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Labour-Use Efficiency in Tunisian Manufacturing Industries

A Flexible Adjustment Model

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Abstract

This paper investigates the process of adjustment in employment. A dynamic model is applied to a panel of six Tunisian manufacturing industries observed over the period 1971–96. The adjustment process is industry and time specific. The adjustment parameter is specified in terms of factors affecting the speed of adjustment. Industries are assumed to adjust their labour inputs towards a desired level of labour-use. A translog labour requirement function is specified in terms of observable variables and is used to model the desired level of labour-use. The labour requirement is specified to be function of wages, output, quasi-fixed capital stock and technology. The empirical results show that in the long-run, employment demand responds greatest to value-added, followed by capital stock changes, and least by wages. The speed of adjustment in employment and the degree of labour-use efficiency show large variations among the sectors and over time.

Keywords: dynamics, employment, labour-use efficiency, panel data, Tunisia, speed of adjustment, technical change

JEL classification: C23, E24, J23, L60

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1 Introduction

Understanding the way policy changes affect labour demand over time requires a model that incorporates the dynamic adjustment process of employment. Models that include dynamic adjustments are certainly not new in the literature. But, it is a role rather than an exception that the speed of adjustment is modelled as a constant parameter assuming the same speed across industries and over time. This is the case even with panel data models where other variables vary with time and units of analysis. In this paper, it is based on a model of employment demand that incorporates a speed of adjustment which is time and industry variant, i.e. a flexible adjustment model. The model is applied to a panel of six Tunisian manufacturing industries observed during 1971–96. The Tunisian manufacturing sector makes a good case study since it has evolved through periods of labour market regulations as well as trade liberalization.

The Tunisian manufacturing sector has been a subject to various shocks and policy related changes. During the import substitution period (1971–85) the manufacturing evolved through a highly regulated economic environment. These controls had a direct or indirect bearing on how the manufacturing sector used resources. In the labour market, for example, the government introduced minimum wages. Employers were prohibited to dismiss workers. Dismissal of workers should only take place following administrative approval by the government employment authorities. Reductions in the labour force proved to be a cumbersome and a costly process. Other than labour market controls, there were practices of price, foreign currency and investment controls as well.[1]

Parallel to the structural adjustment program of 1986, its accession to the General Agreement on Terms of Trade/World Trade Organization (GATT/WTO) and its membership in the Maghreb Customs Union, on 17 July 1995, Tunisia become the first country in the Middle East and North Africa to sign a free-trade agreement with the European Union. One of the main aims of this liberalization programme was to encourage growth and efficiency in the manufacturing sector. In the labour market wages and employment conditions were determined through collective bargaining. At the outset of the program employers took the opportunity to adjust their employment levels in response to, *inter alia*, changing costs. Between 1986 and 1996 the manufacturing industries as a whole increased their labour force from 413,050 to 553,000 – a 33 per cent growth.[2]

It is against the background of policy changes outlined above that a study of the adjustment process of factor input utilization at different manufacturing industries becomes essential. Industries undertake adjustments with the objective to improve on the usage of resources and profitability. Labour is one essential resource in the production process and the speed of adjustment of employment in manufacturing

1 For a selection of previous studies of the Tunisian manufacturing industry and its evolution over time see Nabli (1981), Morrison (1987), Abdennadher et al. (1994), Sekkat (1996) and Boughzala (1997).

2 The growth at industry levels were as follows; food (32 per cent), textiles, clothing and footwear (26 per cent), chemicals (28 per cent), construction material and ceramics (38 per cent), mechanical electric (51 per cent), and other manufacturing (45 per cent).

industries is crucial for their performance and survival. Thus, labour-use efficiency is an important integral part of the adjustment process worth considering. Here, by labour-use efficiency we refer to the minimum amount of labour that is technically necessary to produce a given level of output. Labour-use inefficiency therefore implies that more labour is used than is technically necessary.[3]

The literature on dynamic labour demand is extensive. Detailed summaries are found in Hazledine (1981) and Hamermesh (1993). Similarly, literature on dynamic adjustment in panel data framework is extensive (e.g. Arrelano and Bond 1991, Baltagi and Griffin 1997, Judson and Owen 1999, and Nerlove 2000). However, incorporating a flexible adjustment parameter (as opposed to a restricted constant one) and integrating this with labour-use efficiency is a recent development. Kumbhakar et al. (2002) used a similar model to analyze labour-use efficiency in the Swedish banking industry and Ncube and Heshmati (1998) to analyze the adjustment in employment in the Zimbabwe's manufacturing industries. In this paper we specify a dynamic labour demand model with a flexible speed of adjustment parameter. As labour alone is assumed to be flexible, this boils down to a labour requirement function (see Pindyck and Rotemberg 1997, Kumbhakar and Hjalmarsson 1995). Shifts in the labour requirement function are allowed in the model to capture non-neutral shifts referring to shifts other than those related to technological change.

This study is important regarding policy formulation and evaluation. A knowledge of the adjustment process is essential when evaluating policies that are designed to enhance the flexibility of labour markets and industrial performance. Flexible labour markets are an essential element of policy reforms and subsequent generation of employment and profitability. A general model that allows the adjustment parameter to be industry and time variant is therefore more informative. The main features of the model are as follows. First, the observed level of employment is not necessarily the optimal level. Second, it sheds lights on the nature of the dynamic adjustment in employment by manufacturing industries. Third, the adjustment parameter is specified in terms of determinants of optimal employment and factors that affect the speed of adjustment. The model accommodates the possibility of non-optimality of employment at any point in time and that firms differ in their speed of adjustment towards the optimal level. Fourth, the optimal level as a response to market conditions may change over time for the same industry.

The application of this methodology and the empirical findings show that it is a significant contribution to labour demand literature in general and Tunisian's manufacturing in particular. In addition, the method can easily be generalized to other forms of dynamic adjustment models within a panel data framework. An example of such cases is applications to dynamic adjustment in capital structure of firms (Heshmati 2002).

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3 This approach is different from the stochastic frontier approach of measuring efficiency in the sense that industries' performances are compared to the desired level of labour-use which is both firm and time-specific and no distributional assumptions are imposed on the over-use of labour input. For a comprehensive survey on the frontier functions to estimate productive efficiency, see Kumbhakar and Lovell (2000).

