Local polynomial fitting and spatial price relationships: price transmission in the EU markets for pigmeat

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Contributed paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-18, 2006

Abstract

We apply nonparametric methods to assess price transmission processes within the EU pig markets. We compare results derived from nonparametric regressions with those obtained using alternative nonlinear threshold models. Results show that nonparametric regressions support the parametric results. However, parametric techniques often suggest a higher degree of price transmission than that implied by threshold models

1. Introduction

Spatial price transmission has been a highly investigated topic. The relevance of this issue has yielded a series of empirical methods that allow to assess the extent to which price signals are transmitted between spatially separate markets (Fackler and Goodwin, 2001). Given the usually nonstationary nature of price data series, recent contributions have underlined the need to use econometric techniques adequate for dealing with nonstationary and cointegrated data. A current issue of analysis is the nonlinear nature of spatial price relationships, that has been often attributed to a lack of perfect arbitrage resulting from transactions costs and uncertainty. According to Obstfeld and Taylor (1997), transactions costs and uncertainties may cause arbitrage activities to only take place after price differentials exceed certain amounts. It is also relevant to note though that explicit trade between a pair of markets may not be necessary in order for price adjustments to take place. Consider, for example, two agents in spatially distinct markets selling into a third common market. One would expect that the actions of buyers would result in equilibrating pressures that should equalize prices without any direct flow of commodities existing between the pair of markets. Although competing hypothesis may underlie a certain form of revealed price behavior, we believe it is relevant to characterize the nature of spatial price transmission and thus we make this issue the focus of this article.

Several econometric procedures have been devised to capture nonlinear price relationships. Recently, Chavas and Metha (2004) have proposed an extended error correction model that allows price dynamics to differ across regimes. While these authors treat regime switching as exogenous, more general models of asymmetry incorporate this issue as endogenous. These models include threshold autoregressive (TAR) models (Obstfeld and Taylor, 1997), or threshold vector error correction (TVECM) models (Goodwin and Piggott, 2001). All these approaches have in common their parametric nature. Parametric approaches to model price relationships require the formulation of assumptions about the true nature of price behavior that may be too restrictive or unrealistic. In threshold models, for example, each threshold separates two linear segments representing price adjustment under different regimes. Hence, the transition from one regime to another is assumed sharp and discontinuous, involving that the price differentials that motivate individuals to undertake arbitrage activities and/or adjust prices, are common across economic agents. This assumption may be adequate if transactions costs and uncertainties were homogeneous across different individuals, but might be too restrictive otherwise. The smoothed TAR models introduced by Terasvirta (1994) partially overcome this limitation by allowing for gradual adjustments between regimes. However, in being parametric, these models still carry the potential for specification biases as a result of an inappropriate parametric assumption.

Contrary to parametric models, nonparametric techniques such as local polynomial modeling (see Fan and Gijbels, 1996, chapter 3) do not require any assumption about the functional form characterizing price behavior. In being data driven methods, it is the data that informs and determines the shape of the relationships among the variables studied. Up to date, the use of nonparametric techniques to study nonlinear aspects of price transmission has been very limited. Mancuso, Goodwin and Grennes (2003) assessed capital market integration by using local linear regression models. Though price transmission between spatially separate food markets has been an important research topic, no analysis has attempted to address spatial food price relationships using nonparametric techniques.[1]

The objective of this article is to assess price transmission between EU pigmeat markets by employing nonlinear methods. To do so, we first test for the law of one price by using local

[1] An exception is the paper by Barrett and Li (2002) that includes a semi-parametric test for spatial market equilibrium.

polynomial modeling techniques. We then compare the results derived from these flexible nonparametric techniques with those obtained from more restrictive parametric threshold autoregressive models. Although both techniques yield similar qualitative results, important differences arise in the way price linkages are modeled.

2. The main characteristics of pig sector in the EU

The EU-15 occupies prominent positions in worldwide rankings of pigmeat production and trade. It is the world's second largest swine producer after China and is followed, at a distance, by the United States of America. EU pigmeat productive capacity yields self-sufficiency levels above 100% (almost 107% in 2003) [2], which explains the strong export orientation acquired by this sector. This orientation is especially relevant in some countries such as Denmark. Although there are relevant pigmeat trade flows with non-EU member countries, the most intensive trade streams occur within the EU. In 2002, for example, intra EU pigmeat trade accounted for 2.7 million tones, being EU exports and imports on the order of 1.2 million tones and 51,000 tones respectively.

