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RESEARCH ARTICLE

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Stationarity of seasonal patterns in weekly agricultural prices

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Abstract

Weekly series of agricultural prices usually exhibit seasonal variations and the stationarity of these variations should be taken into account to analyse price relationships. However, unit root tests at seasonal frequencies are unlikely to have good power properties. Furthermore, movements in actual price series are often not as expected when unit roots are present. Therefore, stationarity tests at seasonal frequencies also need to be applied. In this paper, a procedure to test for the null hypothesis of stationarity at seasonal frequencies was extended to the weekly case. Once critical values were obtained by simulation exercises, unit root and stationarity tests were applied to weekly retail prices of different agricultural commodities in Spain. The most relevant finding was that many unit roots that seasonal unit root tests failed to reject did not seem to be present from the results of seasonal stationarity tests, whereas seasonal unit root tests led to the rejection of some unit roots that seemed to be present according to the results of seasonal stationarity tests. In conclusion, unit root tests should be complemented with stationarity tests before making decisions about the behaviour of seasonal patterns.

Additional keywords: agricultural prices; weekly series; unit roots.

Authors' contributions: Both authors participated in the conception and design of the research, methodological proposal, analysis of data and writing of the paper.

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Introduction

In research on agricultural prices, seasonal effects in a season are usually assumed to be fixed over the sample period. Therefore, such effects are modelled by means of seasonal dummies. However, as commented by Cáceres-Hernández & Martín-Rodríguez (2017), wrong assumptions about the seasonal component may lead to erroneous conclusions about the dynamic behaviour of the series and the transmission mechanisms between them[1]. Moreover, as explained by Meyer & Von-Cramon-Taubadel (2004), data frequency plays a crucial role in attempts to identify these important effects to assess agricultural and commercial policies. Therefore, weekly series, increasingly available, could be needed to quantify some dynamic relationships between prices.

For weekly series, seasonal unit root tests based on the proposals by Hylleberg *et al.* (1990) and Franses (1991) have been proposed by Cáceres-Hernández (1996)[2]. However, when the null hypothesis of unit root is not rejected, it should not be concluded that seasonal unit roots explain the changes in the seasonal pattern of the series. As pointed out by Hylleberg (1994), the presence of seasonal unit roots implies the seasonal pattern is more variable than observed in actual series. Taking into account the low power of unit root tests (Ghysels *et al.*, 1994), these test results should be complemented with the results from stationarity tests. Indeed, the KPSS test (Kwiatwokski *et al.*, 1992) has been extended to seasonal frequencies and applied to quarterly and monthly series (Taylor, 2003; Lyhagen, 2006; Khedhiri & Montasser, 2012; Afonso-Rodríguez

[1]Seasonal unit roots force long run relationships and error correction models to be reformulated. As indicated by Palaskas & Crowe (1996), when the presence of seasonal unit roots is ignored, unit root and cointegration tests are found to lack consistency and power. However, the application of inadequate filters to remove potential seasonal roots is a bad solution, due to the distortions in the estimates of the dynamic process of transmission effects between prices.

[2]A generalization of HEGY seasonal unit root tests for any seasonal periodicity is presented in Smith *et al.* (2009). See also Díaz-Emparanza (2014).

& Santana-Gallego, 2014; Montasser, 2015). In this paper, following the proposal by Khedhiri & Montasser (2012), the procedure of testing the null hypothesis of stationarity was extended to the case of weekly series.

Material and methods

Weekly Spanish agricultural price series

The testing procedures described in the following sub-section were applied to weekly series of retail agricultural prices (in €/kg) from 2006 to 2016[3]. Original data are openly available from the web page of the Spanish Ministry of Agriculture, Food and Environment[4]. To avoid weekly series with a high number of missing values, the products finally chosen were: 9 types of vegetables (chards, courgettes, onions, lettuces, beans, potatoes, peppers, tomatoes, carrots), 4 types of fruits (apples, bananas, lemons, pears), eggs, 5 types of meat (pork, rabbit, lamb, chicken and veal) and 12 types of fish (anchovy, blue whiting, mackerel, baby clam, john dory, horse mackerel, mussel, hake, small hake, salmon, sardine, trout)[5].

Test for seasonal unit roots and stationarity

In the first part of this sub-section, the procedure proposed by Cáceres-Hernández (1996) for testing the null hypothesis of seasonal unit roots is described. In the second part, the auxiliary regressions and the statistics for testing the null hypothesis of stationarity are explained.

a) Test for seasonal unit roots

Let the data generating process for the weekly series $\{y_t\}_{t=1,\ldots,T}$ be given by

$$\varphi(B)y_t = d_t + \varepsilon_t, t = 1, \ldots, T, \quad (1)$$

where $\varphi(B)$ is an autoregressive polynomial, d_t represents the deterministic component (trend plus seasonal), and ε_t is a white noise disturbance term. The length of the seasonal period is assumed to be 52 weeks.

To test for seasonal unit roots in weekly series, the procedure described in Cáceres-Hernández (1996), following Franses (1991), can be applied. The following auxiliary regression needs to be estimated,

$$\begin{aligned}\Delta_{52}(B)y_t &= d_t + \pi_1 y_{1,t-1} + \pi_2 y_{2,t-1} + \\ &+ \textstyle\sum_{k=3}^{27}\left[\pi_{k,1}y_{k,t-1} + \pi_{k,2}y_{k,t-2}\right] + \\ &+ \textstyle\sum_{j=1}^{r}\Delta_{52}(B)y_{t-j} + \varepsilon_t\end{aligned} \quad (2)$$

where $\Delta_{52}(B)=1\text{-}B^{52}$, and regressors $y_{1,t},\ldots,y_{27,t}$ are defined as

$$y_{1,t} = \frac{\Delta_{52}(B)}{1-B}y_t = (1 + B + B^2 + \cdots + B^{51})y_t, \quad (3.a)$$

$$y_{2,t} = -\frac{\Delta_{52}(B)}{1+B}y_t = -(1 - B + B^2 - \cdots - B^{51})y_t, \quad (3.b)$$

$$y_{k,t} = -\frac{\Delta_{52}(B)}{1-2cos(\theta_k)B+B^2}y_t, \theta_k = \frac{2(k-2)\pi}{52}, k = 3, \ldots, 27. \quad (3.c)$$

A number of lags of the dependent variable are included in order to ensure serial uncorrelation in the error term. Then, the hypothesis of unit root at zero frequency is rejected when the null hypothesis π_1=0 is rejected against π_1<0 by means of a t type test t_1. The hypothesis of unit root at Nyquist frequency is rejected when the null hypothesis π_2=0 is rejected against π_2<0 by means of another t type test t_2. As regards the remainder of seasonal frequencies, an F type test F_{k-2} about the significance of parameters $\pi_{k,1}$, $\pi_{k,2}$, can be applied to test the presence of a pair of unit roots at the seasonal frequency θ_k,k=3,…,27[6]. In this paper, critical values to these tests are obtained by means of simulation exercises adapted to the sample size of the series analysed.

b) Test for stationarity

To test for the null hypothesis of stationarity at zero and seasonal frequencies, the procedure described in Khedhiri & Montasser (2012), following Kwiatkowski *et al.* (1992), can be applied. Let the data generating process for the series $\{y_t\}_{t=1,\ldots,T}$ be again given by Eq. (1). Once the regressors $y_{1,t},\ldots,y_{27,t}$ are defined as in Eqs.