The rest of the paper is organized as follows. Our basic methodological approach and model is summarized in Section 2. The issues of specification and estimation are discussed in Section 3. In Section 4, we describe the data and variables used in the analysis. This is followed in Section 5, by the discussion of the results. Section 6 is the summary and conclusion.

2 The model

Suppose the economy operates with some firms/industries using more labour than what is technically necessary to produce a given vector of output Y_0. This is possible at any point in time due to the existence of variations in demand for goods produced, performance of firms, their degrees of capacity utilization and the sluggish labour market conditions. But firms in general operate with the objective of minimizing the amount of labour used to produce Y_0. In other words, there is a labour requirement frontier which is the target of every firm. Denote this target level or labour requirement frontier by L^* and the actual labour used by L. We assume that labour is the only variable input used in the production of output Y. If $L > L^*$ it means there is an overuse of labour or employment inefficiency, i.e. the amount of the variable labour input is more than the minimum required. On the other hand if $L = L^*$ then employers are using labour efficiently or they are on the labour requirement frontier. Assuming panel data exits, the labour requirement frontier is defined as

(1) $$L_{it}^* = f(W_{it}, Y_{it}, Z_{it}, t)$$

where as it has been noted above, L_{it}^* is the minimum amount of labour required to produce a given level of output; W_{it} and Y_{it} are real wages and output, respectively; Z_{it} consists of variables that characterizes the nature of the technology and production environment.

In analyzing labour-use in an industry such as manufacturing, a good candidate to enter Z is capital stock K_{it} which captures the characteristics and structure of the industry. The justification for the inclusion of K is that when manufacturing industries move towards the target, the structure of capital stock is important.[4] In addition to the quasi-fixed capital input, production environmental characteristics, economic policy, time and industry specific variables may also enter vector of Z variables. The indexes i and t, respectively represent industries (i = 1, 2, ..., N) and time periods (t = 1, 2, ..., T). Given W and Z variables, industry i at time t may not be able to achieve the labour requirement frontier when producing Y_{it}.This implies that the industry is found to be inefficient as more labour is used than necessary.

Kumbhakar and Hjalmarsson (1998) have modelled the relationship between the actual labour used at time t by industry i and the labour requirement function as

(2) $$L_{it} = L_{it}^* e^{u_{it}}$$

4 Here the capital input is considered to be quasi-fixed in long-run. In a factor requirement model (Diewert 1974) only one single factor input is allowed to be variable, i.e. labour in the current case.

where $u_{it} \geq 0$ for $\forall$ i and t. The u_{it} is interpreted as technical inefficiency. A $u_{it} = 0$ implies that the employer uses labour efficiently. Model in Equation 2 can be rearranged to show that labour-use inefficiency can be defined as $(L_{it} / L_{it}^{*}) \geq 1$ for $\forall$ i and t. Similarly labour-use efficiency is $(L_{it} / L_{it}^{*}) \leq 1$ for $\forall$ i and t. However, the model in Equation 2 does not take into account for any adjustment process. In this paper industries adjust towards the labour requirement frontier. There is a catching up process, where industries adjust to catch up with the frontier.

Under ideal conditions, the observed employment (L_{it}) should equal the optimal employment (L_{it}^{*}). In a dynamic setting, this implies that changes in employment from previous to current period should equal the changes required for the industry to be at optimal at time t, i.e. $L_{it} - L_{it-1} = L_{it}^{*} - L_{it-1}$. However, if adjustment is costly or sluggish, the labour market does not allow for full adjustment and partial adjustment will be undertaken. This non-full adjustment can be represented as

(3) $$\frac{L_{it}}{L_{it-1}} = \left(\frac{L_{it}^{*}}{L_{i,t-1}} \right)^{\delta_{it}}$$

where δ_{it} is the adjustment parameter, which varies both over time and across industries. Taking into account the adjustment process which is industry and time variant, an inefficient industry follows an adjustment process best described by the above partial adjustment model where L_{it} adjusts to its desired level L_{it}^{*} at a flexible rate δ_{it}. The size of δ_{it} determines the degree of adjustment. It can be viewed as the speed of adjustment, a higher δ_{it} denoting a higher speed of adjustment. If $\delta_{it} = 1$, then the entire adjustment is made within one single period. Since the optimal employment itself may shift over time, at any intermediate time a value of 1 does not have any implications for future optimality. If $\delta_{it} < 1$, the adjustment is only partial and finally if $\delta_{it} = 0$, there is no adjustment and the industry is at the optimal level of employment.

An interesting feature of this model is the fact that each industry follows its own adjustment path in catching up with the labour requirement function. The path taken by each industry depends on circumstances that may be peculiar to each employer or policy or technological conditions that affect all employers similarly. Changes in the determinants of the target may cause the target to shift as well. Allowing the speed of adjustment to vary with i, t is justified in that in reality different industries are found to adjust their labour-use differently over time (Kumbhakar et al. 2002).

Contrast this with a standard dynamic adjustment model where δ_{it} is the same for all i and t and L_{it}^{*} is constant. In a standard partial adjustment model there is some rigidity in the convergence process, i.e. the movement from L_{it} to L_{it}^{*}. $L_{it} \rightarrow L_{it}^{*}$ when $t \rightarrow \infty$ and $0 < \delta < 1$. An inefficient industry may take long to attain L_{it}^{*}, unless δ is close to unity. Convergence of L_{it} to L_{it}^{*} is thus asymptotic. In our case, this inherent rigidity is thus relaxed by allowing δ to vary over time and industry. An inefficient industry may reduce its inefficiency faster by adjusting some of the factors that cause this inefficiency. So an inefficient industry may adjust faster to eliminate its inefficiency. In the present paper convergence is not necessarily asymptotic. Industries control their speed of adjustment to attain the target level, L_{it}^{*}. Industries can adjust some of the variables affecting δ. The speed of adjustment is therefore expressed as

(4) $$\delta_{it} = g(Z_{it}, t : \gamma)$$

where γ is a vector of the fixed coefficient associated with the determinants of adjustment, the *Z* variables. Time (*t*) is an important element in the function and captures neutral shifts in the speed of adjustment over time. Note that γ is fixed in this case but δ varies over *i* and *t*.

