An Empirical Analysis Of Seasonality In Agricultural Commodity Series

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It is common for many studies to use seasonally adjusted data or to assume determinist seasonality in their empirical analysis. However, using seasonal adjustment procedure have undesirable effects and assuming deterministic seasonality is inappropriate if the seasonality is generated by a stochastic process. Seasonal integration tests have been developed to test for the presence of non-seasonal and seasonal unit roots. An alternat method for the analysis of seasonal data called periodic integration has also been prop by Franses (1992). In this study, unit root tests for seasonal (or non-periodic) and peri integration are applied to seasonally unadjusted wool and livestock time series. The re indicate that integrated models may be a useful tool for univariate or multivariate fore of some agricultural commodity data.

Introduction

The multiplicative seasonal/non-seasonal model (Box and Jenkins 1970) has been widely used in empirical analysis for seasonal data. However, the influence of the seasonal components and the trend are not independent in the multiplicative seasonal model. Tests such as the HEGY (Hylleberg et al. 1990) and the OCSB test (Osborn et al. 1988) have been developed to address the separate influence of the seasonal and non-seasonal components. A more recent class of model which addresses the question of the type of seasonality in a series is the periodic time series model. A major difference between a seasonally integrated model and a periodic model is that the parameters are not constant and vary with the seasons.

Historically, most empirical analysis of time series with seasonal fluctuations involves the use of seasonal dummies and the assumption of constant seasonal patterns. Recent analyses (Franses 1994, Harrison 1994) has shown that this assumption does not hold for many macro economic time series. A model with constant seasonal parameters may systematically under or over-predict if the true series is a stochastic process.

The choice between a deterministic model and an integrated model depends on the de of variation in the seasonal pattern. Changing seasonal patterns implies there are seas unit roots (i.e. stochastic trend) and the seasonally integrated model may be the corre choice of model. The periodic integrated (PI) model is a less restrictive model than t seasonally integrated model and allows the seasonal coefficients to vary periodically.

There does not appear to have been any investigation of stochastic seasonality in Aus agricultural commodity data. This study will test for seasonal unit roots and periodi roots in wool and livestock commodity data. Using quarterly data for all series standardises the analysis and allows the statistical tests to be more easily constructed study will then examine wool auction prices (nominal) for the Reserve Price Scheme period (1975-90), which provides enough observations for an adequate statistical an Wool production data for the period 1972-93 will also be analysed. Livestock statist production, consumption and real saleyard prices are examined for the period 1972-9 These three series are then disaggregated into the four major types of livestock, name beef, mutton, lamb and pigmeat.

Modelling Seasonal Processes

There are three important types of seasonal processes:

i) Purely deterministic process

ii) Seasonally integrated process

iii) Periodically integrated process

- *Deterministic Seasonal Processes*

A deterministic constant seasonal pattern can be accommodated by the use of seasonal dummies. A non-stationary I(1) quarterly process with deterministic seasonal effects,

$$x_t - x_{t-1} = \Sigma\mu_q D_{q_t} + e_t$$

is stationary after differencing, with Dq as a one/zero dummy for each quarter, q.

- *Seasonally Integrated Processes*

Seasonal unit roots are stochastic processes and the use of seasonal dummies is not appropriate if the seasonal process is an integrated process. For quarterly data,

$$
\begin{aligned}
(1-L^4)x_t &= (1-L)(1+L+L^2+L^3)x_t \\
&= (1-L)(1+L)(1++L^2)x_t \\
&= (1-L)(1+L)(1+iL)(1-iL)x_t
\end{aligned}
$$

Using the operator $(1-L^4)$to induce stationary assumes the presence of four roots on tl unit circle. A seasonal unit root in quarterly data has four roots at different frequenci given by 1, -1, i and -i. The -1 root refers to the biannual frequency, whilst i and -i re the quarter and three-quarter frequency. If a variable has to be differenced to induce stationary, this may be as a result of a zero frequency unit root and/or seasonal freque unit roots. The zero frequency root [(1-L)] corresponds to the conventional unit root process. The Augmented Dickey-Fuller (ADF) test is commonly used to test for this root. The seasonal frequency unit roots correspond to the decomposition of S(L) = $(1+L+L^2+L^3)$. This differencing operator is used in the HEGY and OCSB tests.

