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**ASYMMETRIC AND TIME-VARYING ERROR-CORRECTION:
AN APPLICATION TO LABOUR DEMAND IN THE U.K.**

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Abstract

In this paper we compare the asymmetric and time-varying error-correction models that have recently been proposed, and apply these to the case of UK aggregate labour demand. The aim of the paper is to investigate the possible co-existence of time-varying adjustment on the one hand, and constant asymmetric error-correction on the other hand. We find that without allowing for time-varying adjustment variables, the asymmetric error-correction models of Granger and Lee (1989) and Escribano (1986) work well. But once the time-varying adjustment variables are included, the evidence for time-invariant asymmetric adjustment is marginal.

Key Words

Nonlinear dynamics, nonlinear error correction, dynamic labour demand.

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1. Introduction

Nonlinear error-correction (EC) models allow for nonlinear adjustments to a stochastic long-run equilibrium, that consists of a stationary linear combination of a set of economic variables. Recently, several nonlinear adjustment mechanisms have been proposed with varying empirical success. Granger and Lee (1989) analyse the co-movements of production, sales and inventories for 27 US industries and industrial aggregates, and allow for the error-correcting strength to be different on either side of the equilibrium attractor. To model the unbalanced employment fluctuations in the U.K. over the business cycle, Escribano and Pfann (1990) consider an EC model with asymmetry between increasing and decreasing deviation from the stochastic equilibrium. Escribano (1986) introduced the polynomial EC model as a flexible way of modelling asymmetric adjustment. In particular the cubic EC model has proved to be successful in modelling U.K. money demand (see Escribano (1986), Hendry and Ericsson (1991)).

A different approach has been followed by Burgess (1988, 1992) who derived a time-varying error-correction model for UK labour demand from a structural model with time-varying adjustment costs of labour. The argument is as follows. If employment in the economy is high, labour markets will be tight and hiring costs will be high. The speed of adjustment of employment thus depends on the level of employment inducing non-linear dynamics in labour demand.

In this paper we compare these models in the context of UK aggregate labour demand¹. In order to compare the results of previous studies we will use the same data set as in Burgess (1992). The aim of the paper is to investigate the possible coexistence of time-varying adjustment with the adjustment speed depending on the level of employment on the one hand, and time invariant but asymmetric adjustment on the other hand.

The plan of the paper is as follows. In section 2 we briefly discuss the different approaches to nonlinear error-correction mechanisms derived from a structural optimizing framework. In section 3 we describe the data, and in section 4 we present the results. Section 5 concludes.

2. Asymmetric Error-Correction Models

Consider a representative economic agent (say a firm) that constructs a contingency plan at time t for a purely nondeterministic quasi-fixed decision variable Q_t , in order to minimize the expected real present value of a nonlinear loss-function over an infinite time horizon:

$$\text{Min}_{Q_t} E_t \left\{ \sum_{i=0}^{\infty} \beta^i \left[(1/2)\alpha(Q_{t+i} - Q_{t+i}^*)^2 + (1/2)\gamma[(1-B)Q_{t+i}]^2 \right] \mid \Omega_t \right\} \quad (2.1)$$

¹ Pfann and Palm (1993) have also found evidence of asymmetry in employment dynamics, deriving from an asymmetric adjustment cost function. A closed form solution in terms of an error correction format does not exist for this model, so we do not include it in our comparisons in this paper.

E_t is the mathematical expectations operator, Ω_t is the conditioning set of available information at the t , B is the lag operator, such that $BQ_t = Q_{t-1}$, β is a real discount value lying between zero and one, α and γ are constant positive parameters that measure the quadratic adjustment costs. Sargent(1978) used this *symmetric adjustment cost* objective function to study the dynamic demand for labour in the USA from 1948 to 1972.

Burgess(1988) and, Burgess and Dolado(1989) allow for *time varying adjustment cost*. They consider the following generalization of (2.1),

$$\text{Min}_{Q_t} E_t \left\{ \sum_{i=0}^{\infty} \beta^i \left[(1/2)\alpha(Q_{t+i} - Q_{t+i}^*)^2 + (1/2)\gamma_t[(1-B)Q_{t+i}]^2 \right] \middle| \Omega_t \right\} \quad (2.2)$$

where $\gamma_t = c_0 + c_1 H_t + c_2 F_t$, with c_0 , c_1 , and c_2 being nonnegative constant parameters. To solve this problem, the assumption is made that the firm does not try to forecast the future values of γ_t ; that is, the firm takes H and F to be fixed *within* a plan but reacts to changes in H or F each period when it recomputes the optimal path. The explicit selection of variables H_t and F_t in the context of labour demand models, will be discussed in the next section; but for the moment it is sufficient to say that they represent the hiring and firing costs of the firm.