Pigmeat production represents around 8% of the EU gross agricultural product. Germany, Spain, France and Denmark are the four top EU-15 pigmeat producers. The majority of pigmeat is produced under intensive systems, which generally reduce heterogeneity across countries. In spite of this, there exist relevant differences in average carcass weight preferences across EU member states: while some exceptions occur, north-central Europe has a preference for heavy carcasses and southern Europe chooses lighter deadweights.

Our analysis of pigmeat price transmission focuses on four countries: Germany, Spain, France and Denmark. As noted before, these are the four leading pigmeat producers in the EU,

[2] All data offered in this section are derived from Eurostat and refer to the EU-15 group.

representing more than 60% of net pigmeat output. They also represent a conspicuous part of intra EU trade: almost 40% of total imports and around 55% of total exports in 2003, being Germany the first importer and Denmark, together with the Netherlands,[3] a leading exporter. While Germany and France produce heavy carcasses above the EU average weight (around 87-88 kg), Spain and Denmark have a preference for lighter animals. As it will be shown in the results section, however, these differences in production do not preclude prices being transmitted across these countries.

3. Methodology

Up to date, analyses of price transmission have typically been based on parametric approaches that possibly make too strong and inadequate assumptions on the true nature of price transmission. Because nonparametric techniques do not require any preliminary guess on price behavior, we are interested in applying these techniques to a characterization of spatial price relationships, and in comparing the results with those arising from alternative parametric TAR models. For ease of exposition, we first describe the parametric techniques to then offer details on the nonparametric methods employed.

3.1. Threshold Autoregressive Models

Obstfeld and Taylor (1997) propose the use of a threshold autoregressive model (TAR) of price differentials to assess price transmission across spatially separate markets in the presence of transactions costs or uncertainty. This model introduces an important concept: that of commodity points that may reflect the influence of the aforementioned transactions costs. Threshold models

[3] Our focus is on meat price transmission in the EU. Although the Netherlands is a relevant exporter, this country leads in live animal exports.

are useful in situations where the economic behavior cannot be captured by a single regime. This occurs when some forcing-variable leads a switching, that can occur back and forth, among different regimes. These regimes are represented by different parameter estimates of the underlying model. Usually, analyses of spatial price behavior take the magnitude of regional price differentials as the variable that determines regime-switching (Mancuso, Goodwin, and Grennes, 2003).

A simple autoregressive model (AR) of price differentials can be represented as: $Y_t = \beta X_{t-1} + e_t$, where $Y_t = (P_{it} - P_{jt}) - (P_{it-1} - P_{jt-1})$ represents the adjustment in regional price differences in period t, being P_{it} and P_{jt} the prices of a certain commodity in two spatially separate markets (i and j). $X_{t-1} = (P_{it-1} - P_{jt-1})$ is the value of the regional price differences in the previous period $t-1$, and e_t is a white noise error term. As noted above, under a TAR model, price differences $\left(X_{t-1}\right)$ allow to distinguish among different regimes that represent different price behavior. These different regimes are represented by different values of the parameter β. A three regime TAR can be expressed as follows:

$$Y_t = \begin{cases} \beta^{(1)} X_{t-1} + e_t^{(1)} & if \quad -\infty < X_{t-1} \le c_1 \\ \beta^{(2)} X_{t-1} + e_t^{(2)} & if \quad c_1 < X_{t-1} \le c_2 \\ \beta^{(3)} X_{t-1} + e_t^{(3)} & if \quad c_2 < X_{t-1} \le +\infty \end{cases} \qquad (1)$$