[3]Some papers dealing with seasonal patterns in weekly agricultural prices in Spain are, among others, García *et al.* (2010), Martín-Rodríguez & Cáceres-Hernández (2012, 2013), Cáceres-Hernández & Martín-Rodríguez (2017). Transmission mechanisms between weekly Spanish agricultural prices are also analysed in Sanjuán & Gil (2001), Boshnjaku *et al.* (2003), Ben-Kaabia & Gil (2007), Cruz & Ameneiro (2007), Emmanoulides & Fousekis (2012, 2015), Guillén & Franquesa (2015) and Sidhoum & Serra (2016).

[4]In the original source, there are 53 weekly observations corresponding to years 2009 and 2014. However, in order to obtain a fixed number of seasons, the decision has been made to substitute observations corresponding to weeks 26 and 27 by an average of these two observations. Furthermore, missing values at weeks 51 and 52 in 2006, at week 1 in 2007, and at week 6 in 2010 have been assigned an average of the corresponding contiguous observations.

[5]For the blue whiting series, an anomalous observation and other six missing data were substituted by an average of the corresponding contiguous observations.

[6]Del Barrio-Castro & Sansó (2015) showed that the distribution of the t-ratio unit root tests associated to the zero and Nyquist frequencies and also for the F-type tests associated to the harmonic frequencies are asymptotically equivalent to the corresponding distributions obtained when the regressors defined in Hylleberg *et al.* (1990) are applied.

(3.a) to (3.c) to isolate the effects of other unit roots in the series, the following auxiliary regressions need to be estimated.

The test for the presence of unit root at zero frequency is obtained by assuming that the data generating process for the series $\{y_{1,t}\}_{t=1,\dots,T}$ is such that

$$y_{1,t} = d_t + r_t + u_t, \tag{4}$$

where

$$r_t = r_{t-1} + v_t, \tag{5}$$

and u_t and v_t are zero mean weakly dependent disturbance terms. Then, by estimating the following auxiliary regression

$$y_{1,t} = d_t + u_t, \tag{6}$$

the statistic similar to the one proposed in Kwiatkowski *et al.* (1992) is calculated as

$$\eta^{(0)} = \frac{\sum_{t=1}^{T}\left(S_t^{(0)}\right)^2}{T^2 s^2(l)}, \tag{7}$$

where

$$S_t^{(0)} = \sum_{j=1}^{t} u_j, \tag{8}$$

and

$$s^2(l) = \frac{\sum_{t=1}^{T} u_t^2}{T} + 2\frac{\sum_{s=1}^{l}\left(1-\frac{s}{l+1}\right)\sum_{t=s+1}^{T} u_t u_{t-s}}{T}. \tag{9}$$

The test for the presence of unit root at the Nyquist frequency was obtained by assuming that the data generating process for the series $\{y_{2,t}\}_{t=1,\dots,T}$ is such that:

$$y_{2,t} = d_t + r_t + u_t, \tag{10}$$

where

$$r_t = -r_{t-1} + v_t. \tag{11}$$

Once the auxiliary regression

$$y_{2,t} = d_t + u_t \tag{12}$$

was estimated, the statistic similar to the one proposed in Khedhiri & Montasser (2012) was calculated as

$$\eta^{(\pi)} = \frac{\sum_{t=1}^{T} S_t^{(\pi)} \bar{S}_t^{(\pi)}}{T^2 s^2(l)}, \tag{13}$$

where

$$S_t^{(\pi)} = \sum_{j=1}^{t}\left(e^{i\pi}\right)^j u_j, \tag{14.a}$$

$$\bar{S}_t^{(\pi)} = \sum_{j=1}^{t}\left(e^{-i\pi}\right)^j u_j, \tag{14.b}$$

and

$$s^2(l) = \frac{\sum_{t=1}^{T} u_t^2}{T} + 2\frac{\sum_{s=1}^{l}\left(1-\frac{s}{l+1}\right)\cos(\pi s)\sum_{t=s+1}^{T} u_t u_{t-s}}{T}. \tag{15}$$

Note that

$$\begin{aligned} S_t^{(\pi)} \bar{S}_t^{(\pi)} &= \left[\sum_{j=1}^{t} \cos(\pi j) u_j\right]^2 + \\ &+ \left[\sum_{j=1}^{t} \sin(\pi j) u_j\right]^2 = \left[\sum_{j=1}^{t} (-1)^j u_j\right]^2. \end{aligned} \tag{16}$$

Finally, the test for the presence of unit root at seasonal frequency θ_k was obtained by assuming that the data generating process for the series $\{y_{k,t}\}_{t=1,\dots,T}$ is such that:

$$y_{k,t} = d_t + r_t + u_t, \tag{17}$$

where

$$r_t = 2\cos(\theta_k) r_{t-1} - r_{t-2} + v_t. \tag{18}$$

Then, by estimating the following auxiliary regression

$$y_{k,t} = d_t + u_t, \tag{19}$$

the statistic similar to the one proposed in Khedhiri & Montasser (2012) was calculated as:

$$\eta^{(\theta_k)} = \frac{\sum_{t=1}^{T} S_t^{(\theta_k)} \bar{S}_t^{(\theta_k)}}{T^2 s^2(l)}, \tag{20}$$

where

$$S_t^{(\theta_k)} = \sum_{j=1}^{t}\left(e^{i\theta_k}\right)^j u_j, \tag{21.a}$$

$$\bar{S}_t^{(\theta_k)} = \sum_{j=1}^{t}\left(e^{-i\theta_k}\right)^j u_j, \tag{21.b}$$

and

$$s^2(l) = \frac{\sum_{t=1}^{T} u_t^2}{T} + 2\frac{\sum_{s=1}^{l}\left(1-\frac{s}{l+1}\right)\cos(\theta_k s)\sum_{t=s+1}^{T} u_t u_{t-s}}{T}. \tag{22}$$

