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.

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 them1. 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 (Kwiatkowski 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

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1 Seasonal unit roots force long run relationships and error correction models to be reformulated. As indicated by Palakas & 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).
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,

\[ \Delta_{S2}(B)y_t = d_t + \pi_1 y_{t-1} + \pi_2 y_{t-1} + \sum_{k=3}^{52} \pi_{k,1} y_{t-k} + \pi_{k,2} y_{t-k-1} + \sum_{k=1}^{52} \Delta_{S2}(B) y_{t-k} + \epsilon_t \]

where \( \Delta_{S2}(B) = 1 - B^{52} \), and regressors \( y_{t,1}, \ldots, y_{t,27} \) are defined as

\[ y_{t,1} = \frac{\Delta_{S2}(B)^1 y_t}{1 - B} \]
\[ y_{t,2} = \frac{\Delta_{S2}(B)^2 y_t}{1 - B^2} \]
\[ y_{t,k} = \frac{\Delta_{S2}(B)^k y_t}{1 - B^k}, \quad k = 3, \ldots, 27. \]

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 \( \pi_2 = 0 \) is rejected against \( \pi_2 < 0 \) by means of a \( t \) type test \( t_{1} \). The hypothesis of unit root at Nyquist frequency is rejected when the null hypothesis \( \pi_2 = 0 \) is rejected against \( \pi_2 < 0 \) by means of another \( t \) type test \( t_{2} \). As regards the remainder of seasonal frequencies, an \( F \) type test \( F_{t,2} \) 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 \( \theta_k, k = 3, \ldots, 27 \). 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 weekly series \( \{y_t\}_{t=1}^{T} \) be given by

\[ \varphi(B)y_t = d_t + \epsilon_t, \quad t = 1, \ldots, T, \]

where \( \varphi(B) \) is an autoregressive polynomial, \( d_t \) represents the deterministic component (trend plus seasonal), and \( \epsilon_t \) is a white noise disturbance term.

\[ \Delta_{S2}(B) y_t = d_t + \pi_1 y_{t-1} + \pi_2 y_{t-1} + \sum_{k=3}^{52} \pi_{k,1} y_{t-k} + \pi_{k,2} y_{t-k-1} + \sum_{k=1}^{52} \Delta_{S2}(B) y_{t-k} + \epsilon_t \]

where \( \Delta_{S2}(B) = 1 - B^{52} \), and regressors \( y_{t,1}, \ldots, y_{t,27} \) are defined as in Eqs. (3.a), (3.b), and (3.c).

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(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 \( \{y_{1,t}\}_{t=1,...,T} \) 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

\[
\eta^{(o)} = \frac{\sum_{s=1}^{T} e^{(-i\pi)j}u_j}{T^2 s^2(l)}, \tag{7}
\]

where

\[
S_t^{(o)} = \sum_{j=1}^{T} u_j, \tag{8}
\]

and

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

The test for the presence of unit root at the Nyquist frequency was obtained by assuming that the data generating process for the series \( \{y_{2,t}\}_{t=1,...,T} \) 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

\[
\eta^{(k)} = \frac{\sum_{s=1}^{T} e^{(-i\pi)j}u_j}{T^2 s^2(l)}, \tag{13}
\]

where

\[
S_t^{(k)} = \sum_{j=1}^{T} e^{(-i\pi)j}u_j, \tag{14.a}
\]

and

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

Note that

\[
S_t^{(o)} + S_t^{(k)} = [\sum_{s=1}^{T} \cos(\pi j)u_j]^2 + [\sum_{s=1}^{T} \sin(\pi j)u_j]^2. \tag{16}
\]

