6 Application: International Commodities Prices

A leading application of nonlinearity in ECMs is price adjustment of identical products traded in separate markets. It is reasonable to expect these prices to be cointegrated, otherwise there would be perennial arbitrage opportunities. Yet, for each arbitrageur there must be a minimum deviation to cover transaction costs. Therefore, the adjustment should be nonlinear. Examples are tradable goods in the American CPI in Lo and Zivot (2001) [15], stocks and their respective Depositary Receipts in Chung, Ho and Wei (2005) [4], agricultural commodities prices in Balcombe, Bailey and Brooks (2007) [2], among many others.

In Balcombe, Bailey and Brooks (2007) [2], Bayesian estimation is used to avoid the issues already mentioned in nonlinear ECMs. They find evidence of nonlinearity in adjustment of Brazilian and American prices of maize, soybeans and wheat. We will apply our methodology to a database similar to the one used there. It is a monthly prices series from United States Department of Agriculture (USDA) to USA and Argentina prices and from Institute for Pure and Applied Economics Research (IPEA) to Brazil prices of each one of the three products, consisting of 151 observations from October/1996 to April/2009.

All series are $I(1)$, either by Augmented Dickey-Fuller or Phillips-Perron tests. Both Engle-Granger and Johansen tests for linear cointegration indicate the presence of cointegration vector (1,-1). For the sake of brevity we do not report these results here.

On Table 6.1 we see the results for our nonlinearity test. We find strong evidence of nonlinearity on the adjustments of wheat prices from Argentina (both to Brazil and United States) and weak evidence on the adjustment of soybeans prices from the United States (again, both to Brazil and Argentina).

We will estimate the nonlinear ECM for the two wheat prices pairs. But first, we estimate the linear ECMs for both pairs, in order to compare the results afterwards. The lag length selection is made by the Schwartz

Table 6.1: Linearity Tests.

Commodity	Country Pair	F statistic	P-Value
Wheat	US ARG	35.60026	0.0000
	US BR	5.313077	0.2567
	BR ARG	38.48891	0.0000
Soybean	US ARG	7.716483	0.1025
	US BR	8.660560	0.0702
	BR ARG	2.307507	0.6794
Maize	US BR	3.175390	0.5289

Table 6.2: Linear ECM Estimations for Wheat Prices

United States and Argentina			Brazil and Argentina		
	Estimate	Std. Deviation		Estimate	Std. Deviation
β_2	1.012794	0.004632	β_2	1.004575	0.004522
α_{US}	-0.009278	0.038997	α_{Br}	0.057601	0.060062
α_{Arg}	0.235855	0.099806	α_{Arg}	-0.218631	0.049419
R^2 US equation		0.0524	R^2 Br equation		0.2048
R^2 Arg equation		0.2683	R^2 Arg equation		0.1939

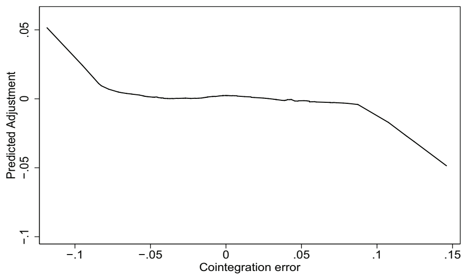
Information Criterion. The ECMs are estimated without constant both in the cointegration equation and in the VAR. The equation to be estimated is

$$\begin{pmatrix} \Delta p_{it} \\ \Delta p_{jt} \end{pmatrix} = \begin{pmatrix} \alpha_i \\ \alpha_j \end{pmatrix} (p_{it-1} - \beta_2 p_{jt-1}) + \mathbf{\Gamma}_1 \Delta \boldsymbol{p}_{t-1} + \boldsymbol{u}_t, \tag{6.1}$$

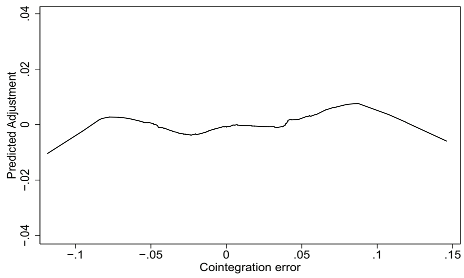
where i and j are the countries. Our parameters of interest are α_i and α_j, which tells us how much prices adjust in response to deviations from the long run equilibrium and β_2, which gives us the long run equilibrium of the prices. The results are in Table 6.2. Both pairs have a (1,-1) cointegration vector, meaning the prices are equal in equilibrium. Furthermore, in both cases it is the price in Argentina that moves in response to disequilibria.