Note that

$$\begin{aligned} S_t^{(\theta_k)} \bar{S}_t^{(\theta_k)} &= \left[\sum_{j=1}^{t} \cos(\theta_k j) u_j\right]^2 + \\ &+ \left[\sum_{j=1}^{t} \sin(\theta_k j) u_j\right]^2. \end{aligned} \tag{23}$$

If the original series $\{y_t\}_{t=1,\dots,T}$ is assumed to be stationary around a deterministic component, the auxiliary regression for testing the null hypothesis of stationarity at any frequency is

$$y_t = d_t + u_t. \quad (24)$$

This being the case, to test for the stationarity hypothesis at a frequency a filtering procedure to remove other unit roots was not necessary. Once this auxiliary regression was estimated, the statistical tests $\eta^{(0)}$, $\eta^{(\pi)}$ and $\eta^{(\theta_k)}$, k=3,…,27, could be calculated from the residuals of such an estimation.

The asymptotic distribution of the test statistic $\eta^{(0)}$ is the one which was obtained in Kwiatkowski *et al.* (1992), whereas for statistics $\eta^{(\pi)}$ and $\eta^{(\theta_k)}$, k=3,…,27, the corresponding asymptotic distributions were the same as those obtained by Khedhiri & Montasser (2012). Note that the asymptotic distribution of statistics $\eta^{(\theta_k)}$, k=3,…,27, was the same at any frequency, and, as shown in Montasser (2015), the frequency of observation had not effect on the asymptotic distribution of statistics $\eta^{(\pi)}$ and $\eta^{(\theta_k)}$. In this paper, critical values were obtained by simulation exercises adapted to the sample size for price series[7].

Results

The tests for zero and seasonal frequencies proposed in the previous section were applied to the weekly price series already mentioned. To assess the instability of the seasonal patterns in these series, a previous approach to these variations was obtained as the difference between original and 52-week moving average series[8]. Then, an evolving periodic cubic spline has been adjusted to these differences[9]. The results of estimating such splines are shown in Figures 1 and 2. According to these figures, seasonal patterns do not seem to be fixed, but these patterns do not change as much as expected when seasonal unit roots are present.

Following the conventional procedure to test for seasonal unit roots, a linear trend and seasonal dummies are included as deterministic components in the auxiliary regressions[10]. However, the slope term has been removed when it is statistically non significant. Furthermore, the results of residual autocorrelation tests show that lags of the dependent variable do not need to be included. Table 1 shows the critical values obtained for the effective sample size (572, 11 years of weekly data). Given that the sample distribution of seasonal unit root tests depends on the deterministic components in the data generating process, Monte Carlo simulation experiments have been designed to obtain critical values depending on the inclusion of a slope term in the auxiliary regression.

Tables 2 and 3 show the values of the statistics for testing the null hypothesis of unit root at zero and seasonal frequencies[11]. Besides the results for the zero frequency, which should be analysed once a conclusion is obtained with regard to seasonal frequencies, the unit root tests fail to reject the null hypothesis at some seasonal frequencies for some price series. At 10% significance level, the unit root hypothesis was not rejected for potato, lemon and pear prices at frequency π. At the same significance level, the tests also failed to reject the null hypothesis for lemon prices at frequencies π/26, 2π/26 and 6π/26, and for pear prices at frequency 5π/26. At 5% significance level, the null hypothesis was not rejected for onion prices at frequency 8π/26, for bean prices at frequency 25π/26, for pepper prices at frequency π, for apple prices at frequency 14π/26, for lemon prices at frequency 3π/26, and for pear prices at frequency 10π/26. In the case of egg prices, the unit root was rejected at frequency π at 5% significance level.

With regard to meat and fish price series, unit root tests failed to reject the null hypothesis at 10% significance level for hake prices at frequency 4π/26, for pork and sardine prices at frequency π, for rabbit prices at frequency 2π/26, and for salmon prices at frequencies 13π/26 and 16π/26. At 5% significance level, the unit root hypothesis was rejected for john dory prices at frequency 4π/26, for blue whiting prices at frequency 5π/26, for hake and salmon prices at frequency 15π/26, for sardine prices at frequency 2π/26, and for trout prices at frequency 18π/26.

Finally, Tables 4 and 5 show the results of testing the null hypothesis of stationarity at zero and seasonal frequencies by estimating the auxiliary regression in Eq. (24). In order for the non-parametric correction of the estimate of the error variance to take the serial correlation into account, the maximum length, l , is set at 3 or 8, following conventional criteria based on the sample size (Newey & West, 1987). Only the minimum values of the test statistics corresponding to these two values of parameter l are shown. According to the

[7]The TSP files to obtain critical values are included as supplementary material accompanying the paper on SJAR's website.
[8]To obtain estimates of seasonal effects in the first half of 2006 and in the second half of 2016, moving average series at these points in time have been calculated using prices observed in 2005 and 2017.
[9]A spline is a piecewise polynomial function which provides smooth estimates of seasonal effects and allow us to observe the changes in the shape of the seasonal pattern. It has been selected a six-segment cubic spline as defined in Cáceres-Hernández & Martín-Rodríguez (2017) when restrictions between years are not imposed. That is to say, spline parameters evolve from year to year whereas break points are located in fixed points for every year. These positions are chosen to minimize the sum of squared residuals when such a spline is fitted to the difference series.
[10]Note that spline functions are not applied as a model for the deterministic seasonal component in auxiliary regressions.
[11]The seasonal difference filter was applied to the original series from 2005 to 2016 in such a way that the effective sample size to estimate auxiliary regression was 572.