In logarithms, and appending a stochastic two-way error component term, the model in (3) can be rewritten as

(5) $$\ln L_{it} = (1-\delta_{it})\ln L_{i,t-1} + \delta_{it}\ln L_{it}^{*} + \varepsilon_{it}$$

(6) $$\varepsilon_{it} = \mu_i + \lambda_t + v_{it}$$

where all variables are as defined above, μ_i are industry-specific effects, λ_t are time-specific effects and v_{it} is the statistical random error term assumed to be identically and independently distributed with mean zero and constant variance (σ_v^2). Important features of model (5) worth emphasizing are that it is dynamic and δ, the adjustment parameter is both time and industry specific. L_{it}^{*} is also allowed to vary over time and across industries. By allowing δ to vary over time we capture the effects of technical change in the production process and the employment decisions of firms.

3 Empirical model and estimation

For estimation purposes a translog functional form is used to approximate L_{it}^{*} as shown:

(7) $$\begin{aligned}\ln L_{it}^{*} &= \alpha_0 + \alpha_Y \ln Y_{it} + \alpha_k \ln K_{it} + \alpha_w \ln W_{it} + 1/2[\alpha_{kk}(\ln K_{it})^2 \\ &+ \alpha_{ww}(\ln W_{it})^2 + \alpha_{YY}(\ln Y_{it})^2] + \alpha_{wk}\ln K_{it}\ln W_{it} \\ &+ \alpha_{Yk}\ln Y_{it}\ln K_{it} + \alpha_{Yw}\ln Y_{it}\ln W_{it} + \alpha_{wt}\ln W_{it}t \\ &+ \alpha_{yt}\ln Y_{it}t + \alpha_{kt}\ln K_{it}t + \sum_i \mu_i D_i + \sum_t \lambda_t D_t + v_{it}\end{aligned}$$

where ln *W*, ln *Y* and ln *K* are log of wages, output and capital variables, respectively, *D* are dummy variables representing unobservable industry- and time-effects and *v* is random error term with mean zero and constant variance.[5] Another alternative is to replace the dummy variable which represents time with a unique temporal tendency (*t*), thus model (7) can be written as:

[5] In order to avoid over-parametrization of the model, for the interaction terms a time trend (*t*) is used.

$$\ln L_{it}^* = \alpha_0 + \alpha_Y \ln Y_{it} + \alpha_k \ln K_{it} + \alpha_w \ln W_{it} + \alpha_t t + 1/2[\alpha_{kk}(\ln K_{it})^2 + \alpha_{ww}(\ln W_{it})^2 + \alpha_{YY}(\ln Y_{it})^2 + \alpha_{tt} t^2] + \alpha_{wk} \ln K_{it} \ln W_{it} + \alpha_{Yk} \ln Y_{it} \ln K_{it} + \alpha_{Yw} \ln Y_{it} \ln W_{it} + \alpha_{wt} \ln W_{it} t + \alpha_{yt} \ln Y_{it} t + \alpha_{kt} \ln K_{it} t + \sum_i \mu_i D_i + v_{it} \quad (8)$$

In turn, the speed of adjustment, i.e. model (4) can be expressed as

$$\delta_{it} = \delta_0 + \sum_i \delta_i D_i + \sum_t \delta_t D_t + \sum_m \delta_m Z_{mit} \quad (9)$$

where D_i and D_t are dummies representing unobservable industry- and time-specific effects, and Z is a vector of production environmental factors determining the individual industries' speed of adjustment towards the optimal level of employment, respectively. Since we are mostly interested in the behaviour of δ over time, we have specified it as a flexible function of time by relating it to time and industry dummies, as well as the absolute difference between actual and desired level of employment.

The elasticities of optimal employment with respect to W, Y and K are computed from Equation (8) as

$$E_w = \partial \ln L_{it}^* / \partial \ln W_{it} = \alpha_w + \alpha_{ww} \ln W_{it} + \alpha_{wk} \ln K_{it} + \alpha_{Yw} \ln Y_{it} + \alpha_{wt} t \quad (10A)$$

$$E_k = \partial \ln L_{it}^* / \partial \ln K_{it} = \alpha_k + \alpha_{kk} \ln K_{it} + \alpha_{wk} \ln W_{it} + \alpha_{Yk} \ln Y_{it} + \alpha_{kt} t \quad (10B)$$

$$E_y = \partial \ln L_{it}^* / \partial \ln Y_{it} = \alpha_y + \alpha_{yy} \ln Y_{it} + \alpha_{wy} \ln W_{it} + \alpha_{Yk} \ln K_{it} + \alpha_{yt} t \quad (10C)$$

The expected signs of E_w and E_y are negative and positive, respectively. E_k is positive only if labour and capital are complements and negative when they are substitutes. In the present model, the labour requirement function (8) is allowed to shift over time. This, as has been noted, captures the effect of technical change on the level of employment. Thus, the exogenous rate of technical change is defined in terms of a shift in the labour requirement function (Kumbhakar and Hjalmarsson 1995, Kumbhakar et al. 2002). From model (7) and (8) technical change (TC) is thus derived as

$$TC = \partial \ln L_{it}^* / \partial t = \alpha_t + \alpha_{tt} t + \alpha_{wt} \ln W_{it} + \alpha_{Yt} \ln Y_{it} + \alpha_{kt} \ln K_{it} \quad (11A)$$

$$TC = \partial \ln L_{it}^* / \partial t = (\lambda_t - \lambda_{t-1}) + \alpha_{wt} \ln W_{it} + \alpha_{Yt} \ln Y_{it} + \alpha_{kt} \ln K_{it} \quad (11B)$$

The pure component ($\alpha_t + \alpha_{tt}t$) in the former is function of trend and changing smoothly, while in the latter it is flexible and captures fluctuations from positive to negative and back to positive growth rates. If the rate of TC is positive, it implies technical regress (labour using technology is employed) and when negative it is technical progress (labour saving). Labour-use efficiency is achieved when the actual level of employment is on the labour requirement frontier, i.e. $L_{it} = L_{it}^*$. Labour-use efficiency (*EFF*) is measured by the ratio of the two variables as

$$EFF_{it} = (L_{it}^* / L_{it}) \quad (12)$$

Efficiency change (catching up effect) can be obtained from the change in the efficiency ratio (12) expressed as

$$\dot{EFF}_{it} = \quad \partial EFF / \partial t = (\partial L_{it}^{*} / t - \partial L_{it} / t) \quad \text{or} \quad \frac{-\partial L_{it}}{\partial t} = \dot{EFF}_{it} + TC_{it}$$

which decomposes productivity growth, defined as decline in the rate of labour-use into technical change and efficiency change components. Efficiency can be shown to be related to δ. By using (3) and (12) efficiency can be expressed as

$$(14) \qquad EFF_{it} = \quad (L_{it} / L_{it-1})^{\frac{1}{\delta_{it}} - 1}$$

where it is clear that labour-use efficiency is determined by δ_{it} and the ratio (L_{it}/L_{it-1}). EFF_{it} and δ_{it} are positively related provided (L_{it}/L_{it-1}) < 1. If δ_{it} is close to one, or L_{it} is close to L_{it-1}, then efficiency would be close to 100 per cent. Thus, the time path of efficiency (convergence or divergence) is determined by the behaviour of δ_{it} as well as the intra-periodical changes in employment.

