hypothesis (ii) Pre-1974	Hypothesis (ii) (change) Post-1974	Hypothesis (iii) Pre-1974	Hypothesis (iii) (change) Post-1974
γ_u	+3.31% (0.45)	−1.36% (0.35)	+3.10% (0.49)	−1.32% (0.38)
γ_s	−0.88% ns (0.49)	+0.20% ns (0.23)	−1.69% (0.46)	+0.58% (0.22)
γ_e	+4.34% (0.90)	+0.31% ns (0.55)	+3.74% (0.85)	+0.61% ns (0.54)

ns=not significantly different from zero.

Table 8: Rates of exogenous technical progress $\gamma_i(\times 100)$ associated with the demand for each factor; with break in 1974.

Table 8 shows the rates of exogenous technical progress γ_i in percentages. Both hypotheses (ii) and (iii) are considered. The table shows that technical progress is systematically unfavourable to unskilled labour, irrespective of the hypothesis retained. Nevertheless, we do not observe an accelerating deterioration in unskilled employment. On the contrary, after 1974, there is a significant drop (but not a total halt) in the erosion of demand for unskilled labour -for a given level of output- due to technical progress. It is interesting to note that this slowdown in productivity gains coincides

[9]With a Cobb-Douglas production function with two factors (labour and capital) for instance, one would have an elasticity of about 0.80 in absolute value, for a given level of output.

with respect to wages are significantly different from zero only under hypothesis (ii). In this case they are of the order of 0.25.

$$\begin{pmatrix} u & s & e & k \\ -0.47 & 0.22 & 0.12 & 0.14 \\ (0.08) & (0.08) & (0.02) & \\ 0.35 & -0.50 & 0.02 & 0.14 \\ (0.12) & & (0.02) & \\ 0.47 & 0.05 & -0.15 & -0.37 \\ (0.09) & (0.05) & (0.04) & \\ 0.22 & 0.14 & -0.15 & -0.20 \end{pmatrix} \qquad \begin{pmatrix} u & s & e & k \\ -0.29 & 0.04 & 0.07 & 0.18 \\ (0.08) & (0.08) & (0.02) & \\ 0.07 & -0.32 & 0.07 & 0.18 \\ (0.12) & & (0.02) & \\ 0.28 & 0.17 & -0.11 & -0.34 \\ (0.09) & (0.05) & (0.04) & \\ 0.28 & 0.18 & -0.14 & -0.33 \end{pmatrix}$$

(ii) symmetry + homogeneity with $\sigma_{uk} = \sigma_{sk}$

(iii) symmetry+ homogeneity with $\sigma_{uk} = \sigma_{sk}$ and $\sigma_{ue} = \sigma_{se}$

(standard errors given in parentheses)

Table 7:Estimates of direct and cross price-elasticities , at given output level.

2- From these elasticities, we can calculate *the elasticity of total employment with respect to wages* (i.e. an overall increase in wages, without any change in relative wages and output). In the case of hypothesis (ii), a 10% increase in all wages would reduce unskilled employment by 2.5% and skilled employment by 1.5%; thus, with given prices for energy and capital, the negative effect would be sharper for unskilled rather than skilled labour. Under hypothesis (iii), an overall 10% increase in wages would cause exactly identical effects both for skilled and unskilled labour; it would reduce total employment by 2.5% without modifying relative employment.

3- *The elasticity of the relative employment of the unskilled* with respect to their relative wages varies a lot according to the hypothesis under which it is estimated. With hypothesis (ii) which is the most likely scenario (i.e. $\sigma_{ue} \neq \sigma_{se}$), we obtain potentially different effects on relative employment, according to whether it is unskilled wages that rise or skilled wages that fall. But the difference is empirically rather small: the elasticity is -0.82 in the first instance and -0.72 in the second. On the other hand, this elasticity becomes much smaller under hypothesis (iii), that is when the extra restriction of $\sigma_{ue} = \sigma_{se}$ is added to hypothesis (ii); in this case the elasticity is reduced to -0.36.