Finally, the test for the presence of unit root at seasonal frequency \( \theta_k \) was obtained by assuming that the data generating process for the series \( \{y_{k,t}\}_{t=1,...,T} \) 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:

\[
\eta^{(k)} = \frac{\sum_{s=1}^{T} e^{(-i\pi)j}u_j}{T^2 s^2(l)}, \tag{20}
\]

where

\[
S_t^{(k)} = \sum_{j=1}^{T} e^{-i\theta_k j}u_j, \tag{21.a}
\]

and

\[
S_t^{(k)} = \sum_{j=1}^{T} e^{-i\theta_k j}u_j, \tag{21.b}
\]

and

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

Note that

\[
S_t^{(o)} S_t^{(k)} = [\sum_{s=1}^{T} \cos(\theta_k j)u_j]^2 + [\sum_{s=1}^{T} \sin(\theta_k j)u_j]^2. \tag{23}
\]

If the original series \( \{y_t\}_{t=1,...,T} \) is assumed to be stationary around a deterministic component, the auxiliary regression for testing the null hypothesis of stationarity at any frequency is...
\[
y_t = d_t + u_t. \tag{24}
\]

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 \(\eta^{(k)}\), \(k=3,\ldots,27\), 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 \(\eta^{(k)}\), \(k=3,\ldots,27\), the corresponding asymptotic distributions were the same as those obtained by Khedhiri & Montasser (2012). Note that the asymptotic distribution of statistics \(\eta^{(k)}\), \(k=3,\ldots,27\), 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 \(\eta^{(0)}\) and \(\eta^{(\pi)}\). 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\(^8\). 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 \(\pi\). At the same significance level, the tests also failed to reject the null hypothesis for lemon prices at frequencies \(\pi/26\), \(2\pi/26\) and \(6\pi/26\), and for pear prices at frequency \(5\pi/26\). At 5% significance level, the null hypothesis was not rejected for potato prices at frequency \(8\pi/26\), for bean prices at frequency \(25\pi/26\), for pepper prices at frequency \(\pi\), for apple prices at frequency \(14\pi/26\), for lemon prices at frequency \(3\pi/26\), and for pear prices at frequency \(10\pi/26\). In the case of egg prices, the unit root was rejected at frequency \(\pi\) 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 \(4\pi/26\), for pork and sardine prices at frequency \(\pi\), for rabbit prices at frequency \(2\pi/26\), and for salmon prices at frequencies \(13\pi/26\) and \(16\pi/26\). At 5% significance level, the unit root hypothesis was rejected for john dory prices at frequency \(4\pi/26\), for blue whiting prices at frequency \(5\pi/26\), for hake and salmon prices at frequency \(15\pi/26\), for sardine prices at frequency \(2\pi/26\), and for trout prices at frequency \(18\pi/26\).

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

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\(^7\)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.
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 $\pi/26$ and $2\pi/26$, for lamb prices at frequency $\pi/26$ and also for sardine prices at frequency $2\pi/26$ at 5% significance level, whereas at 10% significance level the null hypothesis was rejected for lemon prices at frequency $\pi/26$.

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 roots.

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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.
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.

