Asymmetric price transmission and non-linear adjustment in the Iranian Mutton Market

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ABSTRAC:
This paper analyses the asymmetric price transmission and non-linear adjustment at the farm and retail levels in the Iran's mutton market. We applied a multivariate threshold error correction mechanism for monthly price data. We tested the non-linear adjustment using *sup*-LR, *sup*-LM and *sup*-Wald tests. The results confirm the presence of non-linear cointegration relationship between the retail and farm prices. In short-run, the price transmission behavior reveals that reactions of both the retail and farm prices to positive and negative deviations from the long-run price spread are asymmetric. More specially, the retailers show more strong responses to the both positive and negative shocks imposed to the farmers.

Keywords: **Threshold Cointegration, Non-linearity, Mutton, Price, Iran.**

1. Introduction

Threshold cointegration generalizes the linear cointegration allowing adjustment toward long-run equilibrium to be non-linear, i.e. adjustment occur only after the deviation exceed some critical threshold (Seo, 2006). Furthermore, threshold cointegration allows to capture asymmetries in the adjustment, where positive or negative deviations won't be corrected in the same manner. There are some reasons such as the presence of market power, menu costs, policy interventions, transaction costs and asymmetric information that describe asymmetric price adjustment (Serra *et al*, 2006; Meyer and Von Cramon-Taubadel, 2004).

Analyzing vertical price transmission along supply chain could provide relevant policy information on food market structure, market efficiency and welfare distribution. Wlazlowski *et al* (2009) believed that the presence of asymmetric price transmission implies on welfare loss for some group, because welfare distribution under asymmetry could be different from the symmetry case.

In spite of importance of cointegration threshold, there are a few studies on analyzing price transmission behavior in Iran's market, specially mutton market. The objective of this study is to investigate price transmission mechanism in the Iran's mutton market among the farm and retail levels. Specially, we test the non-linear adjustment using Lo and Zivot (2001), Hansen and Seo (2002) and Seo (2006)'s approaches. The asymmetric price transmission behavior analyzed in a threshold vector error correction framework.

2. MATERIALS AND METHODS

Balke and Fomby (1997) proposed application of threshold autoregressive model (TAR) and threshold error correction methods in the univariate setting. They used a two-step strategy for analyzing the price dynamics. First, they test the null hypothesis of no cointegration against the alternative of linear cointegration. If the hypothesis of no cointegration rejected, in the second step, test of the null hypothesis of linearity against the alternative of threshold cointegration would be examined (test of linearity).

Lo and Zivot (2001) adopted a similar two- step strategy but focus instead on multivariate estimation and testing procedures. They used a threshold vector error correction model (TVECM) with a known cointegration vector. As they indicated, the multivariate threshold cointegration procedures that utilize the full structure of the model have higher power than univariate procedures. Hansen and Seo (2002) developed a maximum likelihood based estimation theory for the TVECM with the unknown cointegration vector. They also provided statistics and asymptotic theory for testing the existence of a threshold effect in the two-regime error correction model.

Let $P_t = (RP_t, FP_t)'$ be the log price of mutton at retail (RP_t) and farm (FP_t) levels, assuming that P_t is a vector of *I(1)* time series which is cointegrated with one cointegrating vector $\beta = (1, -\beta_2)$. Let $z_t(\beta) = \beta' P_t$ denote the *I(0)* error-correction term. Following Hansen and Seo (2002), a linear vector error correction model (VECM) of order *k+1* is written as:

$$\Delta P_t = A' X_{t-1}(\beta) + u_t \qquad (1)$$

where $X_{t-1}(\beta) = [1 \;\; z_{t-1}(\beta) \;\; \Delta P_{t-1} \;\; \Delta P_{t-2} .. \Delta P_{t-k}]'$, $z_{t-1}(\beta)$ is the error correction term, u_t is the error term assumed to be an *iid* Gaussian sequence with a covariance matrix $\sum$.