Following Nickell(1985), from the Euler equation of the problem (2.1) and a generating process for the driving variables (P_t) of Q_t^* (where $Q_t^* = AP_t$), we derive a *symmetric error-correction* representation:

$$(1-B)Q_t = -\lambda(Q_{t-1} - Q_{t-1}^*) + a_1(1-B)X_{t-1} + \dots + a_p(1-B)X_{t-p} + \varepsilon_t \quad (2.3)$$

with $X_t = (Q_t, P_t)$ and p being the maximum lag of Q or P . Pesaran(1991) and Escribano and Pfann(1993) investigate the relationship between the maximum lag and the nature of the adjustment cost function.

Burgess (1988, 1992) found empirical evidence of certain types of asymmetries from the error correction representation with time varying parameters, obtained from solving (2.2) to give:

$$(1-B)Q_t = -\lambda(Z_t)(Q_{t-1} - Q_{t-1}^*) + a_1(1-B)X_{t-1} + \dots + a_p(1-B)X_{t-p} + \varepsilon_t \quad (2.4)$$

where the parameter λ of the error correction term $(Q_{t-1} - Q_{t-1}^*)$, changes through time as a function of the driving variables Z_t of the adjustment cost.

In this paper we compare equation (2.4) with alternative nonlinear error correction models. In particular, we will compare it with different *asymmetric error correction representations* that have been proposed in the literature. For example, Granger and Lee(1989) proposed the following *piecewise-linear asymmetric error correction* representation,

$$(1-B)Q_t = -\lambda[\alpha_1(Q_{t-1} - Q_{t-1}^*)^+ + \alpha_2(Q_{t-1} - Q_{t-1}^*)^-] + a_1(1-B)X_{t-1} + \dots + a_p(1-B)X_{t-p} + \varepsilon_t \quad (2.5)$$

where $(Q_t - Q_t^*)^+ = \text{Max}\{(Q_t - Q_t^*), 0\}$ and $(Q_t - Q_t^*)^- = \text{Max}\{-(Q_t - Q_t^*), 0\}$. In this model the adjustment is different (asymmetric) depending on the sign of the error correction term of the previous period.

Escribano and Pfann (1990) proposed a *nonsingle-valued error correction* representation,

$$(1-B)Q_t = -\lambda[\alpha_1(Q_{t-1}-Q_{t-1}^*)^{\Delta+} + \alpha_2(Q_{t-1}-Q_{t-1}^*)^{\Delta-}] + a_1(1-B)X_{t-1} + \dots + a_p(1-B)X_{t-p} + \varepsilon_t \quad (2.6)$$

where $(Q_t - Q_t^*)^{\Delta+} = \{(Q_t - Q_t^*) \text{ if } (1-B)(Q_t - Q_t^*) > 0, \text{ and } 0 \text{ otherwise}\}$ and $(Q_t - Q_t^*)^{\Delta-} = \{(Q_t - Q_t^*) \text{ if } (1-B)(Q_t - Q_t^*) < 0, \text{ and } 0 \text{ otherwise}\}$. In this representation the adjustment parameter is different depending on whether the previous error correction term was increasing ($\lambda\alpha_1$) or decreasing ($\lambda\alpha_2$). Notice that the linear error correction is nested in this model ($\alpha_1=\alpha_2$).

Finally, we will estimate Escribano's (1986) model, *the cubic polynomial error correction* representation,

$$(1-B)Q_t = -\lambda[\alpha_1(Q_{t-1}-Q_{t-1}^*) + \alpha_2(Q_{t-1}-Q_{t-1}^*)^2 + \alpha_3(Q_{t-1}-Q_{t-1}^*)^3] + a_1(1-B)X_{t-1} + \dots + a_p(1-B)X_{t-p} + \varepsilon_t \quad (2.7)$$

This cubic adjustment is more flexible than Granger and Lee because it can smoothly adjust to asymmetric reactions and at the same time we can estimate the breaking point (of zero adjustment) without having to impose it at the outset. This model worked well estimating the money demand function in the U.K from 1978 to 1990, see Escribano (1986) and Hendry and Ericsson (1991).