Figure 2. Seasonal patterns for meat (a) and fish (b-c) price series (2006-2016).
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 | \(-2.635\) | \(-2.363\) | \(-3.170\) | \(-2.892\) |
| \(\pi\) | \(-2.629\) | \(-2.356\) | \(-2.620\) | \(-2.351\) |
| Frequency \(F\) | 90% | 95% | 90% | 95% |
| \(F_{e2}\) | 4.762 | 5.638 | 4.764 | 5.642 |
| **SEASONAL STATIONARITY TESTS** | | |
| Frequency | \(\eta\) | 90% | 95% | 90% | 95% |
| 0 | \(\eta(0)\) | 0.384 | 0.507 | 0.130 | 0.162 |
| \(\pi\) | \(\eta(\pi)\) | 0.385 | 0.507 | 0.377 | 0.496 |
| \(\theta_k, k = 3, \ldots, 27\) | \(\eta(\theta_k)\) | 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, \(F_{e2}, k = 3, \ldots, 27\), 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, \(\eta(\theta_k), k = 3, \ldots, 27\), 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 \(t\) | 9.220 | 10.241 | 9.507 | 11.805 |
| 2\(\pi\)/26 | 12.953 | 9.420 | 10.241 | 9.857 |
| 3\(\pi\)/26 | 10.494 | 9.887 | 10.871 | 14.402 |
| 4\(\pi\)/26 | 8.043 | 7.320 | 9.578 | 10.626 |
| 5\(\pi\)/26 | 11.780 | 13.203 | 10.926 | 12.382 |
| 6\(\pi\)/26 | 23.639 | 13.238 | 14.463 | 13.790 |
| 7\(\pi\)/26 | 18.467 | 8.801 | 13.511 | 9.734 |
| 8\(\pi\)/26 | 13.075 | 7.103 | 12.763 | 11.781 |
| 9\(\pi\)/26 | 12.189 | 9.063 | 12.860 | 15.145 |
| 10\(\pi\)/26 | 10.414 | 12.748 | 12.934 | 6.482 |
| 11\(\pi\)/26 | 9.175 | 12.409 | 16.274 | 10.666 |
| 12\(\pi\)/26 | 15.015 | 12.374 | 12.934 | 9.824 |
| 13\(\pi\)/26 | 13.499 | 12.860 | 12.934 | 9.824 |
| 14\(\pi\)/26 | 16.714 | 12.748 | 11.935 | 9.824 |
| 15\(\pi\)/26 | 13.109 | 7.313 | 11.767 | 9.824 |
| 16\(\pi\)/26 | 12.015 | 8.101 | 7.615 | 10.414 |
| 17\(\pi\)/26 | 6.022 | 8.949 | 7.728 | 14.695 |
| 18\(\pi\)/26 | 7.544 | 9.516 | 22.149 | 14.678 |
| 19\(\pi\)/26 | 9.842 | 11.350 | 10.196 | 10.020 |
| 20\(\pi\)/26 | 10.729 | 11.253 | 10.858 | 9.923 |
Table 2. Continued.

| 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 |
|-------|---------|--------|-------|------|--------|-----|
| 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**

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

| Chicken | Veal | Blue whiting | Baby clam | John dory | Mussel | Hake | Small hake |
|---------|------|--------------|-----------|-----------|--------|------|------------|
| 0       | -2.886| -2.039       | -1.883    | -2.055    | -2.040 | -1.785| -1.398     |
| π       | -4.670| -3.569       | -3.037    | -4.040    | -3.736 | -4.172| -3.191     |

**Frequency**

| 2π/26 | 16.516 | 7.034  | 7.254  | 16.683 | 16.545 | 6.456 | 12.220 | 12.870 |
| 3π/26 | 6.760  | 17.220 | 10.355 | 6.969  | 7.558  | 12.572| 9.397  |       |
| 4π/26 | 8.661  | 7.736  | 7.158  | 8.319  | 10.392 | 9.752 | 13.729 |       |
| 5π/26 | 8.674  | 8.477  | 7.522  | 17.763 | 15.564 | 12.355| 11.870 |       |
| 6π/26 | 7.056  | 15.658 | 7.858  | 9.898  | 14.367 | 7.598 | 11.685 |       |
| 7π/26 | 12.610 | 7.529  | 12.396 | 13.763 | 15.805 | 9.178 | 10.878 |       |
| 8π/26 | 15.947 | 9.220  | 19.080 | 12.432 | 12.266 | 10.983| 6.844  |       |
Table 3. Continued.

| Frequency | Pork | Rabbit | Lamb | Anchovy | Mackerel | Horse mackerel | Salmon | Sardine | Trout |
|-----------|------|--------|------|---------|----------|----------------|--------|---------|-------|
| t         | 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 |
| 8π/26     | 12.964| 10.316| 18.500| 10.940  | 8.682    | 7.929          | 11.410 | 9.345   | 8.979 |
| 9π/26     | 10.077| 10.173| 9.977 | 10.945  | 10.880   | 6.629          | 4.965  | 9.850   | 8.531 |
| 10π/26    | 12.730| 10.547| 12.240| 10.483  | 9.091    | 12.856         | 3.612  | 8.404   | 12.171|
| 11π/26    | 9.982 | 10.963| 12.560| 16.306  | 11.201   | 14.036         | 11.507 | 11.061  | 9.984 |
| 12π/26    | 10.888| 10.851| 7.188 | 7.815   | 8.989    | 10.255         | 9.876  | 5.109   | 7.662 |
| 13π/26    | 10.856| 10.516| 6.126 | 11.800  | 10.149   | 7.674          | 11.556 | 9.706   | 7.662 |
| 14π/26    | 10.768| 11.285| 10.294| 12.247  | 6.357    | 6.932          | 13.504 | 13.346  | 9.789 |