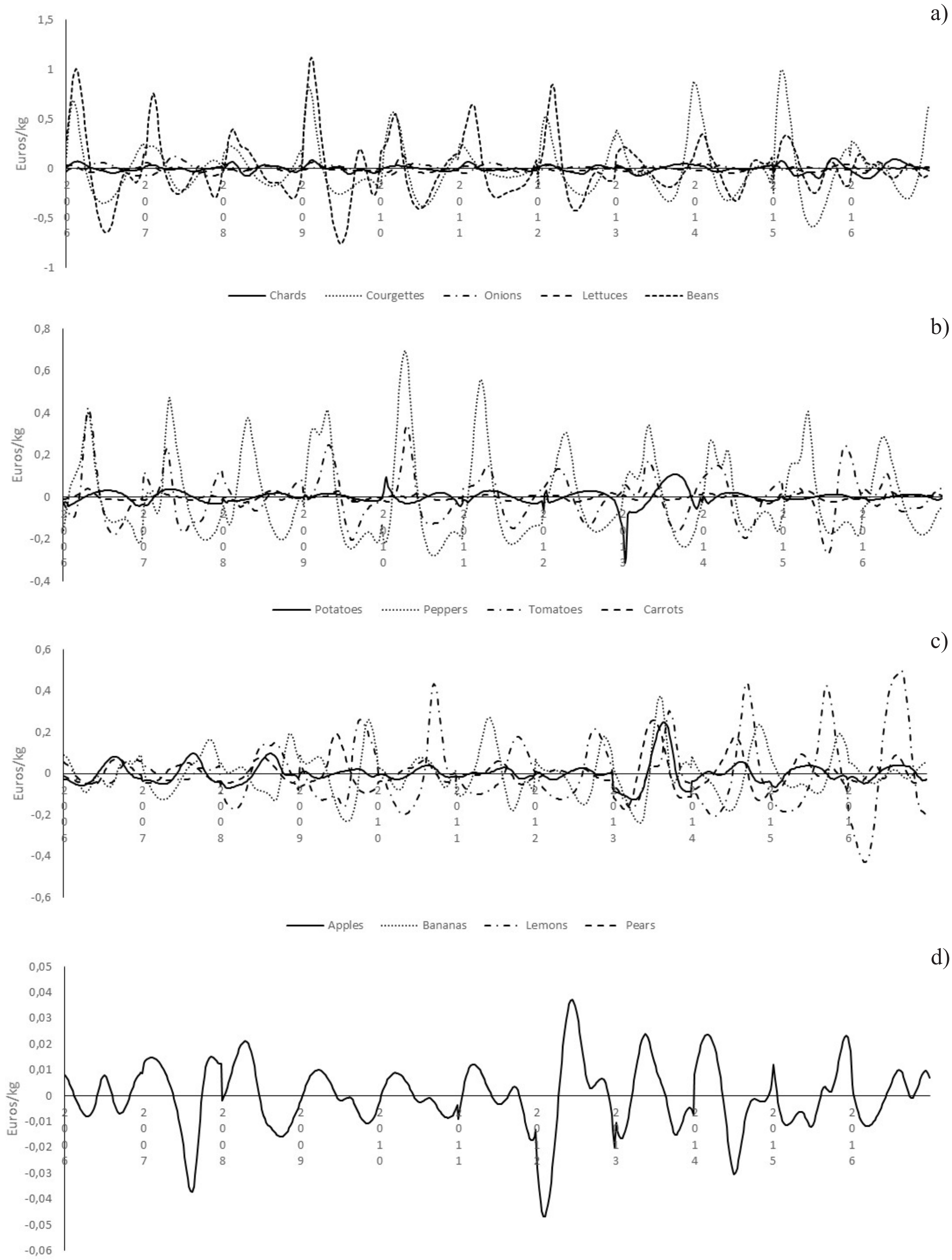

Figure 1. Seasonal patterns for vegetable (a-b), fruit (c) and egg (d) price series (2006-2016)

critical values in Table 1, and leaving aside the rejection of the null hypothesis at the zero frequency for most of the series, the stationarity hypothesis was rejected for bean prices at frequencies π/26 and 2π/26, for lamb prices at frequency π/26 and also for sardine prices at frequency 2π/26 at 5% significance level, whereas at 10% significance level the null hypothesis was rejected for lemon prices at frequency π/26[12].

Note that many unit roots that seasonal unit root tests failed to reject did not seem to be present from the results of seasonal stationarity tests. Furthermore, seasonal unit root tests led to the rejection of some unit

[12]The rejection of the stationarity hypothesis may become non rejection when the original series were filtered of all unit roots except the one corresponding to the frequency tested, but it is not clear these unit roots were present.

