Multivariate Time Series Analysis of Ethiopian Livestock Products Export

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Abstract

Ethiopia has one of the largest livestock populations in Africa. In 2016/17, 9.6% share of the total exports of the country was from live animals, leather and meat. The main aim of this study was to analyze the short-run and long-run relationships between Ethiopian livestock and livestock products export using vector autoregression (VAR) and vector error correction (VEC) models. Quarterly data on Ethiopian livestock and livestock products export and exchange rate that span from the first quarter of 2002 to the third quarter of 2017 were used for analysis. The results indicated the existence of a cointegration (long-run relationship) between the volume of live animals, meat and leather exports. The results of the fitted VEC model also revealed that the volumes of live animal and meat exports were significantly affected by their own past (lagged) volume of export in the short-run. However, we found no significant feedback effects across Ethiopian livestock and livestock products (meat and leather) export in the short-run. This probably is an indication of lack of coordination and linkages among meat processing & export industries (export abattoirs) and firms involved in leather products export.

Key words: *Livestock and livestock products export, VAR, cointegration, VECM*

1. Introduction

In Ethiopia, agricultural development is considered a priority by the government for stimulating overall economic growth, reducing poverty and achieving food security. The average share of agriculture in the gross domestic product (GDP), employment and foreign exchange earnings was 34, 75 and 85 percent in 2016, respectively (NBE, 2018).

Within agriculture, the livestock subsector provides an opportunity for further development. The sheer size of the national livestock herd, one of the largest in Africa, makes it a resource with potential to contribute significantly to national development. According to the Agricultural Sample Survey conducted by the Central Statistical Agency (CSA) of Ethiopia, the country had about 57.83 million heads of cattle, 28.89 million sheep, 29.70 million goats and 60.51 million poultry, plus an assortment of horses, donkeys and camels in 2015 (CSA, 2015/16). The sector contributed up to 40% of agricultural GDP, nearly 20%

of total GDP, and 20% of national foreign exchange earnings in 2017 (NBE, 2018). Furthermore, the country's geographic location offers substantial opportunities for exportation, thus earning foreign exchange from livestock products, especially of red meat to the Gulf and within Africa, as well as leather, honey and other livestock products to Europe.

The government of Ethiopia encourages investments in meat processing, especially focusing on exporting value-added products abroad. In 2016/17, export earnings from leather and leather products decreased by 1.1% due to a 1.6% fall in export volume despite a 0.5% rise in international price. Consequently, the share of leather and leather products in total export revenue stood at 3.9% (NBE, 2018). Djibouti, Egypt, Somalia, Sudan, Saudi Arabia, Yemen and United Arab Emirate are the major importers of Ethiopian live animals.

Most of the studies about livestock & livestock products export and related variables in Ethiopia have been conducted using descriptive univariate time series analysis and/or qualitative methods. Gebregziabher and Sileshi (2019) studied the impact of live animal export on meat and meat products export in Ethiopia. Using descriptive time series analysis, they concluded that live animals export has a negative impact on meat and meat products export due to inadequate live animal supply associated with the long supply chain. Other studies related with live animal and livestock products export that utilized purely qualitative methods or descriptive analysis include those of Mesele et al. (2015), Eyob and Zewudu (2016) and Workneh (2006).

This study utilized multivariate time series (MVTS) analysis whereby a vector of time series (live animal export and livestock (meat and leather) products export) are modeled simultaneously. MVTS deals with the analysis of interaction, co-movements and bi-directional causality of several time series. To the best of our knowledge, there is no study that employed multivariate time series analysis on livestock and livestock products export in Ethiopia. This gap motivated the current study.

2. Materials and Methods

2.1 Source and type of data

The study used secondary data obtained from the National Bank of Ethiopia (NBE) that span from the first quarter of 2002 to the third quarter of 2017. The data pertain to quarterly volume of live animals, meat and leather export of Ethiopia as well as quarterly exchange rate.

2.2 Variables in the study

The vector of endogenous (response) variables (Y_t) is the quarterly volume of Ethiopian livestock and livestock products exported. Specifically, $Y_t = (Y_{1t}, Y_{2t}, Y_{3t})'$, where Y_{1t}, Y_{2t} and Y_{3t} represent the export volume of live animals, meat and leather at time (quarter) t, respectively. The lagged values of quarterly volume of Ethiopian livestock and livestock products were used as independent variables in our VAR specification together with the exogenous covariate quarterly exchange rate (Birr against US dollar).