4- *The elasticity of employment with respect to the price of energy or capital* is positive and relatively small (again for a given level of output!) both for skilled and unskilled workers; it is of the order of 0.00 to 0.10 for energy, and 0.15 for capital.

could directly have resulted from the increase in realtive costs.

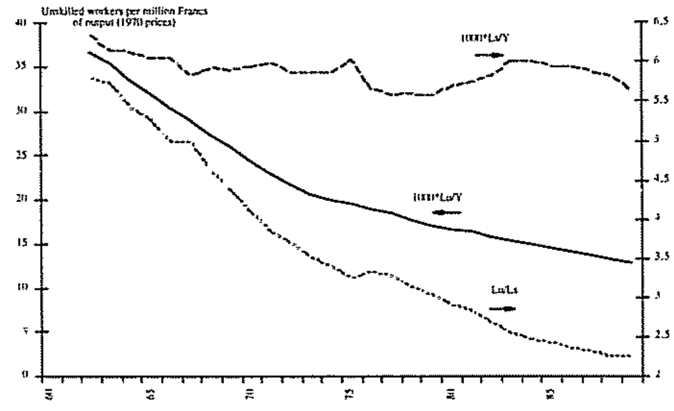

Figure 1: Profile of skilled and unskilled labour (per unit of output).

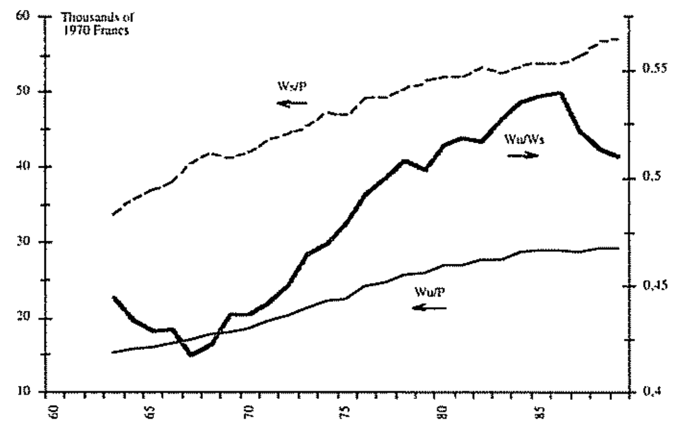

Figure 2: Profile of the real wage costs of skilled and unskilled labour .

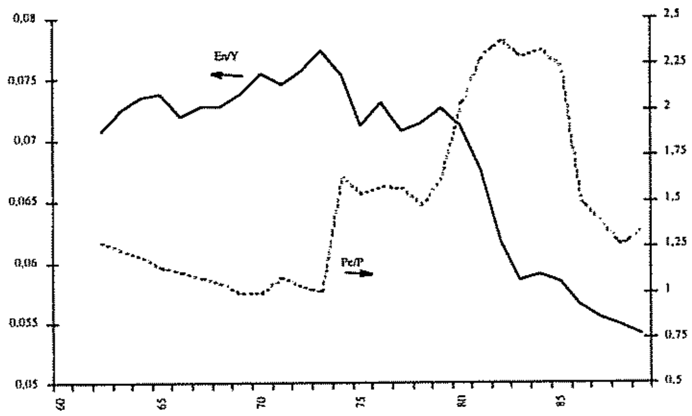

Figure 3:Profile of the real price of energy, and energy over value-added.