The labour-use model is dynamic in nature. The panel data has the advantages that it allows to better understanding of the dynamics of labour-use adjustment. These dynamic relationships are characterized by the presence of a lagged dependent variable among the regressors. Estimation of error component model in (5) and (6) is developed in two directions. First, the fixed effects (FE) model, where μ_i and λ_t are assumed to be fixed and correlated with the explanatory variables. Second, random effects (RE) model, where μ_i and λ_t are assumed to be random and uncorrelated with the explanatory variables. Efficiency, unbiasedness and consistency are properties affecting the choice of model (see Hsiao 1985 and Baltagi 2001). In this study we assume the effects being fixed. The random error component v_{it} is assumed to be independent and identically distributed with mean zero and constant variance, σ_v^2.

4 The data

The data used in this study has been assembled using a diversity of sources (national accounts from of the Tunisian National Statistic Institute (INS) and statistics coming from the Quantitative Economy Institute (IEQ). We did so in order to allow the construction of an integrated database of industrial, labour market and trade statistics feasible. Thus we have a panel on six manufacturing industries from 1971 to 1996. These six industries are included in the free-trade agreement of 1995 between Tunisia and the European Union. Remaining five non-manufacturing industries not included in agreement are left out. The industries included are food industry, textiles, clothing and leather industry, chemical industry, construction material, ceramic and glass industry, mechanical electric industry, and other manufacturing industry (including paper and pulp, plastics, etc.).

The data contains information on inputs, output (value-added), industry characteristics, and a number of economic policy variables. The dependent variable is measured as total employment in each industry (L). The independent variables in the labour demand part of the model are average wages (*W*), capital stock (*K*), and value-added (*Y*). Wages are defined as average annual wage per worker. It is obtained by dividing total wages in each industry by the total number of employees in that industry. Thus, the wage variable is industry specific. The value-added is measured as value of production less material and energy expenses. The average wages are then transferred to fixed 1971 prices using the producer price index. Capital stock is assumed to be quasi-fixed in short-run following an investment decision. It is measured as value of capital equipment. Wages, value-added and capital stock are given in Tunisian dinars and are transferred to fixed 1971 prices using the producer price index.

In the estimation, three economic regimes are controlled for, i.e. pre-trade liberalization (1971–85), trade liberalization (1986–94), and post-liberalization (1994–96) periods. The post-liberalization period refers to the signing of the free-trade agreement with European Union. We capture these periods separately because they represent three different economic regimes.

A vector of *T-1* time dummies are used to represent the exogenous rate of technical change and a time trend (*t*) is used to capture possible shifts in the labour requirement function over time as well. In addition, *N-1* industry dummies are used to capture industry specific effects. The summary statistics are reported in Table 1.

The average employment is 62,000 per industry. Textile industry employee most part of employment forces in manufacturing. Annual real wage per worker is 555 dinars with a standard deviation of 261 dinars. It varies in the interval 126 and 1,083 dinars. Capital stock also shows large variation in capital intensity among industries. The same patterns found concerning value-added.

Looking at Pearson correlation coefficients[6] among the variables we found correlation consistent with expected ones. Labour is negatively correlated with wages (–0.62), positively with capital stock (0.13) and with value-added (0.74). There is positive trend in labour use, capital stock formation, value-added production over time. Capital and value-added are correlated (0.539) indicating presence of some degree of collinearity in the data.

Table 1
Summary statistics of the Tunisian manufacturing data

	Variable definition	Mean	Std dev.	Maximum	Minimum
L	Employment in 1000	61.77	64.02	264.00	8.02
W	Annual wage/worker in dinars	554.84	261.09	1083.03	125.73
K	Capital Stock in million dinars	213.95	124.31	468.80	30.74
Y	Value-added in million dinars	50.57	36.76	214.64	5.80
N	Number of industries	6			
T	Number of periods	26			
No. of obs	156				

Data sources: INS, National accounts and IEQ statistics.

6 The correlation matrix is not reported here to conserve space.

A correlation matrix based on changes in labour, wages, capital, and value-added shows positive and significant association among the dependent variable measured as labour-use, and independent variables of stock of capital and value-added, but insignificant with wages. Value-added shows high responsiveness to changes in capital and wages. All variables, with the exception of labour where the changes are positive, show major fluctuations across industries and over time including both positive and negative changes.

5 Empirical results

The dynamic model is estimated assuming a flexible adjustment parameter which is both industry and time-variant. The variation is facilitated by making the adjustment parameter a function of the distance from optimal level of employment, trend, squared trend and industry dummies: for comparison; a restricted dynamic model where the adjustment parameter is a constant, as it is in traditional dynamic models, and a time trend static model. The three models are estimated using fixed effects model. The dynamic ones are non-linear and require iteration procedure.

The labour requirement frontier L_{it}^{*} was approximated by a translog function. The advantage of this formulation is that it is flexible. The labour requirement frontier is a function of wages, value-added, quasi-fixed capital stock and time dummies. The translog specification was tested using F-test against alternative Cobb-Douglas and generalized translog functional forms with no interaction terms. The test results indicated translog as preferred functional form. The translog models had smaller standard errors, higher frequency of statistical significant coefficients and elasticities consistent with economic theory. The parameter estimates of the models (both static and dynamic) are reported in Table 2.

The static model has 60 per cent of the parameters being statistically significant at any conventional significant levels. In the dynamic case, 62 per cent of the parameters are statistically significant at least 10 per cent level. A closer look at the coefficients of the static and dynamic models shows that the parameters associated with industry and time dummies (for both models) and with the adjustment function, δ_{it} are statistically significant at conventional levels of significance.[7] Test results indicate that the unrestricted dynamic model is preferred to the restricted one where the adjustment parameter is constant across firms and over time. The analysis of the results will subsequently be based on the static and unrestricted dynamic model specifications.

