Dairy Supply Response under Stochastic Trend and Seasonality: A Structural Time Series Analysis in Iran

Forooz Jezghani and Reza Moghaddasi

Department of Agricultural Economics, Science and Research Branch,
Islamic Azad University, Tehran, Iran

Abstract: A structural time series methodology was used to examine the role of stochastic trend and seasonality in dairy supply response model. In this analysis, the dairy supply model with deterministic trend and stochastic seasonality performs best in terms of diagnostic tests, goodness-of-fit measures and forecasting accuracy. It was concluded that Contrary to the classical idea of using a deterministic seasonal variable in the dairy supply model, the model incorporating stochastic seasonality yields the best and correctly specified model.

Key words: Supply Response · Stochastic Seasonality · Stochastic Trend · Forecasting Accuracy

INTRODUCTION

While analyzing the dairy supply responses, the ideal condition would be to include all variables of technological progress. However, in reality it is not possible to measure the impacts of all these variables separately using different proxies. Therefore, most studies of dairy supply response capture the ongoing technological improvements by using a deterministic trend variable, which basically assumes an unchanged rate of technological improvement throughout the sample period. Technological improvements evolve over time and assuming it to be a deterministic component misspecifies the dairy supply response model. Similarly, seasonal aspects of dairy farmers' decisions on culling and replacement of dairy cows might evolve over time. Therefore, also it is suggested against assuming a deterministic seasonal component a prior while the developing dairy supply model.

Many researchers have analyzed the supply response function of dairy and beef cattle industry. The primary purposes of analyzing dairy and cattle supply response include: forecasting of future supplies, identifying the dynamic structure which best describes the observed aggregate data and identifying the response to price levels [1].

Maki [2], Kulshreshthan and Wilson [3], Tyfos [4], Freebairn and Rausser [5], Martin and Haack [6], Arzac and Wilkinson [7], Rucker *et al.* [8], Sun [9] and Kaiser *et al.* [10] have analyzed the dairy and cattle supply response behaviors of farmers. Traditionally dairy and cattle supply responses have been modeled as a function of feed cost, market price of animal, interest rate, institutional variables and lagged dependent variables. Some of the above studies have also incorporated trend and seasonal dummy variables.

One of the severe limitations of above studies was to assume deterministic trend and seasonality components in the dairy and cattle supply model, implying that a model with a constant intercept, a time trend and deterministic seasonal component is correctly specified. In this paper, it is argued that assuming seasonality and trend as deterministic while it is actually stochastic might lead to a mis-specified model and false inferences. A deterministic seasonality and trend may or may not be correct, but it should not be assumed a priori while developing supply model for dairy and cattle industry. Therefore, the main objective of this article was to develop a correctly specified dairy supply response model, especially incorporating seasonality and trend as stochastic components.

We begin our study by selecting a basic dairy cattle supply model as proposed by Sun [9] and by Kaiser *et al.* [10]. The selected model will be further improved by assuming different scenarios of fixed and stochastic seasonality and trend variables. In order to find a correctly specified model, four versions of dairy and cattle supply response were developed:

Corresponding Author: Forooz Jezghani, Department of Agricultural Economics, Science and Research Branch,
Islamic Azad University, Tehran, Iran   E-mail: fjezghani@gmail.com

- Deterministic trend and deterministic seasonality (DTDS),
- Deterministic trend and stochastic seasonality (DTSS),
- Stochastic trend and deterministic seasonality (STDS) and
- Stochastic trend and stochastic seasonality (STSS).

Structural Time Series Model

Empirical Methodology: The Structural Time Series Model (STSM) allows the unobservable trend and seasonal components to change stochastically over time. The STSM is generally developed directly in terms of components of interest, such as trend, seasonal, cyclical and residual or irregular components. The STSM relates to regression model in both technical formulation and model selection methodology. The Kalman filter, which is a simple statistical algorithm and a state-space model play fundamental roles in analyzing structural time series models [11]. STSM model reverts to a standard regression model in the absence of unobservable components [12]. Consider the following STSM quarterly dairy supply model:

$$Ds_t = \mu_t + \gamma_t + Z'_t \delta + \varepsilon_t \tag{1}$$

Where,

Ds_t	=	Quarterly dairy supply
μ_t	=	The trend component
γ_t	=	The seasonal component
Z'_t	=	Vector of explanatory variables (milk-feed price ratio, price of slaughter cow, etc)
δ	=	k*1 Vector of unknown parameters
ε_t	=	White noise disturbance term

With deterministic trend and seasonality variables, the model coefficients of μ_t and γ_t in equation 1 are assumed to be constant. If these coefficients are statistically significant, the dairy supply response will be driven by deterministic trend and seasonality. However, this would be a highly restrictive assumption. Technical and genetic progress may lead to changes in the value of these coefficients over time. Changes in the values of μ_t and γ_t may take different forms, leading to either structural break or a smoothly changing stochastic trend. Therefore, there exist possibilities of miss-specification of the model and false inferences if the seasonality and trend is incorporated as strictly deterministic components. Proposed STSM allows specifying a possible alternative of the above problem by allowing a test for deterministic trend and seasonality against a stochastic trend and seasonality alternative. The stochastic trend, which represents the long term movement in the series, can be represented by