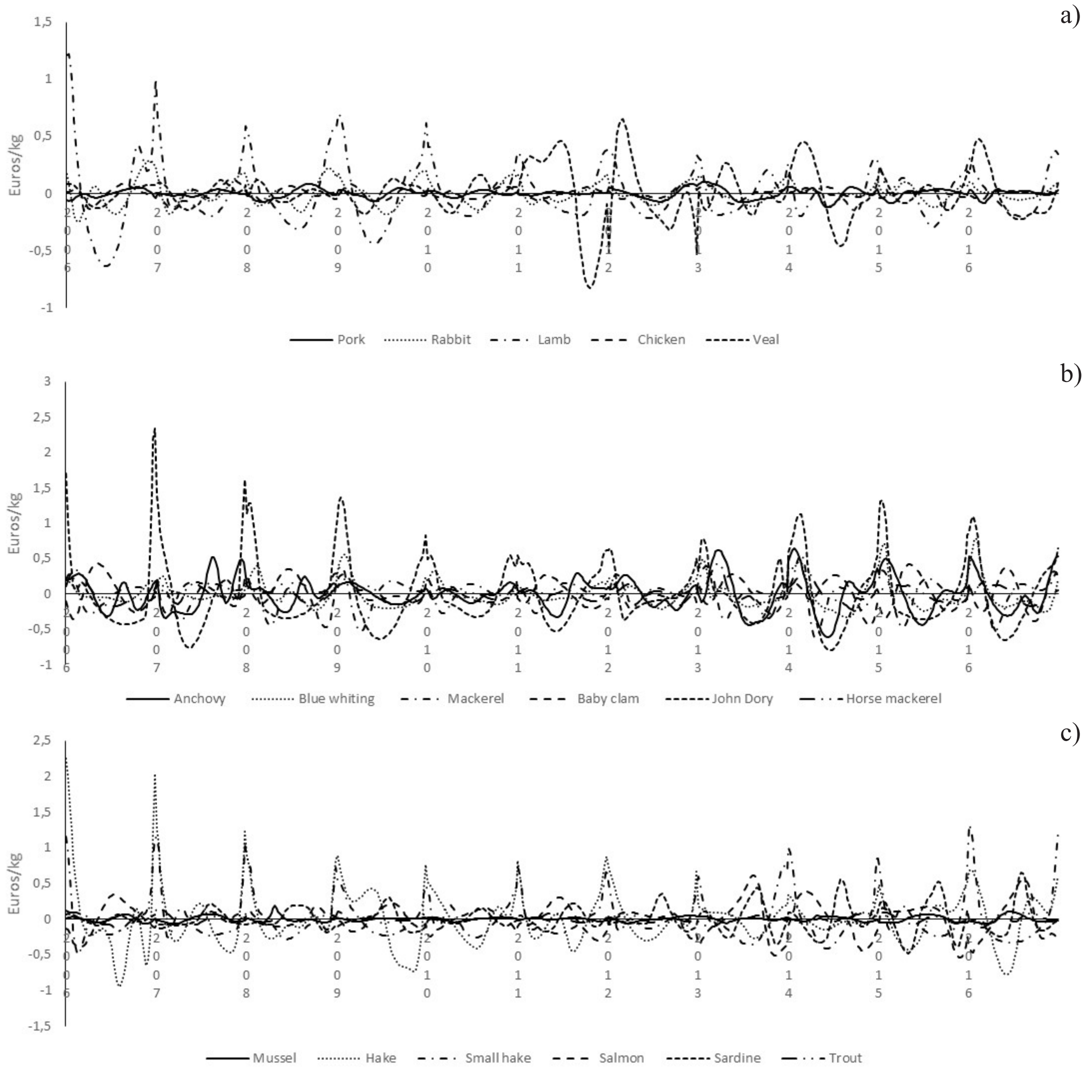

Figure 2. Seasonal patterns for meat (a) and fish (b-c) price series (2006-2016).

roots that seemed to be present according to the results of seasonal stationarity tests.

Discussion

Seasonal patterns in agricultural price series usually exhibit changes such that unit root tests fail to reject the null hypothesis at some seasonal frequencies. However, these changes were not as variable as expected when these seasonal unit roots are causing them. In these circumstances, and taking the bad power performance of unit root tests into account, stationarity tests should also be applied as a complementary testing procedure. The conclusion regarding the presence of a unit root may be right when both procedures lead to such a conclusion. However, when doubts about the presence of seasonal unit roots remain after applying unit root and stationarity tests, some reflections are needed about the behaviour of the seasonal patterns. It should be noted that these testing procedures only take two possibilities into account (unit root or stationarity around a fixed deterministic component), but changes in the deterministic component of the seasonal pattern are another alternative to be explored, as pointed out by Cáceres-Hernández & Martín-Rodríguez (2017), before making a final decision about the presence of seasonal unit roots.

Likewise, a note of caution should be mentioned about the results of these testing procedures when applied to weekly series with small sample sizes. The number of observations corresponding to the same season is usually low in available agricultural price series. Therefore, the changes in the seasonal effect corresponding to a season are not easily observed. Of course, as commented by Hyndman & Kostenko (2007), the minimum sample size requirements increase with the amount of random variation in the data. Furthermore, economic knowledge about agricultural market performance is a key element to identify such changes

Table 1. Critical values for seasonal unit root and stationarity tests in weekly series.

	Statistic	Auxiliary regression includes a constant term and seasonal dummies		Auxiliary regression includes a linear trend and seasonal dummies	
		Critical values[1]		Critical values[1]	
SEASONAL UNIT ROOT TESTS					
Frequency	t	**5%**	**10%**	**5%**	**10%**
0	t_1	-2.635	-2.363	-3.170	-2.892
π	t_2	-2.629	-2.356	-2.620	-2.351
Frequency	F	**90%**	**95%**	**90%**	**95%**
	F_{k-2}	4.762	5.638	4.764	5.642
SEASONAL STATIONARITY TESTS					
Frequency	η	**90%**	**95%**	**90%**	**95%**
0	$\eta^{(0)}$	0.384	0.507	0.130	0.162
π	$\eta^{(\pi)}$	0.385	0.507	0.377	0.496
θ_k, k = 3, ..., 27	$\eta^{(\theta_k)}$	0.332	0.408	0.332	0.408

[1]Critical values were obtained by Monte Carlo simulation experiments using the TSP 5.1 package. Twenty thousand replications were conducted. The effective sample size to estimate auxiliary regressions is 572 (11 years of weekly data). For seasonal unit root tests, the data generating process was a Gaussian seasonal random walk where the disturbance term has unit variance. There were 25 F-type tests, F_{k-2}, k=3,…,27, with the same asymptotic distribution, thus the tests results of the entire simulation are shown. For seasonal stationarity tests, the data generating process was a Gaussian white noise where the disturbance term has unit variance. There were 25 tests, $\eta^{(\theta_k)}$, k=3,…,27, with the same asymptotic distribution, thus the tests results of the entire simulation are shown.

Table 2. Seasonal unit root tests for vegetable and fruit prices.

Auxiliary regression includes a constant term and seasonal dummies							
	Courgette	**Onion**	**Bean**	**Pepper**	**Tomato**	**Carrot**	**Apple**
Frequency	t	t	t	t	t	t	t
0	-2.744	-2.647	-2.347	-1.652	-1.886	-2.303	-2.557
π	-2.871	-2.908	-2.657	-2.392	-2.730	-2.907	-3.345
Frequency	F	F	F	F	F	F	F
π/26	12.953	9.220	7.380	10.241	9.683	7.507	11.805
2π/26	12.303	12.452	8.208	6.183	6.366	6.214	9.026
3π/26	10.494	12.070	9.887	9.181	8.713	7.484	14.402
4π/26	8.043	12.199	7.320	9.758	10.062	10.563	8.011
5π/26	11.780	11.408	13.203	10.926	10.712	12.382	11.242
6π/26	23.639	11.446	13.238	8.940	14.463	13.790	12.614
7π/26	18.467	6.776	8.801	11.329	13.511	9.734	13.120
8π/26	13.075	5.516	7.103	9.010	12.763	11.781	8.008
9π/26	12.189	9.063	7.975	12.860	15.145	8.256	11.927
10π/26	10.414	10.757	12.748	11.935	12.934	6.482	6.490
11π/26	9.175	10.203	12.409	16.274	10.066	8.243	11.110
12π/26	15.015	10.187	8.415	12.734	10.094	11.675	8.890
13π/26	13.499	10.788	8.982	7.923	10.007	10.813	9.461
14π/26	16.714	8.635	7.313	11.767	8.531	13.236	4.971
15π/26	13.109	7.731	10.745	11.047	11.062	10.248	9.824
16π/26	12.015	8.101	7.626	7.615	10.414	12.442	6.975
17π/26	6.022	7.919	8.949	7.728	14.695	14.678	7.868
18π/26	7.544	9.516	22.149	8.140	7.455	11.831	12.422
19π/26	9.842	11.350	13.502	10.196	10.020	10.355	11.743
20π/26	10.729	11.253	10.858	7.837	9.923	6.918	13.228

Table 2. Continued.