An extension of model (1), TVECM with a three-regime takes the form:

$$\Delta P_t = \begin{cases} A_1' X_{t-1}(\beta) + u_t & \text{if } \; z_{t-1}(\beta) < \gamma_1 \\ A_2' X_{t-1}(\beta) + u_t & \text{if } \; \gamma_1 \le z_{t-1}(\beta) \le \gamma_2 \\ A_3' X_{t-1}(\beta) + u_t & \text{if } \; z_{t-1}(\beta) > \gamma_2 \end{cases} \qquad (2)$$

where γ_1 and γ_2 are the threshold parameters. If $\gamma_1 = \gamma_2$ then model (2) converts to a two-regime threshold cointegration model (TVECM(2)):

$$\Delta P_t = \begin{cases} A_1' X_{t-1}(\beta) + u_t & \text{if } \; z_{t-1}(\beta) \le \gamma \\ A_2' X_{t-1}(\beta) + u_t & \text{if } \; z_{t-1}(\beta) > \gamma \end{cases} \qquad (3)$$

Following Hansen and Seo (2002), we estimated threshold parameters and cointegration vector using the grid search procedure over the two-dimensional space (β,γ) relies on the log determinant of the estimated residual covariance matrix of the TVECM(m). The optimal threshold parameters and cointegration vector can be estimated using the following optimization program:

$$(\hat{\beta}, \hat{\gamma}) = \arg\min\left(\log\left|\hat{\Sigma}_m(\beta, \gamma)\right|\right) \qquad (4)$$

subject to the limitation of β that is $\pi_o \le T^{-1} \sum_{t=1}^{T} 1(P_t'\beta \le \gamma) \le 1 - \pi_o$, where $\pi_o > 0$ is a trimming parameter.

In test for linearity, as threshold parameters are not present under the null hypothesis (nuisance parameters), so the test statistic suffer from nonstandard inference. To solving this, Lo and Zivot (2001) following Davis (1987), developed a sup-LR statistic that test a TVECM with *m* regime (TVECM(m), for some *m*>1) against a linear VECM:

$$LR_{1m} = T\left(\ln\left(\left|\hat{\Sigma}\right|\right) - \ln\left(\left|\hat{\Sigma}_m(\hat{\beta}, \hat{\gamma})\right|\right)\right) \qquad (5)$$

where $\hat{\Sigma}$ and $\hat{\Sigma}_m(\hat{\beta}, \hat{\gamma})$ denote the estimated residual covariance matrixes from the linear VECM and TVECM(m), respectively. As the distribution of the sup-LR is nonstandard, Hansen and Seo (2002)'s parametric residual bootstrapping procedure was used to compute *p*-values.

An alternative method for estimating TVECM suggested by Hansen and Seo (2002) is based on maximum likelihood method, which involves a joint search over the threshold parameter and cointagrating vector. They develop a test for the linear cointegartion null hypothesis against alternative of threshold cointegration in a two-regime TVECM model based on Lagrange Multiple (LM) statistic. The employed LM statistic is:

$$LM(\beta,\gamma) = vec(\hat{A}_1(\beta,\gamma) - \hat{A}_2(\beta,\gamma))'(\hat{V}_1(\beta,\gamma) + \hat{V}_2(\beta,\gamma))^{-1} \times vec(\hat{A}_1(\beta,\gamma) - \hat{A}_2(\beta,\gamma)) \qquad (6)$$

where $\hat{A}_1(\beta,\gamma)$ and $\hat{A}_2(\beta,\gamma)$ are the parameters estimated in the first and second regimes of equation 3, respectively. $\hat{V}_1(\beta,\gamma)$ and $\hat{V}_2(\beta,\gamma)$ are the Eicker–White covariance matrix estimators for vec $\hat{A}_1(\beta,\gamma)$ and vec $\hat{A}_2(\beta,\gamma)$, respectively. Because of the presence of nuisance parameter, Hansen and Seo (2002) employed the sup-LM statistic as follow:

$$\sup LM = \sup_{\gamma_L \le \gamma \le \gamma_U} LM(\tilde{\beta},\gamma) \tag{7}$$

where $\tilde{\beta}$ is the null estimate of the conitegrating vector and the search region $[\gamma_L,\gamma_U]$ is set so that γ_L, is the π_o percentile of $z_{t-1}(\tilde{\beta})$ and γ_U is the (1 - π_o) percentile. Such as the Sup-LR, *p*-value of the sup-LM has been calculated by Hansen and Seo (2002)'s parametric residual bootstrap procedure.