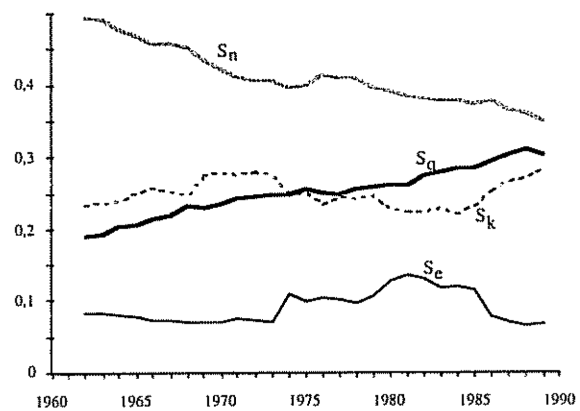

Figure 4:Profile of factor shares in total output (see equation (6)).

u	s	e	k
−3.00	3.27	2.09	0.69
(1.80)	(2.14)	(1.38)	
0.91	−2.05	0.19	0.51
(0.33)	(0.37)	(0.23)	
3.27	−3.13	−2.14	−1.26
(0.75)	(1.12)	(0.43)	
0.69	0.51	−1.26	−1.00

(0) no restrictions(but homogeneity)

u	s	e	k
−1.51	1.05	1.40	0.80
(0.33)	(0.34)	(0.30)	
	−2.05	0.02	0.36
	(0.38)	(0.24)	
		−1.62	−1.62
		(0.40)	
			−1.00

(i) symmetry + homogeneity

u	s	e	k
−1.18	0.88	1.17	0.54
(0.19)	(0.31)	(0.24)	
	−2.02	0.19	0.54
		(0.21)	
		−1.46	−1.48
		(0.36)	
			−0.81

(ii) symmetry + homogeneity

with $\sigma_{uk} = \sigma_{sk}$

u	s	e	k
−0.73	0.18	0.70	0.71
(0.12)	(0.22)	(0.13)	
	−1.27	0.70	0.71
		−1.13	−1.36
		(0.33)	
			−1.30

(iii) symmetry+ homogeneity

with $\sigma_{uk} = \sigma_{sk}$ and $\sigma_{ue} = \sigma_{se}$

(standard errors given in parentheses)

Table 6:Estimates of partial elasticities of substitution, using the error correction formulation.

— Energy is also a substitute for both skilled and unskilled labour; There is however a difference between the partial elasticities of substitution: it is small (zero?) for skilled labour and high (greater than 1) for unskilled labour.

— Energy and capital are strong complements, with a partial elasticity of substitution around -1.50.

(iii) Estimated values of price elasticities (for a given output level)

Given the partial elasticities of substitution (direct and cross), we can derive factor price elasticities for a given level of output. All that is required is to multiply the former by the corresponding average factor shares. We present in table 7 the results obtained under the hypotheses (ii) and (iii). It is worth remembering that the matrix of price elasticities is not in general symmetric. Note the following results:

1- *Direct elasticities of employment to wages* are very close for both skilled and unskilled labour; the estimated value varies from -0.50 under hypothesis (ii) (which is the more likely situation) to -0.30 under hypothesis (iii). It must be stressed again that these are elasticities for a given level of output; when output effects are taken into account, total elasticities can be much higher. *The cross elaticities*

Restrictions	Log of the Likelihood	Likelihood Ratio Tests	
		Sequential tests	Cumulated tests
(0) None	279.773	-	-
(i) Symmetry	274.409	$\chi_3^2 = 10.73(0.013)$	-
(ii) + Homogeneity with $\sigma_{uk} = \sigma_{sk}$	273.526	$\chi_2^2 = 1.77(0.413)$	$\chi_5^2 = 12.49(0.028)$
(ii) + Homogeneity with $\sigma_{ue} = \sigma_{se}$	269.882	$\chi_1^2 = 7.29(0.0074)$	$\chi_6^2 = 19.78(0.004)$

Table 5:Testing inter-equation restrictions. Significance levels in parentheses.

Table 5 shows that hypothesis (i) (symmetry in mean values) is rejected at the 5% significance level, but accepted at 1%. Hypothesis (ii) is easily accepted. Hypothesis (iii) is rejected even at the 1% level; when we test the joint significance of hypotheses (i)-(iii), they have to be rejected jointly as well.

(ii)Estimated values of partial elasticities.