The parameters of the translog model cannot be interpreted directly. The elasticities with respect to wages, output and capital stock were therefore computed as per Equation 10 and technical change as in Equation 11. All elasticities evaluated at the mean values for each year, for each economic regime, by industry and at the sample mean are reported in Table 3 for the static model and in Table 4 and 5 for the dynamic long-run and short-run versions, respectively. Also calculated and reported in Table 4 are the inefficiency ratios and the speed of adjustment (δ_{it}) parameter.

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7 In addition to the firm and time dummies in modelling the speed of adjustment we also tried a model specification that included a number of indicators determining the speed of adjustment. The factors considered were the sales, exports, money supply, government expenditure and interest rate. The presence of these variables were found to be either irrelevant or resulted in a highly non-linear model with severe problem of convergence. Thus, they were subsequently excluded from the specification.

Table 2 Parameter estimates, dependent variable is labour

	Static model		Restricted dynamic model		Unrestricted dynamic model	
Variable	Estimate	Std error	Estimate	Std error	Estimate	Std error
A. Employment function						
β_0	10.848[a]	2.6892	-20.281	15.545	8.3071[b]	4.0042
β_W	-0.1841	0.6282	5.5478[c]	3..2491	1.1441	0.8834
β_Y	-0.0965	0.6220	-4.3562	2.9159	-0.0487	0.7309
β_K	0.1566	0.7534	9.8580[b]	4.6195	0.1638	1.0140
β_T	0.1331[b]	0.0537	0.0327	0.2169	0.0039	0.0847
β_{WW}	-0.0081	0.0497	-0.7387[b]	0.3306	-0.2846[a]	0.0598
β_{YY}	-0.1074[b]	0.0434	0.5798[b]	0.3032	0.1682[a]	0.0466
β_{KK}	0.1274[b]	0.0548	-1.3353[b]	0.5732	-0.4234[a]	0.1249
β_{TT}	-0.0008[c]	0.0005	0.0044[c]	0.0027	0.0046[a]	0.0011
β_{WY}	0.1255[b]	0.0681	0.1451	0.2711	-0.1593[b]	0.0806
β_{WK}	-0.1216	0.0976	0.4288	0.4367	0.5822[a]	0.1415
β_{WT}	0.0048	0.0069	0.0018	0.0278	-0.0052	0.0090
β_{YK}	-0.0468	0.0672	0.1448	0.2763	0.1132	0.0828
β_{YT}	0.0272[a]	0.0076	-0.0825[c]	0.0501	-0.0483[a]	0.0123
β_{KT}	-0.0372[a]	0.0071	0.0248	0.0363	0.0122	0.0152
μ_{MCV}	-0.2479[a]	0.0423	0.6189[c]	0.3565	-0.7780	0.6858
μ_{IME}	0.0868[a]	0.0299	0.1978	0.1255	3.8630[b]	1.6278
μ_{CH}	-0.6268[a]	0.04996	-0.2840	0.2343	-2.3970[a]	0.6760
μ_{TEX}	1.2820[a]	0.0737	0.4536	0.4198	0.4338	0.6037
μ_{IMD}	-0.0979	0.0750	-0.4139	0.3195	-0.1316	0.8321
B. Speed of adjustment						
δ_0			0.0685[b]	0.0231	-0.2740[a]	0.0544
δ_{DIT}					0.0955[a]	0.0287
δ_T					0.0149[a]	0.0030
δ_{TT}					-0.0003[a]	0.0001
δ_{MCV}					0.1153[c]	0.0697
δ_{IME}					-0.3694[a]	0.1359
δ_{CH}					0.3562[a]	0.1063
δ_{TEX}					0.1555[b]	0.0696
δ_{IMD}					0.0510	0.0993
R^2 adjusted	0.9945		0.9996		0.9998	
RMSE	0.0637		0.0174		0.0123	

Note: Significant at less than 1% (a); 1-5% (b), and 5-10% (c) levels of significance. The subscripts *W*, *K*, *Y* and *T* represent wages, capital stock, value-added and trend variables. The subscripts *MCV*, *IME*, *CH*, *TEX* and *IMD* represent construction material, mechanical electric, chemical, textile and other manufacturing industries.

Source: Authors' calculation.

5.1 Elasticities and the exogenous rate of technical change

In this sub section we discuss the elasticities with respect to wages, capital and value-added, reported in Table 3 for the static model and in Table 4 for the unrestricted dynamic case. The short-run elasticities (Table 5) are simply the long-run multiplied by the speed of adjustment coefficient. Our subsequent discussion will be based on the long-run elasticities.

Table 3

Mean elasticities calculated from the static model parameter estimates

Characteristics	Wage (E_w)	Output (E_Y)	Capital (E_K)	TC
A. Mean by industry				
Food	-0.347	-0.026	-0.015	0.058
Construction material & ceramics	-0.447	0.051	0.113	0.031
Mechanical electric industry	-0.410	0.073	0.026	0.043
Chemical	-0.482	0.236	0.001	0.031
Textile, clothing & leather	-0.295	-0.216	0.111	0.059
Other manufacturing	-0.323	-0.020	-0.012	0.061
B. Mean by year				
1972	-0.423	-0.030	0.226	0.084
1973	-0.423	-0.030	0.222	0.079
1974	-0.401	-0.064	0.202	0.080
1975	-0.426	-0.033	0.214	0.070
1976	-0.423	-0.046	0.212	0.066
1977	-0.418	-0.043	0.190	0.064
1978	-0.415	-0.055	0.189	0.060
1979	-0.405	-0.071	0.179	0.058
1980	-0.391	-0.080	0.158	0.057
1981	-0.391	-0.075	0.148	0.053
1982	-0.408	-0.027	0.129	0.047
1983	-0.413	0.004	0.097	0.043
1984	-0.406	-0.002	0.087	0.040
1985	-0.404	0.014	0.067	0.037
1986	-0.398	0.029	0.039	0.035
1987	-0.388	0.032	0.014	0.034
1988	-0.373	0.037	-0.022	0.034
1989	-0.367	0.054	-0.055	0.033
1990	-0.357	0.062	-0.087	0.032
1991	-0.350	0.077	-0.119	0.030
1992	-0.344	0.102	-0.156	0.029
1993	-0.335	0.116	-0.192	0.028
1994	-0.320	0.124	-0.232	0.028
1995	-0.314	0.145	-0.268	0.027
1996	-0.305	0.170	-0.313	0.027
C. Mean by period				
Pre-liberalization period 1972–85	-0.411	-0.038	0.166	0.060
Liberalization period 1986–994	-0.359	0.070	-0.090	0.031
Post-liberalization period 1994–96	-0.309	0.158	-0.290	0.027
D. Overall mean and std deviations				
Mean	-0.384	0.016	0.037	0.047
Std dev.	0.083	0.162	0.184	0.024

Note: TC is the overall rate of technical change.