Escribano and Pfann(1993) have shown that these last three nonlinear error correction models can be derived from a general intertemporal optimization problem,

$$\text{Min}_{Q_t} E_t\{\sum_{i=0}^{\infty} \beta^i [f(Q_{t+i} - Q_{t+i}^*) + (1/2)\gamma[(1-B)Q_{t+i}]^2] | \Omega_t\} \quad (2.8)$$

where the function $f(\cdot)$ changes depending on the type of asymmetry.

After briefly describing the data in the next section, we compare the empirical results of estimating these competing types of asymmetric error correction representations in labour demand models.

3. Data

The dependent variable is employment (all employees in employment in the UK). The variables we include in P , the driving variables, are: the capital stock (K), the real wage (W), a measure of technical progress (TP), a measure of competitiveness ($COMP$), world trade shocks (WT) and a measure of adjusted fiscal stance (AD). Finally, note that all these variables are in logs other than WT and AD and that the equation also contains seasonal dummies.

Turning to the adjustment costs, Z , we consider first hiring costs. Hiring costs depend on labour market tightness² (the number of applications per vacancy) and possibly other factors affecting the job matching rate. An element of this may be the average offer acceptance rate, depending on the unemployment benefit rate. The higher this is, the fewer searchers remain on the market and this raises costs. Our measure of labour market tightness is a modified unemployment/vacancy ratio (denoted h) and we include both h and h^2 to allow for potential convexity of the hiring cost function. Turning to firing costs, two variables are included. These are a measure of the costs imposed by Unfair Dismissal Legislation (udl) and a measure of union power (m) to capture the notion that unions can

² See Burgess (1992) for details.

impose costs on firms wishing to reduce their workforce. A final set of adjustment costs come under neither category. Derivation of (2.4) allowing for quits shows that the quit rate affects the speed of adjustment of employment so this is included (qr).

4. Results

We take as our starting point a model that has already been fit to the data (using $\Delta \log N$ as the dependent variable), namely the time-varying adjustment model of Burgess (1992). This gives us a long run equilibrium³ and the basic dynamic specification. In terms of the notation of section 2, $Q = \log N$, $Q^* = \log K - 2.247 + 0.0782 \cdot \log W - 0.327 \cdot \log \text{COMP} - 1.895 \cdot \text{AD} + 0.046 \cdot \text{TP}$, and the error correction term is $\text{ect} = Q_{t-1} - Q^*_{t-1}$.

The first issue that arises is that unlike the original Granger and Lee (1989) and Escribano (1986) papers, we derive the ect from a dynamic equation, not a cointegrating relationship. Given that we only have around 70 observations, this may be the appropriate course to take to reduce the bias of the estimators. One implication of this decision is that the mean of the ect is not necessarily zero; we return to this below. As noted in the Tables, the equations include in addition to the various terms in the ect, dynamic terms in the lagged dependent variable and the explanatory variables. We did not in this paper engage in any further data search for other specifications, but in all cases, the dynamic terms considered by Burgess (1992) remained significant.

³ See the original article for a discussion of the degree of integration of the series. Constant returns to scale was tested before being imposed.

Table 1 gives the first set of results⁴. The main terms in the ect are presented for the basic linear error-correction model, for the Granger-Lee model, the Escribano-Pfann model, the Escribano (cubic) model and the Burgess model (as in the 1992 paper). The linear model provides a reasonable description of the data, including a well determined ect coefficient with a low value typical of employment equations. This is the standard type of equation that is fit to many datasets. The Granger-Lee model appears to work well, being significantly different from the linear model with the negative component being insignificant. The two ect terms are far apart, one being five times the size of the other. In fact the ect term is very imprecisely determined. This is partly because there are fewer observations for which this is non-zero, see Figure 1: this is the consequence of taking the ect from the long run solution rather than a cointegrating regression. In fact, if we recompute the ect⁺ and ect⁻ terms in the following way: ect⁺ = ect if ect > mean (ect) | zero otherwise, and ect⁻ = ect if ect ≤ mean (ect) | zero otherwise, then nothing much changes (the ect⁻ term becomes slightly better determined): the ect⁺ coefficient becomes -0.123 (t = 6.9) and the ect⁻ coefficient becomes -0.042 (t = 1.9), $\sigma = 0.002838$, mean (ect) = 0.0143, which is 0.41 of a standard deviation (of ect) from zero. We therefore continue to use zero as the threshold rather than the mean of the ect since this seems to fit better with the intuition of the approach.