2.3 Methods of analysis

2.3.1 Tests of stationarity

The first step for an appropriate time series analysis is to determine whether the series under consideration are stationary or not. Many economic and financial time series exhibit a trending behavior or non-stationarity in the mean. Due to non-stationarity, regressions with time series data are very likely to yield spurious results. The test of stationarity that has become widely popular over the past several years, namely, the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979), was used to test for the existence of unit roots.

2.3.2 Vector autoregressive models

The study used multivariate time series models to analyze the Ethiopian livestock and livestock products exported over the period of 2002 to 2017. Vector Autoregressive (VAR) model is one of the most successful, flexible and easy to use models for the analysis of multivariate time series. It is a natural extension of the univariate autoregressive model to dynamic multivariate time series.

VAR modeling is a technique that could be used to characterize the joint dynamic behavior of a collection of time series (variables). Let $Y_t = (Y_{1t}, Y_{2t}, \ldots, Y_{nt})'$ denote an $(n \times 1)$ vector of stationary time series. The basic p-lag VAR model, denoted $\mathrm{VAR(p)}$, has the form:

$$Y_t = C + \Pi_1 Y_{t-1} + \Pi_2 Y_{t-2} + \ldots + \Pi_p Y_{t-p} + U_t \quad , \ t = 1, 2, \ldots, T \ \ldots\ldots\ldots\ldots\ (1)$$

where C denotes an (n x 1) vector of constants and Π_j is an $(n \times n)$ matrix of autoregressive coefficients, $j = 1, 2, \ldots, p$. The $(n \times 1)$ vector U_t is a zero mean white noise process with time invariant and positive definite covariance matrix Σ:

$$E(U_t)=0$$

$$E(U_t U_s')=\begin{cases}\Sigma \ , \ \text{if } t=s \\ 0 \ , \ \text{if } t\neq s\end{cases}$$

Since there are three endogenous variables in this study, a trivariate VAR model was applied. For example, a trivariate $VAR(1)$ model with an exogenous variable (X_t) has the form:

$$\begin{bmatrix} Y_{1t} \\ Y_{2t} \\ Y_{3t} \end{bmatrix} = \begin{bmatrix} C_1 \\ C_2 \\ C_3 \end{bmatrix} + \begin{bmatrix} \pi_{11} & \pi_{12} & \pi_{13} \\ \pi_{21} & \pi_{22} & \pi_{23} \\ \pi_{31} & \pi_{32} & \pi_{33} \end{bmatrix} \begin{bmatrix} Y_{1,t-1} \\ Y_{2,t-1} \\ Y_{3,t-1} \end{bmatrix} + \begin{bmatrix} g_1 \\ g_2 \\ g_3 \end{bmatrix} X_t + \begin{bmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{bmatrix} \quad \text{.................... (2)}$$

In our study, the exogenous input X_t is the exchange rate at time t and g_i ($i=1, 2, 3$) represents the effect of current exchange rate on the contemporaneous volume of exports. The diagonal elements π_{ii} ($i=1, 2, 3$) of matrix Π represent the effect of own one-period-lagged livestock and livestock product export on the respective contemporaneous export, while the off diagonal elements π_{ij} ($i\neq j$) represent the mean effects across Ethiopian livestock and livestock products export.

2.3.3 Estimation of the order of the VAR model

The lag length for $VAR(p)$ model can be determined by using model selection criteria. The general approach is to fit $VAR(p)$ models with orders $p=1, 2, \ldots, p_{max}$ and choose the value of p which leads to minimum value of the Akaike Information Criterion (AIC), Schwarz-Bayesian Information Criterion (BIC) and Hannan-Quinn (HQ) Information Criterion. The general form of model selection criteria is (Lütkepohl, 1991):

$$IC(p) = \ln\left[\det(\tilde{\Sigma}(p))\right] + c_T \varphi(n,p) \quad \text{.. (3)}$$

where $\tilde{\Sigma}(p)$ is the residual covariance matrix, c_T is a sequence indexed by the sample size, and $\varphi(n,p)$ is a penalty factor that penalizes large $VAR(p)$ models.

2.3.4 Cointegration and vector error correction model

Two sets of non-stationary variables are said to be cointegrated if a linear combination of these variables has a lower order of integration. For example, cointegration exists if a set of variables, each of which is integrated of order one ($I(1)$), have linear combinations that are stationary ($I(0)$). The order of integration $I(1)$ tells us that first differences transform the non-stationary series into stationary. The presence of cointegration is an evidence of a long-run equilibrium relationship between the series under consideration. In this study, the Johansen (1991) procedure was applied to test for the presence of cointegration.