Source: Authors' calculation.

Table 4

Mean long-run elasticities, inefficiency and speed of adjustment calculated using unrestricted dynamic model parameter estimates

Characteristics	Wage (E_w)	Output (E_Y)	Capital (E_K)	Ratio	δ	TC Rate	Pure TC
A. Mean by Industry							
Food	-0.277	0.217	0.177	1.417	0.031	-0.037	0.134
Const mat. & ceramic	0.127	0.096	-0.274	1.526	0.061	-0.004	0.134
Mech. electr. industry	-0.101	0.054	0.032	1.097	0.011	-0.009	0.134
Chemical	-0.240	-0.187	0.204	1.638	0.226	0.015	0.134
Text., cloth & leather	0.380	0.463	-0.478	1.593	0.061	-0.038	0.134
Other manufacturing	0.069	0.144	-0.002	1.477	0.037	-0.013	0.134
B. Mean by year							
1972	-0.439	0.217	0.677	1.366	0.040	-0.088	0.023
1973	-0.357	0.215	0.566	1.376	0.048	-0.080	0.032
1974	-0.360	0.271	0.524	1.380	0.058	-0.084	0.041
1975	-0.254	0.224	0.376	1.388	0.068	-0.070	0.051
1976	-0.188	0.247	0.265	1.393	0.075	-0.066	0.060
1977	-0.202	0.247	0.242	1.409	0.073	-0.063	0.069
1978	-0.121	0.264	0.122	1.418	0.075	-0.058	0.079
1979	-0.061	0.286	0.031	1.430	0.077	-0.054	0.088
1980	-0.030	0.297	-0.020	1.443	0.074	-0.050	0.097
1981	0.035	0.286	-0.107	1.453	0.075	-0.042	0.106
1982	0.046	0.213	-0.135	1.462	0.073	-0.029	0.116
1983	0.007	0.169	-0.118	1.469	0.074	-0.022	0.125
1984	0.078	0.173	-0.210	1.477	0.073	-0.016	0.134
1985	0.126	0.142	-0.266	1.483	0.075	-0.006	0.144
1986	0.143	0.115	-0.288	1.488	0.074	0.002	0.153
1987	0.178	0.102	-0.328	1.495	0.073	0.008	0.162
1988	0.170	0.090	-0.324	1.500	0.073	0.013	0.172
1989	0.162	0.061	-0.322	1.502	0.074	0.020	0.181
1990	0.164	0.044	-0.332	1.502	0.076	0.026	0.190
1991	0.167	0.016	-0.339	1.505	0.074	0.033	0.200
1992	0.145	-0.025	-0.319	1.503	0.076	0.041	0.209
1993	0.136	-0.052	-0.312	1.503	0.076	0.047	0.218
1994	0.112	-0.069	-0.290	1.504	0.076	0.052	0.228
1995	0.103	-0.106	-0.279	1.504	0.075	0.060	0.237
1996	0.062	-0.148	-0.235	1.499	0.074	0.067	0.246
C. Mean by period							
Pre-liberal. 1972–85	-0.123	0.232	0.139	1.425	0.068	-0.052	0.083
Liberaliz. 1986–94	0.153	0.031	-0.317	1.500	0.075	0.027	0.190
Post-liberal. 1994–96	0.083	-0.127	-0.257	1.501	0.075	0.063	0.242
D. Sample means							
Mean	-0.007	0.131	-0.057	1.458	0.071	-0.014	0.134
Std dev.	0.333	0.250	0.443	0.185	0.074	0.053	0.067

Source: Authors' calculation.

Table 5
Mean short-run elasticities and technical change calculated using the unrestricted dynamic model parameter estimates

Characteristics	Wage (E_w)	Output (E_Y)	Capital (E_K)	Rate of TC	Pure TC
A. Mean by industry					
Food	-0.010	0.008	0.007	-0.002	0.004
Construction material and ceramic	0.007	0.006	-0.017	-0.000	0.008
Mechanical electric industry	-0.002	0.001	0.001	-0.000	0.001
Chemical	-0.046	-0.005	0.033	0.005	0.032
Textile, clothing and leather	0.023	0.027	-0.030	-0.002	0.009
Other manufacturing	0.003	0.005	-0.000	-0.000	0.005
B. Mean by period					
Pre-liberalization period 1972–85	-0.012	0.008	0.013	-0.003	0.006
Liberalization period 1986–94	-0.009	-0.008	-0.021	0.003	0.014
Post-liberalization period 1994–96	-0.002	-0.17	-0.010	0.005	0.018
C. Overall mean and std deviations					
Mean	-0.004	0.000	-0.001	0.000	0.010
Std dev.	0.031	0.029	0.040	0.006	0.013

Source: Authors' calucalation.

The signs of the average elasticities are as expected; wages (E_W) are negative, value-added (E_Y) are mostly positive and capital (E_K) are positive and negative. The elasticities with respect to wages have a sample mean value of –0.383 (0.083) for the static model and –0.007 (0.333) in unrestricted dynamic model. In numbers in parentheses are the standard deviations.[8] Employment responds greatest to wages in the textile, clothing and leather (0.380), food (–0.277), chemical (0.240) industries. It is least responsive in the other manufacturing industry (0.069) and construction material and ceramic industry (0.127). Over time, although a time trend was used for the interaction between wages and time variable, we observe no systematic pattern in the elasticities with respect to the wages. There is more industry variation in the elasticities than overtime. Turning to the elasticities by period, there is evidence that employment was more responsive to wages during 1971–85 and 1986–94.

During these two economic phases the elasticities with respect to wages were negative and positive, respectively and the average value is 0.015. A lower responsiveness in the phase 1994–96 was expected because of the job security regulations in force during this period. Employers could not easily fire workers, even if there were increases in wage costs.