Seo (2006) indicated that the two-step procedure in threshold cointegration can be misleading because the standard cointegration tests can suffer from substantial power loss when the alternative is threshold cointegration and so, developed a cointegration test in a Band-TVECM with a prespecified cointegration vectors, in which the linear no cointegration null hypothesis was examined against the threshold cointegration. He employed a sup-Wald type statistic and derived its asymptotic distribution. Following Seo(2006), a Band-TVECM for the log prices of a good at retail and farm levels can be written as:

$$\phi(L)\Delta P_t = \alpha_1 z_{t-1} 1\{z_{t-1} \le \gamma\} + \alpha_2 z_{t-1} 1\{z_{t-1} > \gamma\} + \mu + \varepsilon_t \tag{8}$$

where $\phi(L)$ is a *k th*-order polynomial in the lag operator. When γ is given, we can estimate the coefficients by OLS. Let $\theta = (\alpha_1, \alpha_2)'$, then the Wald statistic testing the null hypothesis ($H_0: \alpha_1 = \alpha_2 = 0$) with a fixed γ is $W_T(\gamma) = vec(\hat{\theta}(\gamma))' \operatorname{var}(vec(\hat{\theta}(\gamma)))^{-1} vec(\hat{\theta}(\gamma))$ and sup-Wald statistic is denoted as

$$\sup W = \sup_{\gamma_L \le \gamma \le \gamma_U} W_T(\gamma) \tag{9}$$

We calculate *p*-value of the sup-W by Seo (2006)'s residual-based bootstrap procedure.

Once the presence of threshold effect is confirmed, the next question to answer is what kind of threshold model is more appropriate for the data. To this end, Lo and Zivot (2001) suggested the LR statistic to test the null of a TVECM(2) against the alternative of a TVECM(3):

$$LR_{2,3} = T\left[\ln\left(\left|\hat{\Sigma}_2(\hat{\beta},\hat{\gamma})\right|\right) - \ln\left(\left|\hat{\Sigma}_3(\hat{\beta},\hat{\gamma})\right|\right)\right] \tag{10}$$

where $\hat{\Sigma}_2(\hat{\beta},\hat{\gamma})$ and $\hat{\Sigma}_3(\hat{\beta},\hat{\gamma})$ denote the estimated residual covariance matrices from the unrestricted TVECM(2) and TVECM(3), respectively. The asymptotic distribution of $LR_{2,3}$ are non-standard, and we use Hansen and Seo [12]'s parametric residual bootstrap procedure to calculate related *p*-values.

3. Empirical Analysis and Results

Our application is to monthly mutton prices at the farm and retail levels from 1998 to 2009. The data come from the Ministry of Jihd-e-Agriculture. The empirical analysis is based on natural logarithm transformations of prices. The empirical analysis began with the stationary test for price series. At the second step, we used cointegration test. Under possible cointegration, it would be determined whether the dynamics of the prices can be described by threshold-type of non-linearity. To do this, we utilized Lo and Zivot (2001), Hansen and Seo (2002) and Seo (2006) methods. Finally, we estimated the bivariate TVECM when linearity rejected.

3.1. Unit root and cointegration analysis

The ADF and KPSS tests were carried out in order to assess the order of integration of the price series. The related results are presented in the upper part of table 1. Both tests confirm that the price series are integrated in order one *I(1)*.

For determine whether long-run equilibrium relationship is there between the retail and farm prices, both Johansen[1] and Horvath-Watson (1995) multivariate cointegration tests was employed. Horvath and Watson's test is the standard seemingly unrelated regression (SUR) Wald statistic and its appropriate critical values provided in Horvath and Watson (1995). Lo and Zivot (2001) believed that HW test has higher power than the univariate ADF unit root test.

The related results are shown in the lower part of table 1. The Akaike information criteria (AIC) and Schwartz-Bayesian Criteria (SBC) suggested the appropriate lag lengths of two. In the Johansen test, the maximal eigen value and the trace statistics suggest that there exist at least one cointegrating vector between RP and FP at 5% significance level. The HW test statistic indicates the existence of long-run equilibrium relationship between RP and FP at the 1% level.

Table 1. **Unit root and cointegration tests results**

PRICE SERIES:	LEVELS		FIRST-DIFFERENCES	
	ADF test stat.	KPSS test stat.	ADF test stat.	KPSS test stat.
FP	-1.604	0.176^{**}	-8.614^{*}	0.189
RP	-1.294	0.151^{**}	-8.845^{*}	0.212

Cointegration tests:	**Johansen test**			**HW test stat.**
	Null hypothesis	Trace stat.	Max-eigen value stat.	
RP – FP	None	18.151^{**}	17.780^{**}	
	One at most	0.370	0.370	13.464^{*}

Note: * and ** indicate significance at the 1% and 5% level, respectively. The appropriate lag length was selected based on the AIC and SBC. LM test was used to check for autocorrelation.