The starting point in Johansen's procedure to determine the number of cointegrating vectors is re-parameterizing the VAR representation of Y_t as a vector error correction model (VECM):

$$\Delta Y_t = C + \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + GX_t + U_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where $\Pi = (\sum_{i=1}^{p} \Pi_i) - I_n$, $\Gamma_i = -\sum_{j=i+1}^{p} \Pi_j$, $i = 1, 2, \ldots, (p-1)$ and I_n is the identity matrix (Engle and Granger, 1987).

The rank of the matrix Π determines the number of cointegrating vectors in the system. In cases where $\text{rank}(\Pi) = 0$, there are no cointegrating vectors, and we analyze the system using VAR technique by differencing the non-stationary series. If Π has full rank, i.e., $\text{rank}(\Pi) = n$, then Y_t has no unit root (it is stationary in level). In such cases, VAR methodology is applied to the system in level. Finally, if $\text{rank}(\Pi) = r$, where $0 < r < n$, then there exist r cointegrating vectors that are stationary, and the system is analyzed as VECM. In this case, ΠY_{t-1} is called the error correction term.

VECM is a restricted VAR designed for use with non-stationary series that are known to be cointegrated. It restricts the long-run behavior of the endogenous variables to converge to their cointegrating relationships while allowing for short-run adjustment dynamics. When there is a cointegrating vector, the VAR model should be augmented with an error correction term since any deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments. The size of the error correction term indicates the speed of adjustment of any disequilibrium towards a long-run equilibrium state.

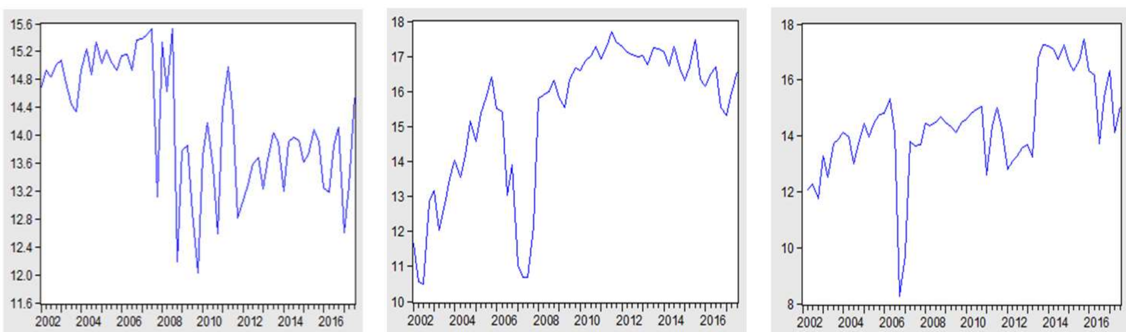
Granger representation theorem (Engle and Granger, 1987; Johansen, 1991) asserts that if the coefficient matrix Π in equation (4) has reduced rank r ($0 < r < n$), then there exist ($n \times r$) matrices α and β

each with rank r such that $\Pi = \alpha\beta'$, where the elements of the matrix α are the adjustment coefficients and β is a matrix of long-run coefficients such that the rows of $\beta' Y_t$ are all stationary ($I(0)$).

3. Results and Discussion

3.1 Time plots of the series

The time plot of each of the series (net weight in tons) is shown in Figure 1. From the time plots, we can in general say that the volume of live animals and meat exports showed an increasing trend over the study period, while the opposite was true for the volume of leather export. We can also notice that the volume of live animals and meat export highly declined around 2007. This was perhaps due to the bans imposed by importing countries as a result of outbreaks of livestock diseases.



Leather export Live animals export Meat export

Figure 1: Time plot of the volume of live animal and livestock products export

3.2 Tests for seasonality and stationarity

3.2.1 Seasonality test

There are two reasons that might cause our data to be affected by seasonality. The first one is the quarterly nature of the data itself. Secondly, consumption of meat in Ethiopia is highly seasonal (with peaks around religious holidays), which in turn affects the export of livestock products. Therefore, before directly testing for the stationarity of the series, we have to check for the periodicity of the data. The study utilized the log of quarterly volume (net weight in tons) of live animal export (LLA), leather export (LLR) and meat export (LME) from the first quarter of 2002 to third quarter of 2017.

The result of seasonality test for the series is presented in Table 1. The seasonality test results show that there is no evidence of stable seasonality for all of the series under consideration (p-value > 0.05).

Moreover, the M7 statistics are all greater than one is further evidence that no seasonal adjustment is necessary.