The value-added elasticity in the static model has a mean value of 0.016 and a standard deviation of (0.162). The long-run elasticity is 0.131 but with a slightly large standard deviation of 0.250. It exhibits more overtime variation than across industries.

8 It has to be noted that these are standard deviations and they measure the dispersion of the elasticities across industries or over time. These are not standard errors that capture the significance of the elasticities.

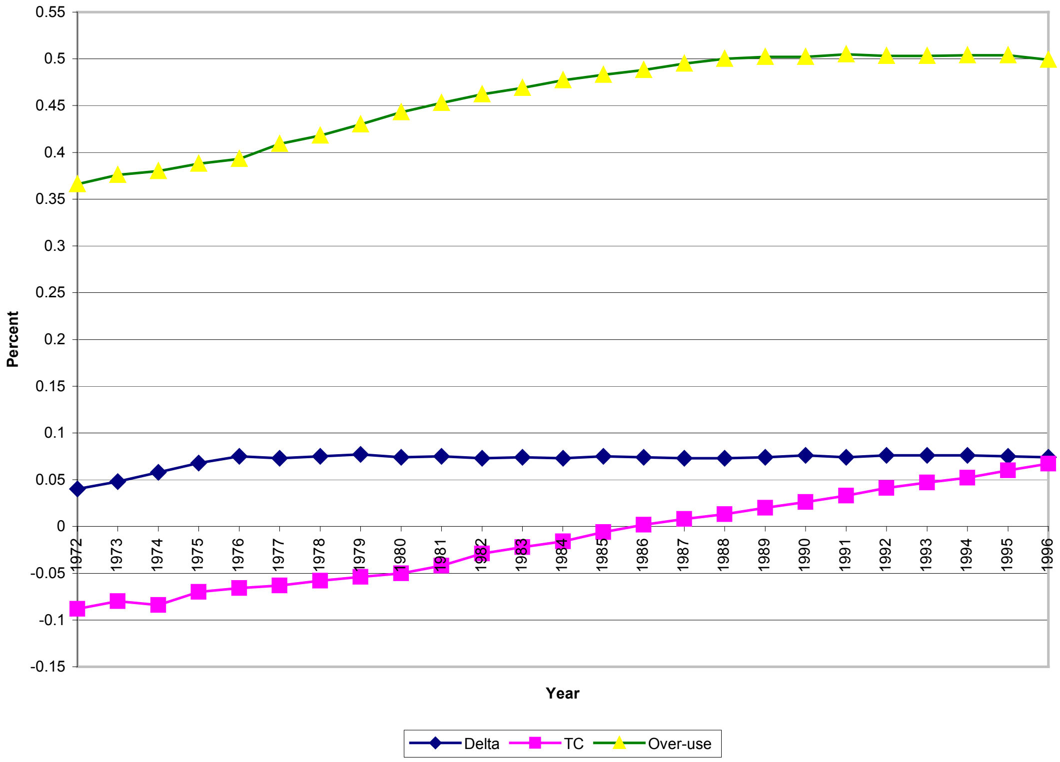
Employment responsiveness to value-added is more pronounced in the textile, clothing and leather and food industries – with elasticities of 0.463 and 0.217, respectively. These two industries are followed by chemical, and the others manufacturing industries. The output elasticity for chemical unlike other industries is negative. Least responsiveness is found in the construction material and ceramic, and mechanical and electric industries.

Over time, there are small surprises in the value-added elasticities. Between 1992 and 1996 the elasticities are negative, contrary to expectations. This negative association is caused by an improvement in labour productivity. Between 1975 and 1981 the value-added elasticities increased. After 1982 the value-added elasticities decrease continuously. The value-added elasticities by period are relatively small during the 1986–94 period, i.e. 0.031. Compare this with 0.232 and 0.127 during the following two phases, respectively. With sanctions dominating the 1986–94 period, it is not surprising that output growth generated so little employment response. This result also indicates that in a liberalized environment output growth generates a larger employment response.

The sample mean long-run capital stock elasticity is –0.057 with a standard deviation of 0.443. The corresponding figures for the static model are 0.037 and 0.184. The elasticities over time are negative between 1980–96 in the dynamic model and between 1988–96 in the static model, positive in the other years, an indication that production process are capital intensive. Across industries the value-added elasticities are negative only in the construction material and ceramic, textile, clothing and leather, and other manufacturing industries. A 1 per cent increase in capital gives decrease to the response rate (–0.4 per cent) in the textile, clothing and leather, and (-0.2 per cent) in the construction material and ceramic industries. This is followed by food, mechanical and electric, and other manufacturing industries with between –0.002 per cent and 0.177 per cent. The least response rate is found in the mechanical and electric, and other manufacturing industries (less than 0.10 per cent).

These results are important in the formulation and targeting of policies, as it gives an indication as to which industries more jobs will be created from more capital accumulation. Over time, there is a general decline in the capital elasticities. The period elasticities indicate that, in the two period (1971–85 and 1986–94) the production process is capital intensive. This result is no surprise. The import substitution industrialization strategy which characterized development in 1971–86 period unprecedented development and diversification in the manufacturing sector. The government assisted this sector (more than any other sector) through subsidies, tax incentives and infrastructural development.

Figure 1
Development of speed of adjustment (delta), over-use of labour and rate of technical change (TC) in Tunisian manufacturing industries



Finally, we turn to exogenous rate of technical change. The long-run sample mean value presented in Table 4 is very small (–1.4 per cent) with a relatively large standard deviation (5.3 per cent). The pure component of technical change is found to be positive (13.4 per cent) while the non-neutral component is negative and relatively smaller (0.031). The scale augmenting component of technical change is positive but close to zero. This is interpreted as the total factor productivity (TFP) growth in Tunisian manufacturing is dominated by exogenous rate of technical change. The annual mean exogenous rate of technical change ranges in the interval –8.8 per cent to 6.7 per cent (see also Figure 1). The results show that in the chemical industry there was technical regress (increasing use of labour for given output, wages and capital stock). In the remaining five industries there was technical progress (decreasing labour use for given output) technological change. Over time, there was technical progress during the pre-liberalization period of 1971–85. In the remaining years there was technical regress. The speed of adjustment (0.29) and degree of labour use efficiency (0.25) are positive and significantly correlated with the exogenous rate of technical change. The numbers in parenthesis are correlation coefficients. Technical progress or reduction in labour use is enhancing efficiency in production.