The TAR model can be estimated using sequential iterated least squares regression in two steps. In the first step a grid search is conducted to estimate the threshold parameters c_1 and c_2. The first or lower threshold is searched over the minimum and the median of the lagged price differences, while the upper threshold is searched over the range that goes from the median to the maximum of the lagged price differences. This search is restricted in order to ensure an adequate number of observations in each regime. For a given pair (c_1, c_2), $\beta^{(1)}$, $\beta^{(2)}$, and $\beta^{(3)}$ can be determined through the OLS regressions of Y_t on X_{t-1} for each subsample. From this estimation, the residual sum of squares is derived giving $\hat{\sigma}(c_1, c_2) = \sum_{t=1}^{n} \hat{e}_t(c_1, c_2)^2$. The aim of the grid search is to maximize a standard *F* test for a linear AR against the alternative of a TAR: $F = \frac{\tilde{\sigma}^2 - \hat{\sigma}^2(c_1, c_2)}{\hat{\sigma}^2(c_1, c_2)} n$, where n represents the number of observations, $\hat{\sigma}^2(c_1, c_2)$ stands for the error variance of the TAR model, being $\tilde{\sigma}^2$ the error variance of the AR model. Hence, in the second step of the process, the estimates of c_1 and c_2 are obtained as: $(c_1, c_2) = \arg\min_{c_1, c_2} \hat{\sigma}^2(c_1, c_2)$, which is equivalent to maximizing *F*. As is usual, the *F* test for the significance of the differences in parameters across regimes is presented (see table 1). Because this test does not have a standard distribution, its p-value is determined following the method provided by Hansen (1997). In case the three-regime TAR is not found significant against the AR model, a two-regime TAR is estimated and tested against the AR.

3.2.. Local polynomial fitting

Locally weighted regression techniques, which consist of locally approximating a polynomial regression, have been thoroughly studied by the literature (see Cleveland, Devlin and Grosse, 1999; Fan, 1992; or Fan and Gijbels, 1995). Specifically, we use a local linear regression (LLR) to estimate a nonparametric version of a threshold autoregressive model of spatial price differentials. To do so, consider a series of independently identically distributed observations (X_{t-1}, Y_t) for *t=1,…,n*, from a population (X_{-1}, Y). As noted, Y_t represents the adjustment in regional price differences in period t and X_{t-1} is the value of the regional price differences in the previous period $t-1$. To estimate the local regression function $m(x_k) = E\left(Y \middle| X_{-1} = x_k\right)$ using a polynomial of order 1, the following weighted least squares problem needs to be solved:

$$\min_{a,b} \sum_{t=1}^{n} \left(Y_t - a - b(X_{t-1} - x_k)\right)^2 K_t\left(\frac{X_{t-1} - x_k}{h_k}\right) \tag{2}$$

where h_k is the bandwidth that controls for the size of the neighborhood of x_k. K is a kernel function with a support contained in $[-1,1]$ whose role is to smooth data points in the given local neighborhood. In other words, K is a weighting scheme to the local least squares problem that down-weights the contribution of those observations away from x_k.

An optimum constant bandwidth ($h_k = h$) is selected using the cross validation technique. This technique chooses h to minimize the squared prediction error: $\sum_{i=1}^{n}\left(Y_t - \hat{Y}_t\right)^2$, where $\hat{Y}_t$ is the predicted value for Y_t using the Nadaraya-Watson estimator: $\hat{Y}_t = \left(\sum_{t=1}^{n} K_t\left(\frac{X_{t-1} - x_k}{h}\right)\right)^{-1}\left(\sum_{t=1}^{n} K_t\left(\frac{X_{t-1} - x_k}{h}\right) Y_t\right)$. The minimization process requires the computation of the squared prediction error at different bandwidth gridpoints. The bandwith h is searched between 0.1 and 2 standard deviations of the independent variable X_{t-1}. As for the smoothing function, the Epanechnikov kernel is selected: $K(g) = \frac{3}{4}\left(1 - \left|g^2\right|\right) I_{[-1,1]}(g)$. The solution to the problem in expression (2) is given by:

$$\hat{m}(x_k) = \frac{S_{n,2}(x_k)T_{n,0}(x_k) - S_{n,1}(x_k)T_{n,1}(x_k)}{S_{n,2}(x_k)S_{n,0}(x_k) - S_{n,1}(x_k)^2} \qquad (3)$$

where:

$$T_{n,l}(x_k) = \sum_{t=1}^{n} K_t\left(\frac{X_{t-1} - x_k}{h}\right)(X_{t-1} - x_k)^l Y_t$$

$$S_{n,j}(x_k) = \sum_{t=1}^{n} K_t\left(\frac{X_{t-1} - x_k}{h}\right)(X_{t-1} - x_k)^j .$$

In the next section we apply the techniques described to a consideration of spatial price relationships in the EU pig markets.