Auxiliary regression includes a linear trend and seasonal dummies							
	Courgette	**Onion**	**Bean**	**Pepper**	**Tomato**	**Carrot**	**Apple**
21π/26	5.799	13.291	11.701	6.666	8.198	8.365	8.506
22π/26	6.172	11.312	10.573	12.109	9.595	8.514	10.894
23π/26	8.928	8.038	12.534	9.029	12.914	8.609	5.877
24π/26	5.960	10.133	16.462	6.613	15.764	9.064	9.427
25π/26	12.255	7.406	5.370	12.477	6.370	9.595	10.684

Auxiliary regression includes a constant term and seasonal dummies							
	Chard	**Lettuce**	**Potato**	**Lemon**	**Pear**	**Banana**	**Egg**
Frequency	***t***	***t***	***t***	***t***	***t***	***t***	***t***
0	-1.764	-4.145	-3.881	-3.177	-2.471	-3.084	-2.918
π	-3.339	-3.379	-2.119	-2.172	-2.326	-3.007	-2.389
Frequency	***F***	***F***	***F***	***F***	***F***	***F***	***F***
π/26	9.823	15.854	7.477	1.719	10.836	9.902	7.145
2π/26	10.593	9.963	12.461	3.259	9.707	11.302	7.812
3π/26	10.233	9.964	12.097	4.852	12.163	7.395	11.465
4π/26	11.928	11.848	9.880	6.010	7.408	10.727	10.363
5π/26	8.964	10.423	11.540	8.918	4.626	6.510	9.751
6π/26	8.928	9.870	9.902	3.597	12.584	11.342	9.205
7π/26	13.451	11.923	10.895	11.327	9.644	14.128	9.318
8π/26	13.336	6.846	18.052	12.536	12.830	11.090	12.441
9π/26	14.471	10.635	15.900	8.321	10.331	12.827	8.297
10π/26	9.813	12.166	12.836	11.019	4.884	6.413	8.894
11π/26	12.506	7.149	22.582	14.256	7.888	7.006	12.739
12π/26	12.835	10.941	7.457	11.299	12.935	10.456	7.033
13π/26	8.488	9.745	21.986	13.288	8.921	10.148	8.006
14π/26	10.149	6.658	17.527	7.223	9.675	9.487	8.357
15π/26	12.665	13.525	12.084	6.025	8.274	7.613	8.580
16π/26	11.394	9.488	16.932	9.812	14.400	11.990	11.725
17π/26	9.570	8.052	8.112	8.360	12.838	12.153	12.790
18π/26	10.363	12.155	15.877	6.280	9.856	6.013	12.279
19π/26	14.685	11.590	6.903	7.861	9.266	12.600	12.042
20π/26	6.760	17.220	10.355	6.969	7.558	12.572	9.397
21π/26	8.661	7.736	7.158	8.319	10.392	9.752	13.729
22π/26	8.674	8.477	7.522	17.763	15.564	12.355	11.870
23π/26	7.056	15.658	7.858	9.898	14.367	7.598	11.685
24π/26	12.610	7.529	12.396	13.763	15.805	9.178	10.878
25π/26	15.947	9.220	19.080	12.432	12.266	10.983	6.844

Table 3. Seasonal unit root tests for meat and fish prices.

Auxiliary regression includes a constant term and seasonal dummies								
	Chicken	**Veal**	**Blue whiting**	**Baby clam**	**John dory**	**Mussel**	**Hake**	**Small hake**
Frequency	***t***	***t***	***t***	***t***	***t***	***t***	***t***	***t***
0	-2.886	-2.039	-1.883	-2.055	-2.040	-1.785	-1.398	-1.340
π	-4.670	-3.569	-3.037	-4.040	-3.736	-4.172	-3.191	-4.053
Frequency	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**
π/26	16.516	7.034	7.254	16.683	16.545	6.456	12.220	12.870

Table 3. Continued.

Auxiliary regression includes a constant term and seasonal dummies								
	Chiken	**Veal**	**Blue whiting**	**Baby clam**	**John dory**	**Mussel**	**Hake**	**Small hake**
2π/26	9.621	6.920	6.517	7.677	7.154	10.983	8.079	8.666
3π/26	13.269	11.203	10.393	10.525	11.601	8.187	6.874	12.462
4π/26	12.020	10.491	8.526	7.632	4.768	8.059	4.664	8.143
5π/26	15.113	11.007	4.801	7.730	7.658	9.286	8.288	7.183
6π/26	9.111	9.620	7.463	13.715	9.781	14.167	13.619	14.424
7π/26	9.904	9.836	11.231	12.106	12.135	12.385	11.128	13.720
8π/26	11.890	8.755	15.969	7.657	9.389	10.517	11.025	8.704
9π/26	12.006	6.402	13.325	5.660	6.925	9.957	6.751	11.768
10π/26	8.029	9.885	12.500	13.472	7.864	6.964	7.331	10.758
11π/26	10.330	12.521	10.548	7.922	11.075	7.838	10.266	7.425
12π/26	9.618	13.682	7.681	9.659	6.529	10.005	11.295	11.257
13π/26	10.201	10.288	13.592	9.257	8.656	8.833	8.206	12.591
14π/26	7.658	8.704	6.663	11.897	12.536	10.770	14.438	9.860
15π/26	11.852	12.007	9.587	11.384	8.529	10.666	5.607	10.566
16π/26	8.994	6.809	6.661	9.372	9.786	8.986	10.746	8.868
17π/26	6.828	8.895	9.099	9.865	15.576	15.102	7.076	10.642
18π/26	8.352	13.619	11.447	10.618	14.015	10.970	11.006	10.971
19π/26	11.691	7.496	9.227	11.076	8.333	10.128	21.153	11.602
20π/26	10.611	9.994	8.919	6.731	10.246	8.058	6.602	9.420
21π/26	10.696	8.590	9.180	6.348	13.024	9.240	7.209	10.616
22π/26	11.645	13.659	15.168	7.891	6.771	17.887	8.915	11.992
23π/26	13.150	9.493	12.324	8.929	12.301	8.873	11.416	10.308
24π/26	15.821	7.962	11.562	7.487	10.056	9.689	10.322	8.533
25π/26	8.200	11.086	10.277	14.809	16.367	13.410	8.912	10.412