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t \tag{2}$$

$$\beta_t = \beta_{t-1} + \xi_t \tag{3}$$

Where

$\eta_t \sim NID(0, \sigma_\eta^2)$
$\xi_t \sim NID(0, \sigma_\xi^2)$

Equations (2) and (3) represent the level and the slope of the trend, respectively. Here, μ_{t-1} is a random walk with a drift factor, β_t, which follows a first-order autoregressive process as represented by equation 3. A stochastic trend variable (μ_t) captures the technological progress and structural change in dairy industry in recent years. The exact form of the trend depends upon whether the variances, σ_η^2 and σ_ξ^2 (also Known as the hyper parameters) is zero or not. If both σ_η^2 and σ_ξ^2 are non-zero, then the trend is said to be stochastic. If both are zero, then the trend is linear and the model reverts to a deterministic linear trend model as follows:

$$Ds_t = \alpha + \gamma_t + \beta_t + Z'_t \delta + \varepsilon_t \tag{4}$$

Economic Model Specification: Following Rucker *et al.* [8], Foster [1], Sun [9], Kaiser *et al.* [10] and Adhikari *et al.* [13], the dairy supply response structural time series model is specified as:

$$DS_t = \mu_t + \gamma_t + \beta_1 DS_{t-1} + \beta_2 DS_{t-2} + \beta_3 DS_{t-3} + \beta_4 MFPR_t + \beta_5 DPSC_t + \varepsilon_t \tag{5}$$

Where,

Ds_t	=	The dairy cattle inventory in current quarter in thousands in Iran
μ_t	=	The trend component
γ_t	=	The seasonal component
Ds_{t-1}	=	He dairy cattle inventory in previous quarter in thousands in Iran
DS_{t-2}	=	The dairy cattle inventory in two lagged quarters in thousands in Iran
Ds_{t-3}	=	The dairy cattle inventory in three lagged quarters in thousands in Iran
$MFPR_t$	=	Milk-Feed Price Ratio
$DPSC_t$	=	Price of slaughter cow deflated by CPI (2004= 100) in cents per pound
ε_t	=	White noise disturbance term

If $\sigma_\eta^2 = \sigma_\xi^2 = \sigma_\omega^2 = 0$, equation 5 collapses to a standard regression model having a linear deterministic time trend and seasonal component and explanatory variables. Therefore, the STSM with explanatory variables in equation 5 is a generalization of the classical linear regression model.

In order to carry out the objectives of the study, all variables were transformed into logarithms.

RESULTS AND DISCUSSIONS

Table 1 reports estimates of trend, season and explanatory variables for four different models of dairy supply. Also included in Table 1 are measures of diagnostic and goodness-of-fit of the model such as Hannan-Quinn criterion, Aikake information criterion (AIC) and Schwarz criterion (SC). The conventional R^2 is not very useful to measure the goodness of fit in our model due to the use of quarterly time series date. Therefore, we report R_S^2, a coefficient of determination, as suggested by *Harvey* [12].

The time-varying parameter estimates of Table 1 are related to the final state vector when the information in the full sample has been utilized. The trend variable (μ_t) and the slope of the trend (β_t) in Table 1 are equivalent to the constant and coefficient of trend variable, respectively, in the standard regression equation. In the meantime, variables γ_1, γ_2 and γ_3 represent the first, second and third quarter seasonal dummy of the classical regression model, respectively.

All dairy supply models (DTDS, DTSS, STDS and STSS) show a strong convergence, reflecting successful maximum likelihood estimation.

H(g) is a test for heteroscedasticity and the 1% critical values of F(g,g), for DTDS, DTSS, STDS and STSS dairy supply models are -6.689, -6.888, -4.935 and -5.547 respectively. These values fail to reject the null hypothesis of presence of heteroscedasticity in the residuals. In our analysis, the estimation procedures converge and the results of diagnostic tests appear satisfactory for the different models of dairy supply response suggesting that all dairy supply models are appropriately specified.

After confirming the validity of the models using different diagnostic tests, we further analyze the four dairy supply models by using explanatory variables as proposed by *Harvey* [12]. The parameter estimates of dairy supply models and hyper parameters are given in Table 1. The study results show a positive and statistically significant role of one and three quarter lagged dairy cow inventory in DTDS model.