The Escribano-Pfann approach produces nothing significantly better than the linear model, the two ect terms being insignificantly different (ie. equivalent to the linear model).

The Escribano model, the cubic in the ect, works better, essentially as well as the Granger-Lee model. Again the additional terms are significant. Interestingly though, the

⁴ Give that there are no contemporaneous variables on the right hand side, we simply used OLS.

estimated coefficients produce an adjustment profile with an unstable region: see Figure 2 for the adjustment profiles of all the models. The backward bending section is unstable, though in fact there is very little mass there: only around 10% of the observations are at or beyond the turning point. Note that the adjustment implied by the Escribano approach mimics that of the Granger-Lee estimates.

As might be expected given the importance of time-varying variables, the three time-invariant asymmetric adjustment models all spectacularly fail the Chow forecast test.

The final column replicates the Burgess (1992) findings. All the Z variables multiplying the *ect* work well. The ones to highlight are the h and h^2 terms since these are capturing the endogenous adjustment costs, the state of the labour market. The estimated signs imply that employment adjustment is increasingly slower in tighter labour markets. The adjustment profile graphed in Figure 2 for this approach is interesting since it does not show a strongly nonlinear relationship to the *ect*. This highlights an important difference between the time-varying parameter approach and the other three models. The Granger-Lee, Escribano-Pfann and Escribano models all define the nonlinear adjustment in terms of the *ect*; that is, the strength of the attractor depends on some function of the disequilibrium. By contrast the time-varying approach sets the speed of adjustment as a function of the *level of the variable*. We return to this point below.

The next stage of the analysis is to test the different representations against each other. To do this, we re-estimate the Granger-Lee, Escribano-Pfann and Escribano models including the time-varying variables as well and compute nested tests. Table 2 contains the results. The Escribano-Pfann model provides no additional explanatory power, the p-value for the difference between the two *ect* terms being 0.55. The Granger-Lee approach produces more marginal results. The two *ect* terms are both significant and are between

one and two standard errors apart. The p-value for a significant difference is 14%; including the full standard ect term and one of the split terms produces a t statistic on the latter of 1.3, with a p-value of 20%. So at standard significance levels, the Granger-Lee hypothesis is rejected, though fairly marginally. The time varying adjustment costs remain strongly significant, particularly the labour market adjustment variables, h and h^2 . If we redefine ect^+ and ect^- as above using the mean (ect) as the threshold, the result is actually less favourable: the χ^2 (1) statistic falls to 1.889. If we delete two of the weakest time-varying variables multiplying the ect , q (quit rate) and m (union membership), the test becomes χ^2 (1) 3.738 (p-value = 5.3%), or a t statistic of 1.73 (p-value = 9%). Thus it seems that both approaches share some common information, and the decision to include the Granger-Lee variables is a matter of economic interpretation.

Comparing Figures 2 and 3, it is interesting to note that the direction of the asymmetry changes sign: including the time-varying variables, it suggests adjustment is slower when the ect is positive (employment is falling), whereas before the reverse was implied. It seems that this may be because in the first run without the extra variables, the split ect terms were trying to do two jobs. They were acting as a crude proxy for the employment adjustment costs (that is, the level of N) as well as the sign of the disequilibrium. In the second run, they are freed of the first duty and can pick up the second factor by itself.

Turning to the Escribano model, again, the time-varying variables remain significant. Of the polynomial terms in ect , the cubic is insignificant, and the square is marginally so. The joint test of the two gives a χ^2 (2) of 3.69 (p-value of 16%). A number of points are worth making. First, the adjustment profile is now stable throughout its range. Second, the second derivative here has also changed sign, again mimicking the

Granger-Lee outcome. Finally, one of the advantages of the cubic estimation is that it is flexible enough to pick up any zero adjustment range around $ect = 0$. It is clear from the graphs that there is no evidence of such a range here.