4. Empirical Implementation

This article assesses price transmission processes in the EU pork markets. Weekly producer prices expressed in euro / 100 kg and covering the period 1994-2004 are used. Prices are obtained from the European Commission's publication "Agricultural Markets - Prices." As explained above, the most relevant countries in terms of pigmeat production and trade are considered: Germany, Spain, France, and Denmark.

In being nonparametric, the LLR is best interpreted by graphical representation, which recommends against specifying too complex models. In this regard, we devise the analysis to be of a pairwise nature: we define pairs of prices composed by a central market price (P_{it}) and another market price (P_{jt}). Following Sanjuán and Gil (2001), who concluded that Germany plays a dominant role in EU pig price formation, we choose Germany as the central market price (P_{it}). For each pair of prices, a TAR model and its parametric counterpart is estimated.

Results derived from the estimation of the threshold autoregressive models are presented in table 1.[4] While a three-regime TAR was statistically significant against an AR model for the pairs of prices composed by Germany and Denmark and Germany and France, price relationships between Germany and Spain were best captured by a two-regime TAR. As expected, in-band parameter estimates are not statistically different from zero, which is consistent with the existence of transactions costs and uncertainties that cause price adjustments to take place only after price differentials exceed a certain minimum amount. Out of band parameters are all negative and statistically significant. The negative out of band parameters suggest that price differentials exceeding threshold values are arbitraged away. The three-regime TAR models suggest that price transmission processes grant a certain advantage to Germany over Denmark and France: while negative price differentials are quickly adjusted, positive price differentials are corrected at a slower path. In contrast, the two-regime TAR shows that price transmission processes leave Spain on equal terms with Germany: the out of band adjustment has the same speed independently on whether price differences are positive or negative. The advantage of Germany over France and Denmark but not over Spain, might be explained both by the greater physical distance between Spain and Germany that might reduce trade flows, and by the fact that both Germany and Spain are the leading EU pigmeat producers and thus can compete on more equal conditions.

We find transactions costs bands to be largest for the Germany-Denmark model. While Denmark is a leading EU pigmeat exporter, Germany is the first importer. Hence, prices in Germany do probably carry a significant transactions costs charge (transportation costs for example) not reflected in Denmark prices. Hence, transactions costs bands are expected to be

[4] Before the estimation of the TAR models, each individual price series was tested for stationarity. Standard unit-root tests would confirm the presence of a unit root in all price series.

wider between an exporter and an importing country, than between two alternative importing markets. Consistently with this hypothesis, transactions costs between France (which, as Germany, has also a negative balance in the intra-EU pigmeat trade) and Germany are considerably below the transactions costs band derived in the Germany-Denmark model. Spain has a positive balance in the intra-EU pigmeat trade, being thus a net exporter. The transactions costs band for the Germany-Spain model is unexpectedly small. This small band, however, could be explained by a less intensive commercial flow between Germany and Spain relative to the trade between Denmark and Germany, which may reduce the adequateness of the interpretation of the thresholds as transactions costs bands.

The results arising from the local polynomial fitting technique are graphed in figures 1 to 3 where, for comparison purposes, the predicted TAR values are also presented. As it can be appreciated, nonparametric regressions bear a resemblance to the TAR models. Both models suggest that prices are transmitted across spatially separate EU pig markets. As a general rule, and consistently with parametric findings, the slope of the nonparametric regressions is higher for price differentials outside a certain band and smaller within this band. Hence, and as suggested by the TAR models, there exists a range of price differentials where equilibrating price adjustments may be less intense, which is compatible with the existence of transactions costs. In spite of the similarities between the two models, important differences arise. First, because local linear regression techniques do not assume homogeneous transactions costs across individuals, the transition from one regime to another is allowed to be smooth, which contrasts with the sharp and discontinuous transitions implied by the parametric techniques. A second difference comes up between the parametric within-band price behavior and the equivalent predicted values by the nonparametric techniques. Where TAR models suggest a still market, local polynomial fitting shows that a price adjustment takes place. Furthermore, this adjustment can be relatively quick as is the case with the Germany-France model. Hence, the LLR implies that markets are more strongly interconnected either through information transmission, or through arbitrage activities, than what one may conclude from simple observation of the TAR model. In the third place, nonparametric techniques suggest that TAR models, in that they are estimated with a limited number of regimes, may have difficulties in capturing the true nature of price relationships. In the Germany-Spain model, for example, big positive price differences above 15 euros, accelerate the speed of price adjustment. This acceleration is not captured by the parametric method, suggesting that another regime might be necessary if the TAR is to correctly represent true price relationships. However, a three-regime TAR for this pair of markets was estimated and rejected against a linear AR. Following the same argument and as a general rule, for big positive price differences the speed of price adjustment suggested by parametric models is slower than the one derived from the LLR. Conversely, for negative differences, the slope of the TAR regression is steeper than (or coincides with) the nonparametric one.