To decide which nonlinear model to estimate, we make a semi-parametric regression. The results, seen in Figure 6.1, panels (a), (b), (c) and (d), show that for small deviations there is no adjustment. After a threshold the adjustment is proportional to the deviation size. This features are consistent with the presence of transaction costs. Moreover, two graphics show no reaction to deviations, which are exactly the non-significant coefficients from the linear estimates. The function shape is very similar to the Smooth Transition Model from Suárez-Fariãs, Pedreira and Medeiros (2004) [24], of which the graphic is in Figure 6.1(e). We will estimate the model with this nonlinear function.

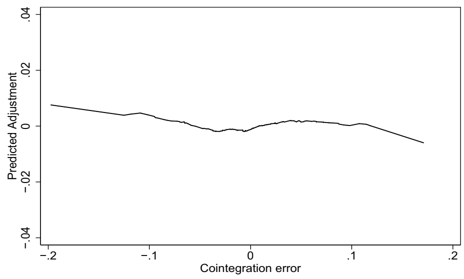
The expression for the function is



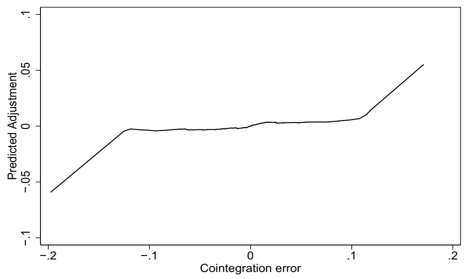
6.1(a): Nonparametric Argentina's reaction to Brazil



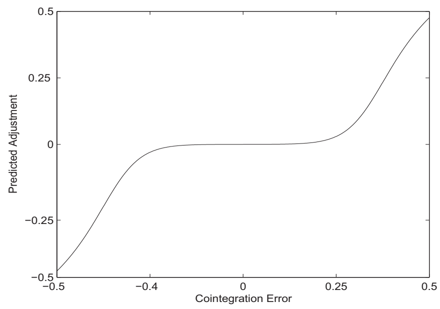
6.1(b): Nonparametric Brazil's reaction to Argentina



6.1(c): Nonparametric United States' reaction to Argentina



6.1(d): Nonparametric Argentina's reaction to United States



6.1(e): Proposed parametric function

Figure 6.1: Adjustment functions

Panels (a), (b), (c) and (d) display the nonparametric estimations. Panel (e) displays the function used in the estimation.

Table 6.3: Nonlinear ECM Estimations for Wheat Prices

United States and Argentina			Brazil and Argentina		
	Estimate	Std. Deviation		Estimate	Std. Deviation
λ	28.0915	10.8536	λ	65.2485	18.1752
c	0.1742	0.0284	c	0.1211	0.0112
β_2	1.0135	0.0069	β_2	1.0038	0.0068
α_{US}	-0.1516	0.1083	α_{Br}	0.1440	0.1010
α_{Arg}	0.8819	0.2073	α_{Arg}	-0.9164	0.1726
1st Regime %		0.054	1st Regime %		0.044
R^2 US equation		0.0716	R^2 Br equation		0.2204
R^2 Arg equation		0.4129	R^2 Arg equation		0.3871

$$\begin{aligned} F(p_{it-1} - \beta_2 p_{jt-1}, \lambda, c) = 1 + & \frac{1}{1 + \exp[-\lambda(p_{it-1} - \beta_2 p_{jt-1} - c)]} \\ - & \frac{1}{1 + \exp[-\lambda(p_{it-1} - \beta_2 p_{jt-1} + c)]} \end{aligned} \tag{6.2}$$