5. Conclusions

In this paper we investigate the empirical content of three asymmetric error correction models that have recently been proposed. Granger and Lee (1989) and Escribano (1986) allow for the error correction force to have different strength either side of the equilibrium attractor. Escribano and Pfann (1990) model asymmetric adjustment in terms of the change increasing or decreasing disequilibrium. These models are compared with the work of Burgess (1988, 1992) on time-varying (endogenous) adjustment models, in the context of UK employment determination.

We can summarise the results as follows. Excluding the time-varying variables, both the Granger-Lee and the Escribano models perform well. Inclusion of the time-varying variables renders the split error correction term of Granger-Lee and the polynomial terms of Escribano insignificant, though marginally so. Interestingly, the nature of the asymmetry changes between including and excluding the time-varying variables.

The main point of interest to emerge is that nonlinearities in the dynamics of aggregate employment appear to be better modelled as a function of the level of employment than as a function of the employment disequilibrium. One way to interpret

this is that asymmetries within the firm (of the adjustment cost function) are less important than asymmetries imposed at the level of the market, that is aggregate labour market tightness.

Table 1: Asymmetric and Time-Varying Error Correction Representations

Variable	Linear Model	Granger-Lee		Escribano-Pfann		Escribano (cubic)		Burgess	
ect	-0.092 (6.0)	ect+	-0.136 (7.1)	ect Δ +	-0.103 (5.5)	ect	-0.107 (5.4)	ect	-0.134 (10.0)
		ect-	-0.025 (1.0)	ect Δ -	-0.081 (4.4)	ect ²	-0.742 (3.5)	ect*u	1.3e-7 (7.8)
						ect ³	7.278 (1.9)	ect*b	0.847 (2.8)
								ect*m	1.187 (2.5)
								ect*q	-0.055 (1.9)
								ect*h	-0.021 (4.5)
								ect*h ²	0.2e-3 (4.0)
Rbar ²	0.810		0.840		0.811		0.839		0.911
σ	0.00302		0.00277		0.00302		0.00278		0.00207
Test against Linear (p-value)		$\chi^2(1)$	12.78	$\chi^2(1)$	1.36	$\chi^2(2)$	13.47	$\chi^2(6)$	58.51
LM(5) (p-value)		$\chi^2(5)$	8.86	$\chi^2(5)$	13.76	$\chi^2(5)$	8.26	$\chi^2(5)$	8.56
ARCH(5) (p-value)		$\chi^2(5)$	6.16	$\chi^2(5)$	4.25	$\chi^2(5)$	3.37	$\chi^2(5)$	2.35
Heteroskedasticity (p-value)		$\chi^2(16)$	19.59	$\chi^2(16)$	59.57	$\chi^2(16)$	16.56	$\chi^2(16)$	15.35
Chow (p-value)		$\chi^2(24)$	62.08	$\chi^2(24)$	78.21	$\chi^2(24)$	65.70	$\chi^2(24)$	35.81

Note that each column also includes the following variables: constant, seasonal dummies, $\Delta \log N_{123}$, $\Delta_2 \log w_{t-1}$, $\Delta_1 \log comp_{t-1}$, and $\Delta_3 w_{t-1}$. The estimates of these coefficients (available from the authors) are very similar between the specifications and are omitted to enhance clarity. t stats in parentheses. LM test is for serial correlation; Heteroskedasticity is the White test; Chow is the Chow forecast test over a break at 1980:1. The test against linear is a simple difference in log likelihood values.

Table 2: Testing Asymmetric Error Correction Against Time-Varying Nonlinear Dynamics

	Granger-Lee		Escribano-Pfann		Escribano (cubic)	
	ect ⁺	-0.1138 (5.5)	ect ^{Δ+}	-0.1309 (8.8)	ect	-0.1507 (8.1)
	ect ⁻	-0.1872 (4.3)	ect ^{Δ-}	-0.1394 (8.3)	ect ²	0.6116 (1.6)
					ect ³	-1.2543 (0.3)
	ect* ^u	1.51e-7 (6.4)	ect* ^u	1.31e-7 (7.7)	ect* ^u	1.56e-7 (6.6)
	ect* ^b	1.088 (3.0)	ect* ^b	0.859 (2.8)	ect* ^b	1.108 (3.1)
	ect* ^m	1.124 (2.3)	ect* ^m	1.201 (2.5)	ect* ^m	0.921 (1.8)
	ect* ^q	-0.048 (1.6)	ect* ^q	-0.057 (1.9)	ect* ^q	-0.047 (1.6)
	ect* ^h	-0.019 (3.9)	ect* ^h	-0.021 (4.5)	ect* ^h	-0.018 (3.6)
	ect* ^h ²	0.21e-3 (3.1)	ect* ^h ²	0.25e-3 (4.0)	ect* ^h ²	0.20e-3 (2.9)
Rbar ²		0.9116		0.9092		0.9119
σ		0.00206 †		0.002090		0.002059
Test against Burgess: (p.val)	χ ² (1)	2.1670	χ ² (1)	0.3642	χ ² (2)	3.6936
		0.141		0.546		0.158