5. Concluding Remarks

A topic that has recently drawn analysts' attention within the field of price transmission is the nonlinear nature of price relationships. The economic literature has argued that price adjustments may only take place when regional price differences exceed a minimum amount. Threshold parametric models have been widely used to capture nonlinear price adjustments. We argue that these techniques might involve too restrictive or unrealistic assumptions about the true nature of price behavior. To overcome this limitation, we use nonparametric methods to a consideration of price transmission processes within the EU pig markets in the period of time from 1994 to 2004. We use weekly country-level price series for Germany, Spain, France, and Denmark, representing the four leading EU pigmeat producers and traders.

Results derived from nonparametric techniques are compared with those obtained from more restrictive parametric threshold models. Both methodologies suggest that EU pig markets are interrelated in that prices are spatially transmitted. However, local polynomial fitting techniques often suggest a higher degree of price transmission than that implied by TAR models. Specifically, while TAR models support the existence of a band of price differentials where no adjustment takes place, nonparametric regressions imply price adjustments even within thresholds. Hence, according to the LLR, markets are more strongly interconnected either through information or trade flows. Also, TAR models seem to have difficulties in capturing the true speed of price changes for out of band price differentials. Where an increase in out of band price differentials often changes the slope of the nonparametric regressions to make transmission processes quicker, TAR models assume the speed of adjustment is constant.

Though with some differences, both methodologies suggest that while price transmission processes grant a certain advantage to Germany over Denmark and France, they leave the two leading EU pigmeat producers (Spain and Germany) on equal terms. While negative price differentials between Germany and Denmark or France are quickly corrected, and positive price differences are arbitraged away at a slower path, the out-of-band adjustment for the Germany-Spain model has the same speed independently on the sign of the price differences.

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TABLE 1. Tsay's Test, Thresholds and the Sup-LR Test

Markets	Thresholds and F-test			TAR parameters		
	c_1	c_2	F-test (p-value)	$\beta^{(1)}$	$\beta^{(2)}$	$\beta^{(3)}$
Germany-Denmark	2.41	33.3	18.30** (0.02)	-0.50** (0.16)	-0.01 (0.01)	-0.08** (0.02)
Germany-Spain	4.77		2.46** (0.00)	-0.10** (0.02)	0.14 (0.15)	-0.10** (0.02)
Germany-France	-0.08	11.40	20.24** (0.01)	-0.36** (0.07)	0.02 (0.04)	-0.11** (0.02)