- *Periodically Integrated Processes*

Seasonal unit root are non-periodic stochastic processes that use the (1-L) operator to induce stationarity. A periodic process utilises the $(1-\phi_s L)$ differencing operator to re the stochastic trend, where all ϕ_s need not equal one, but where $\sum_{s=1}^{S} \phi_s = 1$. If $\left|\sum_{s=1}^{S} \phi_s (1\right|$ the series is stationary, i.e. PI (0), and has no periodic unit root (Franses 1994).

For a periodically integrated process (PIAR) of order p, the model:

$$x_t = \sum_{s=1}^{S} \phi_s D_{st} x_{t-1} + \sum_{j=1}^{p-1} \sum_{s=1}^{S} \beta_{js} D_{st} (x_{t-j} - \phi_{s-j} x_{t-j-1}) + \sum_{s=1}^{S} \alpha_s D_{st} + \varepsilon_t$$

is estimated by non-linear least squares under the restriction of a single unit root, i.e. $|\phi_1\phi_2\phi_3\phi_4| = 1$ (Boswijk and Franses 1994). This process is periodically stationary when $|\phi_1\phi_2\phi_3\phi_4| = 1$, and x_t is then periodically integrated of order one, PI (1).

A seasonally integrated process for quarterly data entails the presence of four unit roots on the unit circle and there is no common trend in the series (Boswijk and Franses 1994). In contrast, the periodically integrated process has a single unit root and the quarters have a common stochastic trend. The conventional I (1) process is a special case of periodic integration. The hypotheses of a non-periodic unit root [$\phi_1 = \phi_2 = \phi_3 = \phi_4 = 1$] can be tested against the restriction of a periodic unit root [$\sum\phi_s = 1$, but not all $\phi_s = 1$].

For quarterly data which is stationary, the periodic autoregressive process PAR (1) car

estimated by applying OLS to:

$$x_t = \sum_{q=1}^{4} \psi_q D_{qt} + \sum_{q=1}^{4} \phi_q D_{qt} x_{t-1} + u_t$$

If x_t is non-stationary, then we can also estimate the following:

$$\Delta x_t = \sum_{q=1}^{4} \psi_q D_{qt} + \sum_{q=1}^{4} (\phi_q - 1) D_{qt} x_{t-1} + u_t$$

and using the Wald statistic test the hypothesis that:

$$\phi_1\phi_2\phi_3\phi_4 = 1 \quad vs \quad \phi_1\phi_2\phi_3\phi_4 \neq 1$$

The ADF, HEGY and OCSB tests cannot discriminate between a periodic and non-p

process. If these tests are applies to a data generating process which is PI(1), they m

incorrectly conclude the process is I(1,0), particularly when all the ϕq's are close to c

In contrast to the ADF, HEGY and the OCSB approaches, periodic integration does not assume the parameters are constant over seasons.

ADF, OCSB, HEGY and PAR test results

All the tests include seasonal dummies to capture any deterministic seasonality in the series. The lag length (p) was chosen by the Lagrangian Multiplier (LM) test indicating the absence of serial correlation. The periodic integration results are only detailed if the LM test on the PAR(1) model indicates there is no residual serial correlation. Due to the difficulties of estimation, higher order PAR processes are considered outside the scope of this study. The results of the tests are summarised in Table 1and Table 2.