Auxiliary regression includes a linear trend and seasonal dummies									
	Pork	**Rabbit**	**Lamb**	**Anchovy**	**Mackerel**	**Horse mackerel**	**Salmon**	**Sardine**	**Trout**
Frequency	***t***	***t***	***t***	***t***	***t***	***t***	***t***	***t***	***t***
0	-3.541	-2.286	-2.647	-2.883	-1.027	-2.775	-3.890	-2.532	-1.400
π	-2.220	-3.387	-4.223	-3.157	-3.310	-3.558	-3.700	-1.909	-3.127
Frequency	***F***	***F***	***F***	***F***	***F***	***F***	***F***	***F***	***F***
π/26	5.911	10.729	19.833	7.841	6.264	12.130	7.089	9.513	7.975
2π/26	10.166	4.526	22.832	9.476	8.449	15.386	6.726	5.099	13.360
3π/26	10.871	8.320	13.092	16.858	9.859	7.038	7.268	18.289	6.984
4π/26	14.035	8.577	6.334	15.973	6.324	12.387	8.638	13.034	10.150
5π/26	10.143	9.032	8.496	9.648	8.014	9.905	14.673	11.200	11.509
6π/26	10.717	8.038	15.107	7.621	9.829	7.406	8.944	9.992	6.080
7π/26	15.540	11.070	8.083	8.478	10.832	8.473	13.617	11.868	9.243
14π/26	12.964	10.316	18.500	10.940	8.682	7.929	11.410	9.345	8.979
15π/26	10.077	10.173	9.977	10.945	10.880	6.629	4.965	9.850	8.531
16π/26	12.730	10.547	12.240	10.483	9.091	12.856	3.612	8.404	12.171
17π/26	9.982	10.963	12.560	16.306	11.201	14.036	11.507	11.061	9.984
18π/26	10.888	10.851	7.188	7.815	8.989	10.255	10.039	9.876	5.109
19π/26	10.856	10.516	6.126	11.800	10.149	7.674	11.556	9.706	7.662
20π/26	10.768	11.285	10.294	12.247	6.357	6.932	13.504	13.346	9.789

Table 3. Continued.

	Auxiliary regression includes a linear trend and seasonal dummies								
	Pork	Rabbit	Lamb	Anchovy	Mackerel	Horse mackerel	Salmon	Sardine	Trout
21π/26	10.917	8.640	10.001	11.108	11.144	9.658	11.638	7.194	7.580
22π/26	9.075	12.533	12.009	12.186	8.553	10.832	9.105	12.250	12.614
23π/26	9.300	11.540	6.562	8.509	9.957	11.154	8.291	9.415	7.565
24π/26	7.003	10.130	7.473	12.813	8.584	12.590	16.836	9.648	11.241
25π/26	7.334	10.480	14.780	7.114	8.871	10.015	13.830	10.196	14.790

Table 4. Seasonal stationarity tests for vegetable and fruit prices.

Auxiliary regression includes a constant term and seasonal dummies							
	Courgette	Onion	Bean	Pepper	Tomato	Carrot	Apple
Frequency	η	η	η	η	η	η	η
0	0.424	0.609	0.374	1.909	1.872	1.093	0.994
π	0.031	0.012	0.037	0.011	0.026	0.032	0.010
π/26	0.131	0.077	0.533	0.111	0.228	0.072	0.058
2π/26	0.096	0.017	0.437	0.082	0.059	0.065	0.014
3π/26	0.062	0.010	0.118	0.046	0.085	0.089	0.007
4π/26	0.023	0.009	0.060	0.030	0.058	0.038	0.006
5π/26	0.033	0.006	0.074	0.015	0.018	0.014	0.006
6π/26	0.009	0.004	0.012	0.023	0.019	0.009	0.006
7π/26	0.022	0.005	0.065	0.006	0.024	0.011	0.007
8π/26	0.012	0.007	0.035	0.013	0.019	0.010	0.005
9π/26	0.018	0.012	0.067	0.004	0.008	0.017	0.010
10π/26	0.018	0.012	0.054	0.014	0.025	0.086	0.011
11π/26	0.022	0.016	0.039	0.013	0.085	0.036	0.012
12π/26	0.081	0.078	0.056	0.052	0.062	0.088	0.072
13π/26	0.057	0.032	0.047	0.058	0.020	0.070	0.017
14π/26	0.023	0.012	0.033	0.014	0.020	0.028	0.016
15π/26	0.055	0.021	0.036	0.025	0.020	0.023	0.010
16π/26	0.027	0.016	0.035	0.016	0.014	0.035	0.014
17π/26	0.028	0.012	0.020	0.011	0.007	0.015	0.017
18π/26	0.015	0.010	0.006	0.007	0.011	0.012	0.007
19π/26	0.012	0.006	0.018	0.008	0.006	0.010	0.005
23π/26	0.015	0.014	0.012	0.014	0.013	0.052	0.022
24π/26	0.036	0.021	0.012	0.033	0.024	0.043	0.038
25π/26	0.062	0.017	0.033	0.014	0.093	0.036	0.041
Auxiliary regression includes a linear trend and seasonal dummies							
	Chard	Lettuce	Potato	Lemon	Pear	Banana	Egg
Frequency	η	η	η	η	η	η	η
0	0.698	0.079	0.272	0.528	0.558	0.179	0.551
π	0.014	0.015	0.078	0.006	0.026	0.010	0.022
π/26	0.270	0.215	0.064	0.387	0.089	0.143	0.033
2π/26	0.043	0.172	0.015	0.029	0.014	0.045	0.013
3π/26	0.011	0.040	0.016	0.027	0.016	0.045	0.007
4π/26	0.009	0.018	0.018	0.016	0.005	0.010	0.005
5π/26	0.010	0.011	0.011	0.005	0.006	0.012	0.005

Table 4. Continued.

Auxiliary regression includes a linear trend and seasonal dummies							
	Chard	**Lettuce**	**Potato**	**Lemon**	**Pear**	**Banana**	**Egg**
6π/26	0.004	0.013	0.024	0.004	0.003	0.006	0.006
7π/26	0.004	0.007	0.012	0.003	0.008	0.008	0.006
8π/26	0.007	0.011	0.011	0.003	0.004	0.008	0.005
9π/26	0.006	0.011	0.021	0.003	0.006	0.007	0.007
10π/26	0.018	0.013	0.066	0.005	0.008	0.020	0.011
11π/26	0.035	0.066	0.019	0.008	0.019	0.027	0.017
12π/26	0.100	0.106	0.242	0.027	0.053	0.028	0.050
13π/26	0.026	0.156	0.029	0.011	0.032	0.024	0.023
14π/26	0.024	0.083	0.064	0.005	0.015	0.019	0.011
15π/26	0.020	0.032	0.055	0.008	0.012	0.014	0.007
16π/26	0.027	0.024	0.027	0.005	0.012	0.011	0.011
17π/26	0.016	0.021	0.052	0.003	0.014	0.007	0.008
18π/26	0.010	0.016	0.018	0.003	0.011	0.008	0.005
19π/26	0.005	0.012	0.065	0.002	0.004	0.006	0.005
20π/26	0.007	0.007	0.056	0.003	0.009	0.010	0.009
21π/26	0.005	0.018	0.121	0.004	0.009	0.007	0.007
22π/26	0.008	0.027	0.117	0.004	0.007	0.006	0.013
23π/26	0.019	0.012	0.070	0.005	0.010	0.007	0.010
24π/26	0.020	0.041	0.054	0.013	0.024	0.024	0.021
25π/26	0.020	0.033	0.036	0.007	0.022	0.011	0.025

Table 5. Seasonal stationarity tests for meat and fish prices.