3.2. Testing Threshold Cointegration

As, there is a long run equilibrium relationship between two pairs of prices, in the next step we evaluated existence of non-linearities in the adjustment process. To this end, the TVECM was specified and then the Lo and Zivot's (2001) LR test ($supLR_{1,3}$) , Hansen and Seo's (2002) LM test and Seo's (2006) Wald tests were carried out. These testes were calculated by setting π_o=0.10 using 100×100 grid points on the parameters (γ, β). In the using of Lo and Zivot (2001) and Hansen and Seo (2002) tests we considered both threshold parameter and cointegration vector are unknown. Whereas, in the Seo (2006) test the cointegration vector assumed to be known. The *p*-values for $supLR_{1,3}$, supLM and supWald calculated by the parametric residual bootstrap procedure from 1000 simulation replications. Table 2 contains the results of the linearity tests. As can be observed from table 2, the $supLR_{1,3}$, supLM and supWald test statistics indicated that the null of linearity is rejected at the 5% level, in favor of threshold model.

Given that no cointegration and linearity are rejected, next we determine which threshold model is more appropriate to explain the non-linear adjustment process of prices. A TVECM(3) was tested against a TVECM(2) using the $supLR_{2,3}$ test from equation 10. Based on results at table 2, the $LR_{2,3}$ statistic can not reject the null of TVECM(2) against the alternative of

[1] The maximum likelihood estimation procedure provides a likelihood ratio test, referred to as a trace test, with the likelihood ratio test being the test for maximum eigenvalue.

TVECM(3) at 5% significance level. Consequently, it can be concluded that the price transmission mechanism in the Iran's mutton marketing chain, can be characterized by the two-regime threshold process which allows us to fully emphasis the asymmetric nature of the adjustments process.

Table 2. **Testing for non-linearites in price adjustment**

	$supLR_{1,3}$	supLM	supWald	$SupLR_{2,3}$
Test statistic	49.188	25.593	29.422	15.982
Critical values (5%)	47.258	23.954	28.955	30.446
Threshold Parameters	(-0.0647, 0.0198)	0.1309	(0.0534, 0.0803)	

For comparison reasons, a linear VECM, given by equation 1, was estimated using the error correction term generated by the Johansen method. The number of included lags was determined by AIC. The result of linear VECM estimations was reported in table 3. It is important to note that the estimated coefficient of the error correction terms (z_{t-1}) is statistically significant at the 5% level, only on the retail price equation. This indicates that the price adjustment to the long-run equilibrium take place only from the side of retailer. As, for a one-unit gap away from long-run equilibrium, the retail and farm prices of mutton are adjusted -6.4%, regardless of the sign of the deviation from long-run equilibrium.

Table 3. **Linear VECM and TVECM(2) estimations for the mutton retail and farm prices**

	Linear VECM		TVECM(2)			
			Retail price equation		Farm price equation	
Ind.	Retail price equation	Farm price equation	Regime I $z_{t-1} \leq 0.131$	Regime II $z_{t-1} > 0.131$	Regime I $z_{t-1} \leq 0.131$	Regime II $z_{t-1} > 0.131$
constant	0.024*	0.003	0.0189	0.122	0.015	-0.048
	(0.001)	(0.009)	(0.004)	(0.042)	(0.005)	(0.033)
ΔRP_{t-1}	-0.077	-0.013	-0.005	-0.375	-0.371	-0.580
	(0.134)	(0.201)	(0.155)	(0.237)	(0.218)	(0.135)
ΔRP_{t-2}	-0.084	0.029	-0.024	-0.780	0.049	-0.797
	(0.108)	(0.176)	(0.106)	(0.259)	(0.164)	(0.169)
ΔFP_{t-1}	0.389*	0.613*	0.322	0.696	0.788	0.398
	(0.073)	(0.119)	(0.078)	(0.104)	(0.118)	(0.118)
ΔFP_{t-2}	-0.088	-0.282**	-0.116	0.202	-0.299	0.340
	(0.079)	(0.125)	(0.091)	(0.126)	(0.136)	(0.139)
z_{t-1}	-0.064***	0.062	-0.095**	-0.672**	0.068	0.492**
	(0.033)	(0.046)	(0.043)	(0.266)	(0.056)	(0.219)
Cointegration vector estimate=1.0638			Percentage of Obs. in: Regime I=0.851 RegimeII=0.149 Cointegration vector estimate=1.0734 Wald Test[(a)]: Equality of dynamic coefficients=79.72 (0.00) Equality of EC coefficients=40.302 (0.00)			

Notes: values in parentheses are Eicker-White standard errors. *, ** and *** indicate significance at the 1%, 5% and 10% levels, respectively. (a). values in parentheses are p-values.