The results of the ADF test indicate that all variables, except pigmeat consumption and the livestock saleyard variables are integrated of order I(1). The OCSB and HEGY tests also indicate that most of the variables are integrated at the zero frequency only. The OCSB test alone indicates that mutton production, consumption and sales, and lamb production are not integrated at any frequencies. Only pigmeat consumption is judged to seasonally integrated and the test of a periodically integrated process was rejected. Within the PAR

Table 2: Wool Results

	ADF	OCSB		HEGY		PAR
Variable	Order	p	Order	p	Order	Order
M 19	1	8	0,0	4	1,0	#
M 20	1	8	0,0	4	1,0	#
M 21	1	4	0,0	8	1,1	#
M 22	1	8	1,1	8	1,1	#
M23	1	8	1,0	8	1,1	#
M 24	1	4	1,0	8	1,1	PI (1)
M 25	1	4	1,0	8	1,1	PI (1)
M27	1	4	1,1	4	1,1	PI (1)
M30	1	4	1,0	4	1,0	1,0
WP	1	8	0,0	4	1,0	#

M19: Micron 19, etc.: # serial correlation at 1%

WP: Wool Production

The test results indicate that many of the wool microns have both seasonal and non-seasonal unit roots. The tests suggest that microns 19, 20 and 30, and wool production may only have non-seasonal unit roots. Restrictions on the PAR (1) model accepts micron 30 only has a non-seasonal unit root. Only for microns 22 and 27 do both tests conclude test, a nested test for an ordinary integrated process [(1,0)] was then performed on all f saleyard price series and the beef production series. This restriction was accepted for a five series and the conclusion is that these series are an I (1,0) process. Therefore, of t livestock series only pigmeat consumption is judged to be seasonally integrated.

Table 1: Livestock Results

	ADF	OCSB		HEGY		PAI
Variable	Order	p	Order	p	Order	Orde
BP	1	4	1,0	0	1,0	1,0
MP	1	4	0,0	0	1,0	#
LP	1	4	0,0	0	1,0	#
PP	1	12	1,0	4	1 0	1,0
BC	1	4	1,0	4	1,0	#
MC	1	8	0,0	4	1,0	#
LC	1	6	1,0	4	1,0	#
PC	0	8	0,1	8	0,1	PI (0
BS	0	4	1,0	0	1,0	1,0
LS	0	12	1,0	7	1,0	1,0
MS	0	4	0,0	9	1,0	1,0
PS	0	8	1,0	2	1,0	1,0

BP: Beef Production, etc.; # serial correlation at 1 the series has a seasonal unit root and is I (1,1). Since the tests are biased towards rejecting that the series are I (1,1) in favour of I(1,0), this implies there is high power i accepting that microns 22 and 27 have a seasonal unit root in the data generating proc An estimated PAR(1) model indicates that microns 24, 25 and 27 are periodically integrated, rather than seasonally integrated as indicated by the other tests. The HEG also indicates that microns 21,22,23 have a seasonal unit root. The PAR(1) model for microns indicated the presence of serial correlation. Since higher order PAR models not estimated, it is not possible to indicate whether these microns are periodically integrated.

Deterministic seasonality

Seasonal integration and periodic integration has now been investigated as a possible generating process for the commodity series. To assess the true seasonal process, it is necessary to consider the deterministic component of seasonality in the series. To firs remove the trend in any series, differences of the variables classified by the HEGY te I(1,0) or I(0,1) were taken (Osborne 1990). The relative importance of the determini component of seasonality is indicated by $\overline{R}^2$ for the following equation.

$$X_t^* = \delta + \alpha_1(D_{1,t} - D_{4,t}) + \alpha_2(D_{2,t} - D_{4,t}) + \alpha_3(D_{3,t} - D_{4,t}) + \varepsilon_t$$

where X_t^* is the transformed series, and D_{it} are seasonal dummies for quarter i= 1,2,3.4.

This regression imposes the condition that the seasonal dummy coefficients are constant throughout the sample period. Although this assumption may not be true, this regression does offer some insights into the relative importance of deterministic seasonality.