Note that each column also includes the following variables: constant, seasonal dummies, $\Delta \log N_{123}$, $\Delta_2 \log w_{t-1}$, $\Delta_4 \log comp_{t-1}$, and $\Delta_3 w_{t-1}$. The estimates of these coefficients (available from the authors) are very similar between the specifications and are omitted to enhance clarity. t stats in parentheses. The test against Burgess is a simple difference in log likelihood values.

Fig. 1: Error Correction Term: +/- Split

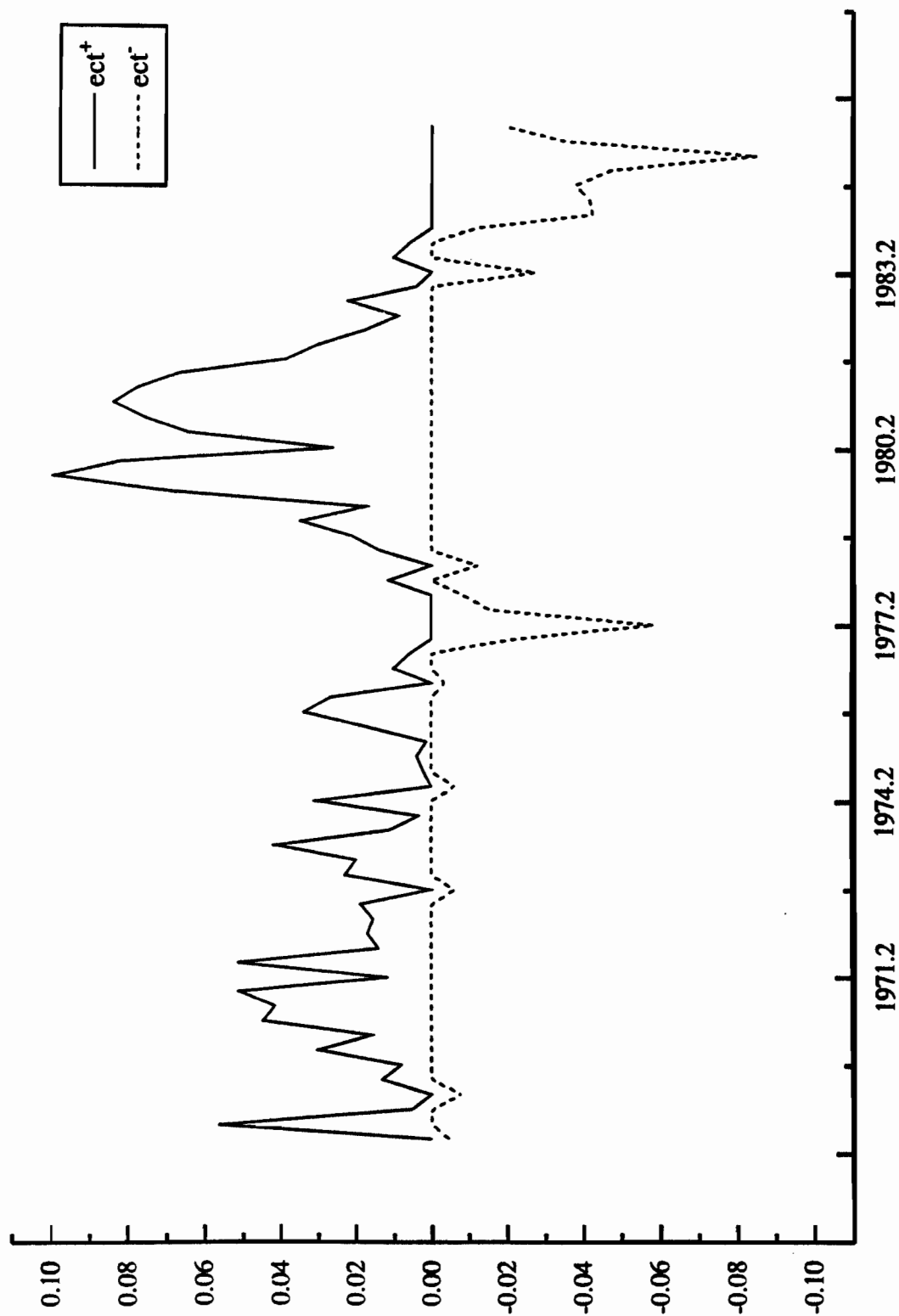


Fig. 2: Asymmetric and Time-Varying Error Correction
Representations of Nonlinear Adjustment