The matrices below reproduce the estimated values of the partial elasticities of substitution in the different situations. Standard errors are given in parentheses. All direct elasticities are negative, as required by theory. Looking carefully at the unrestricted estimates, we find that the off-diagonal elements have the same sign as their symmetric counterpart, and are even of the same order when allowing for their standard errors. The only exceptions are the coefficients σ_{se} and σ_{es}. The former is positive with a relatively high standard error, whereas the latter is negative and significantly different from zero. This explains why the hypothesis of symmetry is only accepted only at 1%; it also explains the difficulty in accepting hypothesis (iii). Let us also note the following results:

— Skilled and unskilled labour are substitutes; the value of the partial elasticity of substitution varies a great deal with the restrictions imposed; it goes from 0.88 under hypothesis (ii) to0.18 under hypothesis (iii).

— Capital is a substitute for both skilled and unskilled labour; the value of the partial elasticity of substitution is relatively stable, about 0.60 for both categories of labour.

Figure 3 looks at energy levels and prices. It shows clearly the negative impact of energy prices on the quantities used per unit of ouput, except after the price fall of 1985. Figure 4 shows the changes in factor shares in total output (see equation (9)).

3.2 Basic characteristics of the series.

In order to determine the appropriate dynamic specification of the model, it is important to establish whether or not the series are stationary. Table 1 presents the results of the usual *ADF* augmented Dickey-Fuller tests of unit roots for the various series that appear in equations (7)-(8) and (10), as well as for *DUL*, the degree of utilisation of labour, which we will use later. We have retained lagged values of the first differences of each series whenever the corresponding t-statistic was greater than 2. All regressions used to test the hypothesis of a unit root include a constant term and a trend, except in the case of energy prices where trend was not included. For regressions on the shares of unskilled and skilled labour, energy and for wages, a break in the trend is also used in 1973-74; moreover, regressions on the share of skilled labour include an auxiliary 0-1 variable, taking the value of 1 from 1976 to 1981 in order to allow for the statistical irregularity mentioned earlier. We have used the asymptotic critical values given by Perron(1989)[7] When testing for an order of integration equal to 2, one needs to keep in mind that the trend becomes a constant, and the trend break becomes an auxiliary 0-1 variable. Perron doesnot give the critical values when the model contains an auxiliary varibale and no trend. Failing that, we will use the critical values for the model with no trend and no auxiliary variable. This favors the rejection of the $I(2)$ hypothesis.

Table 1 shows that the null hypothesis of a unit root in *DUL* is rejected, and it is therefore treated as stationary. But for all the other variables, the null hypothesis of a unit root cannot be rejected. The hypothesis of a unit root in the first difference of the series (implying that they are $I(2)$) is clearly rejected at the 5% significance level for all series except for unskilled real wages. We will nevertheless treat this variable also as $I(1)$, given that the *ADF* test has low power especially with such a small sample (the probability of rejecting $I(2)$ when $I(1)$ is true is relatively small).

[7]Perron's approach is slightly different, in that the auxiliary variable he uses retains the value of 1 until the end of the sample. We don't expect this slight modification to change the results of the tests.