Table 1: Estimation Results of Dairy Supply Response Model under Different Assumptions of Trend and Seasonality Variable

Parameter	DTDS	DTSS	STDS	STSS
μ_t	1.015	0.127	2.069	2.920
	(0.000)	(0.000)	(0.000)	(0.000)
β_t	0.002	0.066	0.000	0.086
	(0.000)	(0.000)	(0.000)	(0.035)
γ_1	0.004	-0.021	0.000	0.000
	(0.045)	(0.001)	(0.008)	(0.007)
γ_2	0.034	0.037	0.042	0.034
	(0.000)	(0.000)	(0.000)	(0.000)
γ_3	0.002	0.042	0.032	0.026
	(0.049)	(0.000)	(0.000)	(0.000)
Ds_{t-1}	0.316	-0.368	-0.157	-0.154
	(0.000)	(0.016)	(0.037)	(0.000)
Ds_{t-2}	-0.064	0.733	0.507	0.381
	(0.003)	(0.000)	(0.000)	(0.000)
Ds_{t-3}	0.147	0.159	0.375	0.330
	(0.000)	(0.000)	(0.000)	(0.000)
$MFPR_t$	-0.010	-0.003	-0.015	-0.002
	(0.000)	(0.008)	(0.027)	(0.038)
$DPSC_t$	-0.008	-0.056	-0.045	-0.008
	(0.005)	(0.030)	(0.021)	(0.035)
AIC	-6.847	-7.047	-5.107	-5.718
SC	-6.445	-6.645	-4.672	-5.284
H(g)	-6.689	-6.888	-4.935	-5.547
R_S^2	0.422	0.452	0.213	0.419
RMSE	0.0062	0.0000	0.0061	0.0003

The number in the parenthesis shows probability.

However, in DTDS model two quarter lagged cow inventory also show significant but negative result, a result consistent with the finding of *Kaiser et al.* [10].

Also the results show a positive and statistically significant role of two and three quarter lagged dairy cow inventory in DTSS, STDS and STSS models. In these models one quarter lagged cow inventory also show significant but negative result.

As expected, all dairy supply models show a statistically significant and inverse relationship between milk-feed price ratio ($MFPR_t$) and dairy cow supply. The finding is consistent with the findings of *Kaiser et al.* [10] and *Adhikari et al.* [13]. Analysis shows that an increase of milk-feed price ratio by 1 percent decreases the supply of dairy cow by 0.010, 0.003, 0.015 and 0.002 percent respectively in DTDS, DTSS, STDS and STSS dairy supply models. All dairy supply models show a significant but negative impact of slaughter cow price on supply of dairy cows. This finding demonstrates that an increase in price of slaughter cow by 1 percent decreases the supply of dairy cows by 0.008, 0.056, 0.045 and 0.008percent, respectively, in DTDS, DTSS, STDS and STSS dairy supply models.

Table 2. Dairy Supply Forecasts (In Thousands)

		DTDS	DTSS	STDS	STSS
period	real	forecast	forecast	forecast	forecast
2004.1	829	832	828	823	827
2004.2	853	854	854	852	852
2004.3	844	843	843	837	841
2004.4	832	834	833	830	833
2005.1	847	842	842	837	840
2005.2	873	867	866	860	861
2005.3	864	866	864	852	853
2005.4	852	855	852	855	848
2006.1		788	860	862	855
2006.2		882	885	891	879
2006.3		868	870	872	866
2006.4		860	864	859	856
2007.1		868	889	863	862
2007.2		890	877	891	886
2007.3		978	867	875	874
2007.4		870	860	876	866

The Best Model and Supply Forecasts: The main goal of this analysis was to specify a correct dairy supply model. The values of AIC and SC and R_S^2 values were considered as the main criteria of the best model specifications. In our analysis, DTSS dairy supply model yields the smallest AIC and SC values of -7.047 and -6.645 respectively (Table 1). The DTSS model also yields highest R_S^2 value of 0.452 (Table 1). These statistics are significantly different from remaining dairy supply models, especially the STDS and DTDS, making DTSS a superior and correctly specified model of dairy supply. The study results clearly reject the classical idea of incorporating deterministic seasonal variables in the dairy supply model as a priori.

The forecasting performance of dairy supply models using out-of-sample predictions (Table 2) were furtherly analyzed. Forecasts are made for all dairy supply models for the period from the first quarter of 2006 to the fourth quarter of 2007. The forecasting performance of the model is evaluated by comparing these forecasts with the true values of corresponding variables for the 2004-2007 periods. A root mean square error (RMSE) criterion is used to evaluate the forecasting ability of the model. The forecasts, together with their estimated root mean square errors and actual dairy supplies are reported in Table 2. With small RMSE values, DTSS and STSS dairy supply models lead to more accurate forecasts in comparison to the DTDS and STDS dairy supply model. However, the smallest RMSE value clearly shows that DTSS model is superior in forecasting performance.

CONCLUSIONS

Contrary to the classical idea of using a deterministic seasonal variable in the dairy supply model, our results demonstrate that a dairy supply model incorporating stochastic seasonality (DTSS) yields the best and correctly specified model. The results also demonstrate that the out-of-sample forecasting power of the correctly specified model is superior. However, our analysis suggests against incorporating deterministic trend variable in the dairy supply model. In our opinion, technological advancements are a slowly evolving phenomenon and have been on going in the dairy sector over the past 50 years. The quarterly time series data might not be enough to capture the evolving technological progresses in the dairy industry. Based on our analysis, we do not rule out the possibilities of different empirical results for different statistical and econometric applications, but our study does show the importance of incorporating stochastic trend variable in applied supply studies.

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