Auxiliary regression includes a constant term and seasonal dummies								
	Chicken	**Veal**	**Blue whiting**	**Baby clam**	**John dory**	**Mussel**	**Hake**	**Small hake**
Frequency	***η***	***η***	***η***	***η***	***η***	***η***	***η***	***η***
0	1.336	4.190	2.331	0.480	3.463	2.825	4.343	5.073
π	0.032	0.016	0.108	0.065	0.026	0.009	0.026	0.008
π/26	0.145	0.102	0.235	0.072	0.023	0.050	0.050	0.027
2π/26	0.034	0.018	0.089	0.068	0.015	0.030	0.029	0.011
3π/26	0.010	0.010	0.082	0.030	0.025	0.012	0.034	0.010
4π/26	0.011	0.008	0.056	0.043	0.074	0.025	0.026	0.014
5π/26	0.020	0.005	0.137	0.012	0.015	0.012	0.008	0.004
6π/26	0.010	0.006	0.033	0.014	0.007	0.007	0.007	0.004
7π/26	0.006	0.007	0.019	0.010	0.008	0.020	0.006	0.007
8π/26	0.008	0.005	0.012	0.016	0.019	0.008	0.007	0.007
9π/26	0.010	0.008	0.015	0.012	0.033	0.020	0.020	0.007
10π/26	0.018	0.007	0.020	0.028	0.018	0.015	0.017	0.012
11π/26	0.030	0.026	0.027	0.149	0.047	0.042	0.031	0.028
12π/26	0.093	0.039	0.051	0.188	0.136	0.033	0.071	0.073
13π/26	0.027	0.029	0.077	0.032	0.064	0.021	0.039	0.024
14π/26	0.011	0.014	0.111	0.075	0.029	0.022	0.016	0.010
15π/26	0.013	0.014	0.019	0.023	0.054	0.017	0.013	0.013
16π/26	0.012	0.011	0.034	0.033	0.046	0.018	0.014	0.009
17π/26	0.011	0.006	0.042	0.016	0.010	0.013	0.008	0.006
18π/26	0.010	0.007	0.016	0.009	0.012	0.017	0.010	0.004

Table 5. Continued.

Auxiliary regression includes a constant term and seasonal dummies								
	Chicken	**Veal**	**Blue whiting**	**Baby clan**	**John dory**	**Mussel**	**Hake**	**Small hake**
19π/26	0.007	0.005	0.034	0.013	0.024	0.018	0.004	0.006
20π/26	0.006	0.006	0.084	0.017	0.019	0.013	0.007	0.008
21π/26	0.008	0.008	0.056	0.049	0.011	0.007	0.014	0.005
22π/26	0.014	0.006	0.017	0.043	0.016	0.007	0.018	0.012
23π/26	0.014	0.011	0.050	0.027	0.013	0.029	0.009	0.010
24π/26	0.036	0.022	0.077	0.132	0.031	0.016	0.020	0.013
25π/26	0.021	0.018	0.052	0.024	0.013	0.017	0.027	0.011

Auxiliary regression includes a linear trend and seasonal dummies									
	Pork	**Rabbit**	**Lamb**	**Anchovy**	**Mackerel**	**Horse mackerel**	**Salmon**	**Sardine**	**Trout**
Frequency	η	η	η	η	η	η	η	η	η
0	0.429	0.458	0.305	0.359	0.287	0.248	0.335	0.382	1.124
π	0.019	0.028	0.045	0.038	0.142	0.136	0.015	0.183	0.015
π/26	0.133	0.086	0.570	0.250	0.155	0.098	0.115	0.223	0.157
2π/26	0.015	0.157	0.078	0.044	0.207	0.031	0.031	0.629	0.031
3π/26	0.026	0.022	0.149	0.040	0.149	0.104	0.034	0.018	0.019
4π/26	0.016	0.024	0.122	0.028	0.252	0.029	0.013	0.031	0.017
5π/26	0.032	0.009	0.023	0.037	0.137	0.018	0.007	0.054	0.009
6π/26	0.007	0.031	0.031	0.088	0.037	0.095	0.008	0.025	0.020
7π/26	0.008	0.008	0.052	0.100	0.016	0.037	0.006	0.016	0.012
8π/26	0.008	0.019	0.026	0.051	0.014	0.067	0.007	0.055	0.026
9π/26	0.013	0.037	0.026	0.050	0.132	0.038	0.025	0.031	0.014
10π/26	0.010	0.019	0.068	0.022	0.130	0.014	0.021	0.032	0.015
11π/26	0.067	0.027	0.073	0.063	0.036	0.062	0.017	0.107	0.060
12π/26	0.066	0.132	0.063	0.107	0.104	0.094	0.055	0.062	0.098
13π/26	0.034	0.029	0.115	0.104	0.300	0.081	0.040	0.109	0.031
14π/26	0.033	0.035	0.063	0.142	0.164	0.037	0.076	0.127	0.027
15π/26	0.021	0.010	0.119	0.126	0.054	0.056	0.081	0.123	0.027
16π/26	0.017	0.029	0.041	0.140	0.035	0.047	0.044	0.052	0.016
17π/26	0.020	0.017	0.032	0.015	0.041	0.022	0.017	0.029	0.011
18π/26	0.007	0.006	0.014	0.104	0.071	0.067	0.025	0.073	0.028
19π/26	0.007	0.008	0.035	0.035	0.037	0.029	0.008	0.069	0.012
20π/26	0.009	0.009	0.049	0.030	0.083	0.034	0.012	0.025	0.006
21π/26	0.020	0.023	0.020	0.058	0.076	0.028	0.009	0.064	0.021
22π/26	0.013	0.021	0.031	0.051	0.017	0.030	0.023	0.048	0.018
23π/26	0.028	0.012	0.024	0.037	0.038	0.055	0.031	0.056	0.037
24π/26	0.069	0.046	0.045	0.030	0.044	0.027	0.044	0.062	0.025
25π/26	0.038	0.030	0.082	0.063	0.059	0.060	0.031	0.037	0.032

in price behavior and, obviously, this knowledge is also very useful to model price relationships.

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