Variable X	Form of equation in levels	TEST I(1) Dependent variable: $\Delta logX$			TEST I(2) Dependent variable: $\Delta^2 logX$		
	c=const t=trend ts=tr. shift du=dumm	number of lags	t-statistic coef. of $logX_{-1}$	Critical value at 5%	number of lags	t-statistic coef. of $\Delta logX_{-1}$	Critical value at 5%
$\frac{L_u}{Y_v}$	c,t,ts	0	-3.44	-3.96^p	0	-6.09^*	(-2.97^k)
$\frac{L_s}{Y_v}$	c,t,ts,du	0	-2.81	-4.24^p	0	-6.23^*	(-2.97^k)
$\frac{E}{Y_v}$	c,t,ts	0	-2.30	-3.96^p	0	-4.02^*	(-2.97^k)
$S_u = \frac{a_u W_u}{P}$	c,t,ts	0	-2.46	-3.96^p	0	-4.27^*	(-2.97^k)
$S_s = \frac{a_s W_s}{P}$	c,t,ts,du	0	-4.08	-4.24^p	0	-7.24^*	(-2.97^k)
$S_e = \frac{b P_e}{P}$	c,t,ts	0	-2.55	-3.96^p	0	-5.84^*	(-2.97^k)
$\frac{W_u}{P_v}$	c,t,ts	1	-1.37	-3.96^p	1	-2.35	(-2.97^k)
$\frac{W_s}{P_v}$	c,t,ts	0	-3.19	-3.96^p	0	-6.01^*	(-2.97^k)
$\frac{P_e}{P_v}$	c	0	-1.26	-2.97^k	0	-4.48^*	(-1.95^k)
$\frac{L_u}{L_s}$	c,t,ts,du	0	-2.81	-4.24^p	0	-6.18^*	(-2.97^k)
$\frac{W_u}{W_s}$	c,t,ts	0	-0.31	-3.96^p	0	-3.26^*	(-2.97^k)
DUL	c	0	-3.16^*	(-2.97^k)			

p= Perron(1989), asymptotic value for $\lambda = 0.5$;
k=MacKinnon(1991), correction made for small sample;
* indicates rejection of the null hypothesis at 5%;

Table 1: ADF tests for the presence of a unit root.

4. EMPIRICAL RESULTS

Our main aim is to estimate price elaticities (the η_{ij}'s) and direct and cross partial elasticities of substitution (the σ_{ij}'s) especially those that relate to substitution between skilled and unskilled labour. We will estimate a system of three equations (the fourth being redundant), with a dynamic formulation of the error correction type. We will apply Johansen's maximum likelihood method

4.2 Modelling the structural equations: Error Correction

Our interest is mainly focused on substitution between skilled and unskilled labour, that is the first two equations in (8). It is nevertheless useful to also estimate the equation relating to energy. In particular, if as suggested by theory, the equations satisfy the condition of symmetry (i.e. $\sigma_{ij} = \sigma_{ji}$), then the coefficients in the employment equations should be estimated more precisely.

(i)<u>Inter-equation restrictions.</u>

We estimated these equations using the Least Squares option in the programme TSP, using instruments for the wage variables, and allowing for contemporaneous correlations between the residuals ($SURE$). Table 5 shows how the likelihood function progressed as we successively imposed the following restrictions:

(0) no restrictions (except for homogeneity);

(i) symmetry ($\sigma_{ij} = \sigma_{ji}$; three restrictions in all);

(ii) equality of the partial elasticity of substitution between unskilled labour and capital and that between skilled labour and capital (i.e. $\sigma_{uk} = \sigma_{sk}$); if we also assume homogeneity, this restriction implies in addition the following restriction on the direct elasticity of skilled labour: that $\sigma_{ss} = \sigma_{us} - (1 - \frac{s_u}{s_s}) + \frac{s_e}{s_s}(\sigma_{ue} - \sigma_{se})$). Therefore two extra restrictions;

(iii) equality of the partial elasticity of substitution between unskilled labour and energy and that between skilled labour and energy (i.e. one additional restriction $\sigma_{ue} = \sigma_{se}$).

To enable us to test these restrictions, the coefficients of the regressors in (8) were rewritten in terms of elasticities of substitution. We used the following average factor shares: s_u=0.40, s_s=0.25, s_e= 0.10. We are therefore estimating the mean value of the elasticities of substitution. The actual values are functions of factor shares. Similarly, the various tests reported below (especially symmetry) refer to the mean values.

We still have three cointegrating relations, and unskilled labour (per unit of value-added) now has to be considered as endogenous at the 5% level, conditional on the exogeneity of real energy prices (see table 4). Given the similarities between the two formulations, we will consider the three cointegration relations thus obtained, as corresponding to the three equations in the system (8).