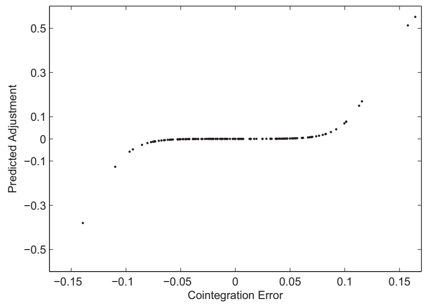
And the model to be estimated is

$$\begin{pmatrix} \Delta p_{it} \\ \Delta p_{jt} \end{pmatrix} = \begin{pmatrix} \alpha_i \\ \alpha_j \end{pmatrix} (p_{it-1} - \beta_2 p_{jt-1}) \, F\,(p_{it-1} - \beta_2 p_{jt-1}, \lambda, c) + \boldsymbol{\Gamma}_1 \Delta \boldsymbol{p}_{t-1} + \boldsymbol{u}_t.$$

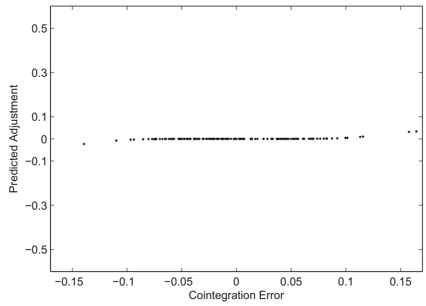
The estimation procedure is not straightforward. As noted in Terasvirta (1994) [25], the joint estimation of λ and the rest of the parameters is difficult. Numerical problems arise, making the convergence too slow and inflating the estimated parameter. We adopt the same solution proposed in that paper, which is to perform a grid search over (λ, c) and then estimate the rest of the parameters given these numbers. Afterwards we use these estimates as starting points for the minimization problem in Equation (4.1).

The results are in Table 6.3. For the prices from United States and Argentina, the estimated threshold is 0.1742. In our motivation, this means that if the difference between prices is less than 17.42%, there is not enough arbitrage pressure to drive the prices back to the equilibrium. When the difference is bigger than 17.42%, arbitrageurs enter the market, forcing the prices back to the long run equilibrium. For the prices from Brazil and Argentina, this threshold is 12.11%, less than the previous one. This makes sense, since we expect the transaction costs to be smaller between markets closer to each other.

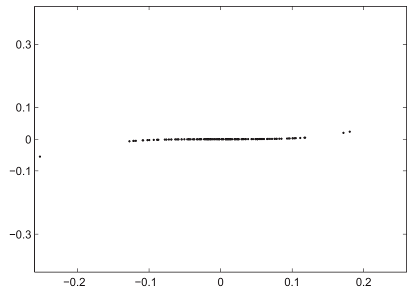
As expected, in comparison with the linear model, the estimated long run equilibrium, β, has almost not changed. The adjustment coefficients estimates, α, are not directly comparable. They have the same meaning only for sufficiently large cointegration errors, when the nonlinear adjustment function is already proximate to its linear limit. For small deviations, Figure 6.2 shows the shape of the estimated functions in each equation of the two nonlinear ECMs. Since in the linear ECM, this function would be linear with inclination equal to α_i, it is clear that our nonlinear estimates predict smaller adjustment for smaller cointegration errors and higher adjustment for higher cointegration errors.



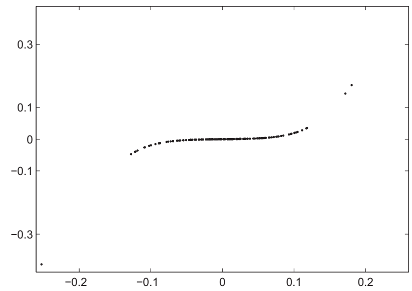
6.2(a): Estimated Argentina's reaction to Brazil



6.2(b): Estimated Brazil's reaction to Argentina



6.2(c): Estimated United States' reaction to Argentina



6.2(d): Estimated Argentina's reaction to United States

Figure 6.2: Estimated Adjustment Functions