The results show that, in general, the livestock series have a greater deterministic component than the wool price series. Unlike the wool price series, wool production has a large deterministic component.

Table 3: Deterministic Seasonality

Variable	$\overline{R}^2$	Variable	$\overline{R}^2$
BP	.40	M 19	.01
MP	.64	M 20	.01
LP	.52	M 21	.06
PP	.67	M 22	.09
BC	.23	M23	.09
MC	.16	M 24	.09
LC	.37	M 25	.09
PC	.67	M27	.01
BS	.07	M30	.00
LS	.36	WP	.60
MS	.00		
PS	.23		

Implications of results

- *Livestock Data*

Seasonal and periodic integration processes are rejected for all the lamb and mutton

It appears that the most of the lamb/mutton series have a deterministic seasonal com

It appears that beef consumption and saleyard prices are non-seasonal processes and is not a large deterministic seasonal component in either series. A deterministic model may be most appropriate for beef production. Pigmeat saleyard prices show little intra-year variation and all tests indicate there is little deterministic or stochastic seasonality. Pigmeat production can best be modelled with deterministic seasonality. Consumption has a large deterministic component and examination of the data reveals pigmeat consumption in the first quarter of the year to be always lower than the preceding December quarter. The tests also indicate that pigmeat consumption may also be seasonally integrated. The forecasting performance of models utilising deterministic or stochastic seasonality was not evaluated.

- *Wool Data*

Wool production did not exhibit seasonal unit roots but does have a deterministic seasonal component. The deterministic component of the wool auction price series was estimated to be less than 10% for all microns. A model assuming this simple structure may conclude that seasonality was unimportant for modelling the price series. Contrary to these expectations, the tests indicate the presence of seasonal and periodic integration in some wool price series.

The finer fleece microns (19 and 20) and the coarse grade (30) are judged not to have

seasonal unit root. These results may follow from two factors. Price variability of th

fleece microns was most reduced by the presence of the RPS. Micron 30 was regular

close to the floor price during the RPS period and large quantities were purchased by

Wool Commission to support the minimum floor price. Results for the medium grad

microns (21-27) show some conflict, although the indications generally that seasonal

not deterministic in these series. The PAR (1) models indicated some of the medium

microns are periodically integrated. For those microns 21-23, further estimation of h

order PAR processes is required, due to residual serial correlation. If microns 21-27

found to be periodically integrated, then a multivariate analysis could be conducted.

periodically integrated model would offer superior forecasting ability over a determi

model.

Conclusions

The assumption of deterministic seasonality should not be summarily imposed on agricultural commodity series and the systematic application of tests for periodic or periodic unit roots should be preferred. A univariate modelling approach that allow the incorporation of seasonal coefficients that are either seasonally or periodically integrated would then follow. This type of forecasting model offers the possibility of superior univariate forecasts over models that assume the simpler deterministic seasonal process. Where a series is determined to be periodically integrated, a univariate model should out-perform or at least equal the performance of the non-periodic model.

Most of the livestock series did not exhibit seasonal unit roots and may best be modelled by deterministic seasonality. The presence of the Reserve Price Scheme (RPS) was expected to have lessened the importance of modelling seasonality in the wool price series. The results show that the microns most heavily supported by the RPS had no significant deterministic or stochastic seasonal component. The other fleece types (i.e. excluding microns 19, 20 and 30) were all found to contain either a seasonal unit root, or were periodically integrated. In contrast to wool prices, it was found that wool production can best be modelled with deterministic seasonality.

The fact that most of the microns were seasonally or periodically integrated offers a possibility for improved forecasting of prices. The present wool futures contract is tr against the "standard" 22 micron indicator. Since the correlation of other grades to th micron indicator varies over time, producers of wool fleece other than the 22 micron an additional source of price variability. The analysis of this price variability would r a multivariate approach in estimating a seasonal or periodic cointegration process bet the different micron types.

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