Variable	Value of the χ^2_3 statistic and the significance level	
	General model	P_e/P_v exogenous
L_u/Y	6.81 (0.08)	8.28*(0.04)
L_s/Y	18.53*(0.00)	18.63*(0.00)
E/Y	13.05*(0.00)	11.58*(0.01)
W_u/P_v	10.11*(0.02)	10.07*(0.02)
W_s/P_v	11.77*(0.01)	18.79*(0.00)
P_e/P_v	6.74 (0.08)	

*indicates rejection of that hypothesis at 5%.

Table 4:Testing weak exogeneity for long-term parameters with the alternative formulation.

We now have to interpret the estimated coefficients in the matrix β. This task is unfortunately not so simple, given that the estimated coefficients represent a linear combination of the structural parameters. If we accept this system of equations as indeed a system of demand for factors (i.e. equations (8)), we could obtain the underlying structural coefficients by solving the system of the three cointegrating relations $\beta' Z$ for the three variables of interest: S_u, S_s and S_e. However, we found that the values of coefficients, derived in this way, are unrealistic, with abnormally large rates of technical progress. This problem may be due to the difficulties and simplifications we already mentioned; it probably also reflects the sensitivity of the Johansen procedure to the choice of the maximal lag, on which all subsequent tests are conditioned.

We next proceed to estimating equations (8), using an error correction formulation, keeping in mind some of the results of the cointegration analysis. We will be interested in testing inter-equation restrictions (symmetry in particular).

for the system (see Johansen (1988,1991)), and investigate the existence of long-run cointegrating relationships in this set of $I(1)$ variables. This method of testing for cointegration is preferable, as it treats all the variables simultaneously and symmetrically. But it does have certain limitations: our sample is very small and little is known about the small sample behaviour of this procedure. We can, at the same time, check if any of the variables in the system can be treated as weakly exogenous, and therefore not be modelled. Thereafter, we will estimate the model and impose and test restrictions.

4.1 Long-run relations

When dealing with $I(1)$ variables in dynamic systems, the maximum likelihood procedure proposed by Johansen is the most appropriate method of testing for the existence of cointegrating relations, or economic long-run equilibria, by estimating the VAR. In this method, all the variables in the system are treated symmetrically as endogenous. Thus, equation (8) in its dynamic form, will comprise six equations and six endogenous variables. We will also introduce the possibility of a break in 1974, in the trend representing exogenous technical progress, as suggested by the previous figures and tests. We will estimate the following dynamic model:

$$\Delta log Z_t = \sum_{i=1}^{n} \delta_i \Delta log \tilde{Z}_{t-i} + \Pi log \tilde{Z}_{t-1} + \Psi D_t + \epsilon_t \qquad (12)$$

where $Z = (S_u, S_s, S_e, \frac{W_u}{P_v}, \frac{W_s}{P_v}, \frac{P_e}{P_v})$ is the vector of all the $I(1)$ variables in the system;

$\tilde{Z}$ is the same vector to which are added a trend and a "trend shift" variable $TS74$;

D is the vector of all the $I(0)$ or non-stochastic variables (constant, $logDUL$, $logDUC$, DUM_{76} and their first differences);

Π, δ, and Ψ are the parameters corresponding to these variables;

ϵ is a vector of stationary random errors with zero mean.

Once equation (12) has been estimated, Johansen's method then tests for the number of independent cointegration relations (i.e. long-run relations) that may exist among the variables of interest. One can also test for weak exogeneity of the regressors, which can prove useful when interpreting the empirical results. The advantage of this approach is that no restrictions are imposed *a priori*; on the other hand, it has the disadvantage that a great number of parameters need to be estimated (Π is a

6x8 matrix, while we only have 6x27 observations). Given our small sample, we are forced to drop all lagged values of the left hand variables and impose $\delta_i = 0, \forall i$. This restriction drastically limits dynamic adjustments, and may lead to biased estimates of the other parameters.