Auxiliary regression includes a linear trend and seasonal dummies
### Table 3. Continued.

|                         | 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.

|                         | 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 |
| 2n/26                   | 0.096      | 0.017 | 0.437 | 0.082 | 0.059  | 0.065 | 0.014 |
| 3n/26                   | 0.062      | 0.010 | 0.118 | 0.046 | 0.085  | 0.089 | 0.007 |
| 4n/26                   | 0.023      | 0.009 | 0.060 | 0.030 | 0.058  | 0.038 | 0.006 |
| 5n/26                   | 0.033      | 0.006 | 0.074 | 0.015 | 0.018  | 0.014 | 0.006 |
| 6n/26                   | 0.009      | 0.004 | 0.012 | 0.023 | 0.019  | 0.009 | 0.006 |
| 7n/26                   | 0.022      | 0.005 | 0.065 | 0.006 | 0.024  | 0.011 | 0.007 |
| 8n/26                   | 0.012      | 0.007 | 0.035 | 0.013 | 0.019  | 0.016 | 0.006 |
| 9n/26                   | 0.018      | 0.012 | 0.067 | 0.004 | 0.008  | 0.017 | 0.010 |
| 10n/26                  | 0.018      | 0.012 | 0.054 | 0.014 | 0.025  | 0.086 | 0.011 |
| 11n/26                  | 0.022      | 0.016 | 0.039 | 0.013 | 0.085  | 0.036 | 0.012 |
| 12n/26                  | 0.081      | 0.078 | 0.056 | 0.052 | 0.062  | 0.088 | 0.072 |
| 13n/26                  | 0.057      | 0.032 | 0.047 | 0.058 | 0.020  | 0.070 | 0.017 |
| 14n/26                  | 0.023      | 0.012 | 0.033 | 0.014 | 0.020  | 0.028 | 0.016 |
| 15n/26                  | 0.055      | 0.021 | 0.036 | 0.025 | 0.020  | 0.023 | 0.010 |
| 16n/26                  | 0.027      | 0.016 | 0.035 | 0.016 | 0.014  | 0.035 | 0.014 |
| 17n/26                  | 0.028      | 0.012 | 0.020 | 0.011 | 0.007  | 0.015 | 0.017 |
| 18n/26                  | 0.015      | 0.010 | 0.006 | 0.007 | 0.011  | 0.012 | 0.007 |
| 19n/26                  | 0.012      | 0.006 | 0.018 | 0.008 | 0.006  | 0.010 | 0.005 |
| 23n/26                  | 0.015      | 0.014 | 0.012 | 0.014 | 0.013  | 0.052 | 0.022 |
| 24n/26                  | 0.036      | 0.021 | 0.012 | 0.033 | 0.024  | 0.043 | 0.038 |
| 25n/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 |
| 2n/26                   | 0.043 | 0.172   | 0.015  | 0.029 | 0.014 | 0.045  | 0.013 |
| 3n/26                   | 0.011 | 0.040   | 0.016  | 0.027 | 0.016 | 0.045  | 0.007 |
| 4n/26                   | 0.009 | 0.018   | 0.018  | 0.016 | 0.005 | 0.010  | 0.005 |
| 5n/26                   | 0.010 | 0.011   | 0.011  | 0.005 | 0.006 | 0.012  | 0.005 |
Table 4. Continued.

| Auxiliar 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.

| Auxiliar 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.

| Frequency | Pork | Rabbit | Lamb | Anchovy | Mackerel | Horse mackerel | Salmon | Sardine | Trout |
|-----------|------|--------|------|---------|----------|----------------|--------|---------|-------|
| 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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