To summarize, the long-run elasticity values show that employment is more responsive to value-added, followed by capital stock and least by wage. The sample mean value of technical change shows some technical progress (labour saving). During 1971–85 period employment growth was due mostly from value-added growth than from capital accumulation. In the other two periods employment growth was mainly from output growth than to altered capital.

5.2 Labour-use inefficiency

Labour-use inefficiency is the ratio of actual (L_{it}) to optimal (L_{it}^{*}) employment. A ratio greater than one means over use of labour for a given level of value-added produced using industries own optimal production technology. The inefficiency results are reported in Table 4. The sample mean labour-use inefficiency is 1.458 with a standard deviation of 0.185. This value indicates that industries closer to the mean are on average over using labour by 45.8 per cent compared to an industry with the best practice technology in the sample. Among the industries, labour-use inefficiency ranges between 9.7 per cent to 63.8 per cent. The most inefficient industries are chemical, textile, clothing and leather, construction material and ceramic, other manufacturing, and food industries all which over use labour by about 40 per cent. On the lower end of the spectrum are mechanical and electric industry, which for a given level of value-added, could be better off by reducing employment by 9.8 per cent.

In general, there is an increase over time in labour-use inefficiency rates. It is continuously increasing before 1986 (see Figure 1). The highest inefficiency levels were recorded in the 1986–94 period – with labour over use of 50 per cent on average. There is no surprise found on the inefficiency by period result. Our expectations were that the ratio could be higher during the two latest periods. Such an expectation was motivated by the tight labour market regulations in place (i.e. the firms' inability to adjust employment by firing excess labour force) during the 1986–96 that may have forced employers to retain excess labour. The results show that this was not entirely the case. Instead, industries were more efficient during this period of stiff controls. The explanation for this is not that obvious, but probably this was due to the fact that the private sector offered more incentives to get reed of excess labour.

5.3 Speed of adjustment

The results of the speed of adjustment parameter are reported in Table 4. The sample mean speed of adjustment is 0.071 with a relatively large standard deviation (0.074) indicating presence of large industrial heterogeneity in the speed of adjustment in labour-use. Industries close to the mean adjust 7.1 per cent of their deviations off the equilibrium (observed employment equals the optimal) in every year.

There are similarities in the time behaviour of the adjustment parameter among industries. At the same time there is a wider variation in the speed of adjustment across industries. Employment adjustment is fastest in the chemical industry (23 per cent). The slowest adjusters are mechanical and electric, food, other manufacturing, construction material and ceramic, and textile, clothing and leather industries.

Over time there is a general increase in the speed of adjustment but at a decreasing rate. As expected adjustment was faster during the liberalization 1986–94 and post-liberalization 1994–96 periods (7.5 per cent). It was slower (6.8 per cent) during the pre-liberalization 1971–85 phase – most likely reflecting the tight labour market regulations in existence. What this implies is that during reforms labour markets have become more flexible as the higher speed of adjustment indicates (see Figure 1).

From Equation 14 one would expect some relationship between the adjustment rate parameter and the efficiency rate. Industries less efficient would be expected to adjust faster than (as they try to eliminate their inefficiency faster) those most efficient. In other words, industries closer to the labour requirement frontier would be expected to have a lower speed of adjustment than industries farther away from it. Results indicate convergence towards equilibrium level of labour-use and catching up process in the effective use of labour. In all industries we found systematic relationship between efficiency and adjustment rates indicating a process of convergence and catching up in the Tunisian manufacturing industry.

6 Conclusion

This study was concerned with two important issues. First, modelling dynamic employment demand with a flexible adjustment parameter. Second, considering labour-use efficiency. These are important issues in the understanding of how labour markets function and as a guide to policy formulation and evaluation. A labour requirement function was used to represent employment demand. Employment demand was modelled as a function of wages, value-added and capital stock. The adjustment parameter was allowed to increase over time and industries allowing for a flexible speed of adjustment. Thus, employers choose their own individual adjustment paths 'to catch up' with the labour requirement frontier. The labour requirement frontier was compared with the actual amount of labour employed to measure labour-use inefficiency or to derive the amount of labour used in excess of that which is technical necessary to produce a given level of value-added.

The discussion of the results was mainly based on the long-run estimates obtained from the unrestricted dynamic labour-use adjustment model. The long-run sample mean elasticities indicates that employment demand responds greatest to value-added, followed by capital and then least by wage. The sample mean rate of technical change was close to zero. Over time it varies in the interval –8.8 per cent to 6.7 per cent per annum. Labour-use inefficiency ranges across industries from 9.7 per cent to 64 per cent. The sample mean is 46 per cent, implying that industries close to the mean had they use best practice technology could reduce the labour force by 46 per cent for given output. The inefficiency ratio was highest during the 1994–96 period (50.1 per cent), followed by 42 per cent during 1971–85 period.

Industries were least efficient during the first decade after independence. The overprotection and subsidies might have contributed to higher inefficiencies in the 1971–85 era. However, we would have expected higher rates during the 1986–96 period since there were regulations that prevented necessary reductions in the excess labour force. The speed of adjustment is relatively slow – with a sample mean value of 7 per cent. It ranges from 3 per cent (i.e. food industry) to 23 per cent (i.e. chemical industry). The speed of adjustment was greatest during 1986–94 (7.5 per cent) compared to the 1971–85 (6.8 per cent).

The results in above support the conclusion that under liberalization period labour markets have become more flexible, i.e. employers are able to adjust faster. As such the whole discussion is part of a broader debate about labour market flexibility. This study is subject to some caveats worth mentioning, especially on the application. First, we assumed a homogenous labour force. If data permits, a better alternative would be decomposing the data into interesting groups, e.g. skilled vs unskilled etc. The adjustment process of labour market groups is known to be different. Second, but related, this study uses aggregated manufacturing data. The assumption is that the production structures are the same.

Again data permitting, an application to micro data would be an added advantage as this would capture differences in the production functions. In spite of these shortcomings, the framework developed here is important as it could be used for policy purposes to identify those industries that are inefficient and slow to adjust. The study also sends a methodological message that when modelling the adjustment process in a panel data framework, the speed of adjustment must be made flexible. Modelling the speed of adjustment in this fashion offers an added opportunity, if need be, of estimating the determinants of the speed of adjustment. In conclusion, this model has the added advantage that it can be adapted easily to other forms of dynamics.

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