The test of the number of cointegrating relations is a test of the rank of the matrix Π. We have used the program CATS in RATS to obtain the results in table 2 (see Johansen-Juselius(1990)). Both the maximal eigenvalue test statistic and the trace test statistic are reported. Based on the latter, we can reject the hypothesis that the rank of Π is 2 against the alternative that it is greater than 2, but we have to accept that it is 3 against the alternative that it is greater than 3[8] We conclude therefore that there exist three independent cointegrating relations, so that Π can be written as:

$$\Pi_{6\times 8} = \alpha_{6\times 3}\beta^{'}_{8\times 3} \qquad (13)$$

where β is an 8×3 matrix of the parameters in the three cointegrating relations $\beta^{'} log\tilde{Z}_t$ and α is a 6×3 matrix of the dynamic coefficients of the error correction terms $\beta^{'} log\tilde{Z}_{t-1}$ in the short run variations of the endogenous variables $\Delta log Z_t$.

Eigenvalues of the matrix Π	Testing the rank of the matrix Π				
	Hypothesis	λ-max		Trace	
Π	H_0	Statistic	Critical value 5%[1]	Statistic	Critical value 5%[1]
.932	Rank=0	72.48*	43.97	211.15*	114.90
.923	1	69.10*	37.52	138.67*	87.31
.673	2	30.16	31.46	69.57*	62.99
.545	3	21.28	25.54	39.41	42.44
.396	4	13.63	18.96	18.13	25.32
.154	5	4.50	12.25	4.50	12.25

1 Critical values from Osterwald-Lenum (1992).

Table 2:Testing the rank of matrix Π. (* indicates rejection of H_0 at 5%)

[8]This holds even when making corrections for a small sample

Testing for exogeneity of the variables is based on testing the significance of α. A variable in the vector $logZ$ is weakly exogenous as far as the estimation of the long-run parameters are concerned, if its marginal distribution is uninfluenced by the cointegrating relations. This means that the row in α corresponding to that variable is not significantly different from zero. Johansen and Juselius (1990) propose the maximum likelihood test. Table 3 summarises our results for these tests. The null hypothesis in each case is $H_0 : \alpha_{j.} = 0$. If we take the 5% significance level, the null hypothesis is rejected for S_s as well as both categories of real wages, but is accepted for the other three variables. It is surprising to get this result for S_u and S_e. If we treat real energy prices as exogenous, we obtain the results in the right hand column. We can now reject exogeneity of S_e at the 5% significance level, but S_u still appears exogenous.

Variable	Value of the χ^2_3 statistic and the significance level	
	General model	P_e/P_v exogenous
S_u	3.48 (0.32)	4.19 (0.24)
S_s	46.67*(0.00)	46.53*(0.00)
S_e	5.64 (0.13)	12.46*(0.01)
W_u/P_v	9.24*(0.03)	9.00*(0.03)
W_s/P_v	12.07*(0.01)	20.69*(0.00)
P_e/P_v	6.96 (0.07)	

*indicates rejection of that hypothesis at 5%.

Table 3:Testing weak exogeneity for long-term parameters .

These results must of course be treated with caution. We have kept the dynamic structure as simple as possible, so as to retain a larger degree of freedom. It is clear for instance, that an increase in wages has,*ceteris paribus* an immediate and accountable effect on the share of wages in the value of output. Hence, imposing the impact coefficient to zero ($\delta_i = 0$) is clearly inappropriate and likely to cause bias in the results. We therefore repeated the exercise (estimation and testing) with the alternative formulation mentioned in section 2, where the endogenous variables are not the shares of factors, but the quantity of each factor per unit of value-added (i.e. $Z = \left(\frac{L_u}{Y_v}, \frac{L_s}{Y_v}, \frac{E}{Y_v}, \frac{W_u}{P_v}, \frac{W_s}{P_v}, \frac{P_e}{P_v}\right)$).