In the next step, we estimated the two-regimes threshold vector error correction model TVECM(2) for the cointegrated pairs of retail and farm prices. Following Hansen and Seo (2002), we used the maximum likelihood estimation (MLE) as mentioned in Section 2. Table 3 reports the TVECM(2) estimation result.

As can be observed, the estimated cointegration relationship is $z_{t-1} = RP_{t-1} - 1.0734FP_{t-1}$, quite close to a unit coefficient. The estimated threshold parameter is γ=0.131 that identify two regimes with statistically different error correction (EC) coefficients (the Wald test for equality for the EC coefficient is significant at the 1%). The first regime occurs when $RP_{t-1} - 1.0734FP_{t-1} \leq 0.131$, i.e., when the mutton retail price is less than 0.131 percentage points above the mutton farm price (after appropriate adjustment through cointegrating relationship). The first regime (Regime I) that contains 85.1 % of all observation is referred as an "typical" regime. Conversely, the second regime (Regime II), is when $RP_{t-1} - 1.0734FP_{t-1} > 0.131$, comprised of 14.9% of all the observation and is referred as an "extreme" regime. Calculated at the average prices, this deviation indicates that the retail marketing margin is 2620 Rls./Kg. Indeed, the TVECM(2) splits the price adjustment process depending on whether the retail marketing margin lies below or above 2620 Rls./kg.

It is important to note, the Wald test results reject the null hypothesis of equality of the dynamic coefficients across the two regimes, statistically at 1% significance level. Hence, the short-run dynamic effects of the retail and farm prices show significant differences between typical and extreme regimes.

The mutton's retail price adjustment parameters are statistically significant at 5% levels in both typical and extreme regimes, while the farm price only has statistically significant error correction effects in the extreme regime. This indicates that in the typical regime, containing the low marketing margin, adjustment toward long-run equilibrium take place only from the side of the mutton retail price. In contrast, in the extreme regime that contains the bigger marketing margin, the adjustment to the long-run equilibrium occurs at both the retail and farm levels. This implies the mutton retail price adjusts to any short-run deviations. However, the retail price presents two different adjustments. More specifically, retail price responses are more slower (-9.5%) when the marketing margin is below 2620Rls./kg, than when it is greater than 2620Rls./kg, (-67.2%).

The estimated coefficients reveal that the retail prices are adjusted moderately faster to both positive and negative shock than the farm prices. As, within any month, the retail price would be adjusted roughly -67% and the farm prices would be adjusted 49% in response to a positive shock, generated in the previous period. Whereas, in the case of a negative shock the speed adjustments are -9.5 % and 6.8%, respectively.

In the other hand, the estimated adjustment parameter in the linear VECM suggest that only the mutton retail prices react to deviations from the long-term equilibrium.

4. Conclusions

In this study, we evaluated the asymmetries and non-linearities in the price transmission mechanism between the retail and farm prices of mutton in Iran. The results revealed that the non-linearities exist in the mutton price adjustment process. Moreover, the result of Lo and Zivot's sup-LR test confirmed that the asymmetric prices transmission behavior can be characterized by two-regime threshold error correction model. Finally, the TVECM (2) was specified by the maximum likelihood to consider both short-run and long-run effects.

The mutton retail and farm prices are perfectly integrated in the long-run, indicating fully transmission of any change in each of prices to the rest. However, in the short-run, price behavior was found to be asymmetric. As we already discussed, the key characteristic in the threshold models is the pattern of the estimated error correction coefficients in each regime. In the mutton market, most of adjustment coefficients are significant, indicating a feedback effect between the mutton retail and farm prices. Morever, the both retail and farm prices are adjusted much faster to a positive shock than a negative shock. These results represent the asymmetric price transmission in the Iranian mutton subsection.

Finally, the retailers show more strong responses to the both positive and negative shocks rather than farmers. Thus, as expected, the retailers are more flexible than the farmers to any shock that affects supply or demand conditions. Furthermore, in the first regime, indicating the negative shocks, marketing margin tends to remain stabilized.

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