Note: Two asterisks (**) denote statistical significance at the $\alpha = 0.05$

FIGURE 1. Nonparametric and TAR model: Germany-Denmark

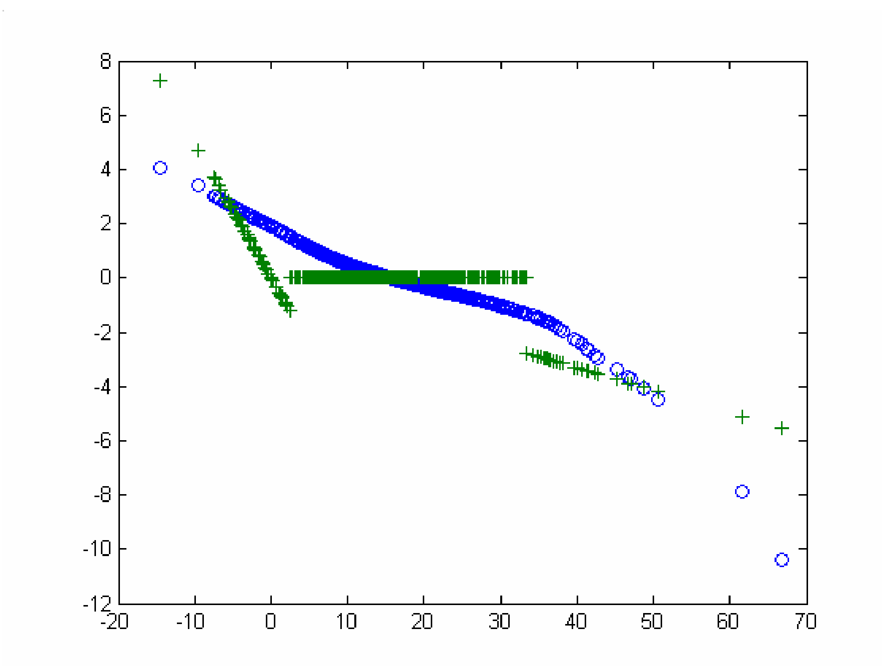
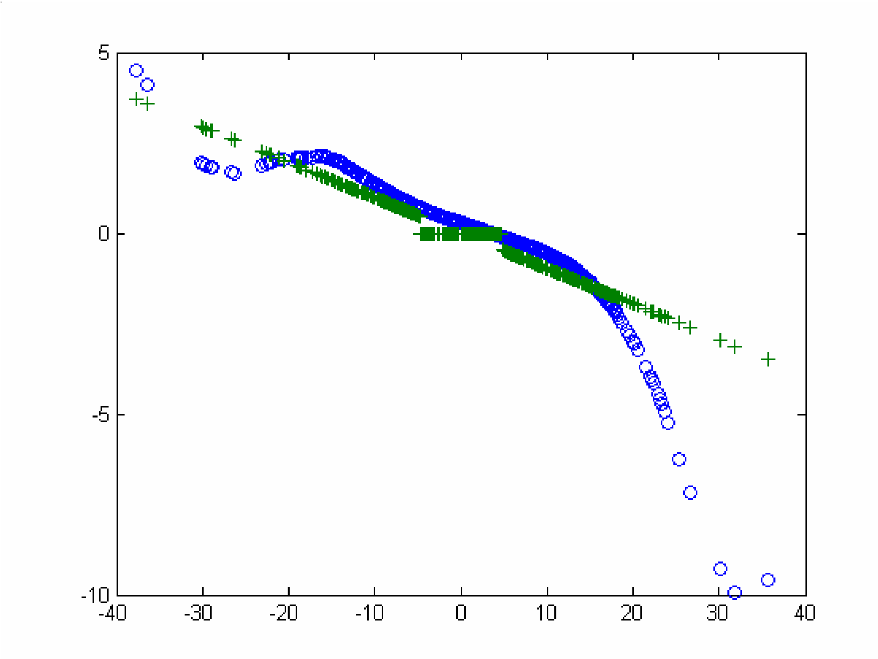


FIGURE 2. Nonparametric and TAR model: Germany-Spain

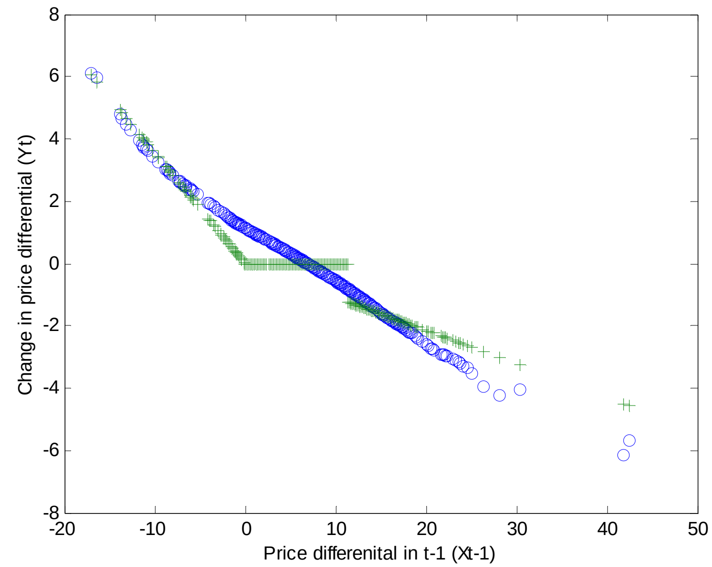


where:

○ represents the LLRE model

+ represents the TAR model

FIGURE 3. Nonparametric and TAR model: Germany-France



where:

○ represents the LLRE model

+ represents the TAR model