The horizontal axis is the ect, the vertical axis is the adjustment

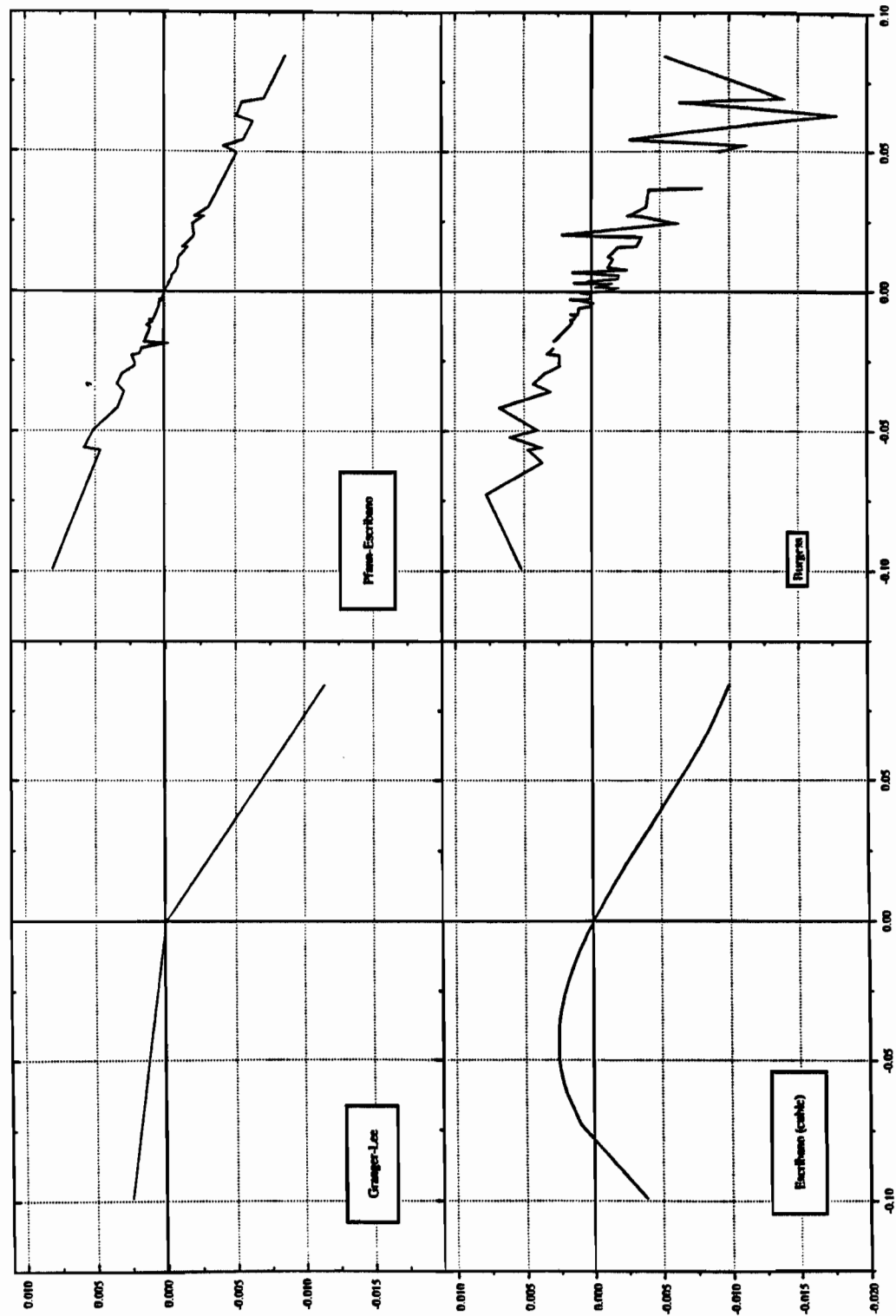
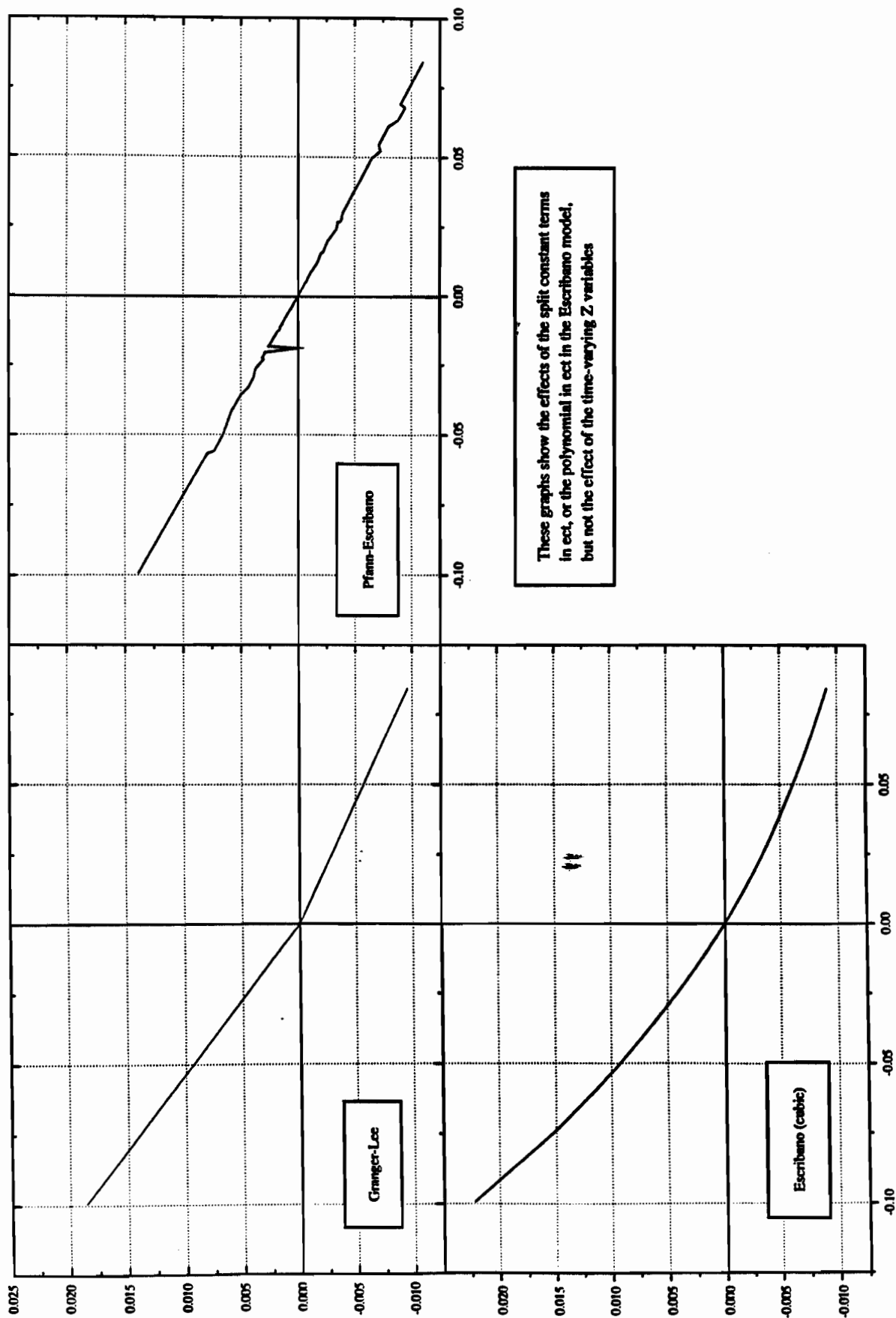


Fig. 3: Alternative Representations of Nonlinear Adjustment

The horizontal axis is the ect, the vertical axis is the adjustment



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