Table 1: Results of seasonality test for the series

Series	F- statistic	M 7	Kruskal - Wallis statistic (p-value)
LLA	1.942	1.955	5.776 (0.12304)
LLR	4.590	1.224	7.601 (0.05502)
LME	0.565	3.000	1.753 (0.62510)

3.2.2 Unit root test

Before we attempt to fit a suitable model, we have to test for the presence of unit root(s) so that the order of integration of each series could be determined. The results of ADF test both at level and first difference for each series are presented in Tables 2. Here LER is the log of exchange rate. The null hypothesis that the series in levels contains unit root cannot be rejected for each of the variables, while the same is rejected for the first difference of the series. This implies that the time series under consideration are all integrated of order one (I(1)).

Table 2: Unit root test results

Series	At level		First difference	
	ADF statistic	p-value	ADF statistic	p-value
LLA	-2.519	0.317	-7.698	0.000
LLR	-1.635	0.766	-10.867	0.000
LME	-2.845	0.188	-8.704	0.000
LER	-0.040	0.950	-3.026	0.038

3.3 Cointegration analysis

Since the variables are integrated of the same order, we proceed to cointegration test. The main purpose of cointegration analysis is to model the long-run relationship between the underlying variables. If the test indicates that there are no cointegrating vectors, however, we need to analyze the system using VAR technique by differencing the non-stationary series. The results of trace and maximum eigenvalue tests of cointegration for LLA, LME and LLR are reported in Table 3.

From the Johansen cointegration tests, the rank of the cointegration matrix was found to be one. In other words, there is one linear combination of the three $I(1)$ series that is stationary. The implication is that there exists a long-run causal relationship among LLA, LLR and LME, and thus, we need to go for a restricted vector autoregressive (restricted VAR) model, that is, a vector error correction model (VECM).

Table 3: Johansen cointegration test results

Hypothesized No. of CE(s)	Eigenvalue	Trace test			Maximum eigenvalue test		
		Statistic	Critical value	Prob.	Statistic	Critical value	Prob.
None	0.255284	33.134	29.797	0.0199	28.874	21.132	0.0033
At most 1	0.172862	15.154	15.495	0.0562	11.156	14.265	0.1466
At most 2	0.056959	3.577	3.841	0.0586	5.335	3.841	0.0209

3.4 VEC model estimation and analysis

Having concluded that the series under consideration are cointegrated, we proceed to estimate the short-run behavior and the adjustment to the long-run equilibrium, which is represented by VECM. For subsequent modeling choices, specifying the lag length has strong implications. As an initial stage, we fitted a VECM of order (or lag interval) four. We then checked whether the chosen lag is optimal or not using Wald lag exclusion test. The results indicated that the first lags of the endogenous variables were statistically significant, while all higher lags were insignificant. Therefore, we adopted the restricted $\mathrm{VAR}(1)$ model for estimation purposes. The results of the fitted VEC model are presented in Table 4.

The fitted long-run model is given by:

$$\mathrm{LLA}_{t-1} = -14.39 + 3.91 * \mathrm{LME}_{t-1} - 5.27 * \mathrm{LLR}_{t-1}$$

The long-run equation shows that a one percent increase in the volume of meat export induces, on average, an increase of about 3.91 percent in the volume of live animals in the long-run. This result is unexpected since the export of live animals should have a negative impact on the value adding industries (meat and meat products exporting industries) by reducing the availability of the desired inputs (live animals) in the market to those industries. This result is inconsistent with those of Gebregziabher and Sileshi (2019) who concluded that live animals export has a negative impact on meat and meat products export using descriptive and qualitative analysis. However, our result may be an indication that the Ethiopian livestock resource is underutilized due to limited processing and exporting capacity of meat export firms (export abattoirs) established in the country.

Moreover, for a one percent increase in the volume of leather export, the volume of live animal export decreases by 5.27% in the long-run.

Table 4: Vector error correction estimates

Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1		
LLA(-1)	1.000000		
LLR(-1)	5.267334*		
	(1.43794)		
	[3.66312]		
LME(-1)	-3.909227*		
	(0.62645)		
	[-6.24032]		
C	14.39		
Error Correction:	**D(LLA)**	**D(LLR)**	**D(LME)**
CointEq1	-0.104701	-0.037182 *	0.047054
	(0.06410)	(0.01538)	(0.03085)
	[-1.63344]	[-2.41777]	[1.52542]
D(LLA(-1))	-0.201626 *	0.013388	-0.122875 *
	(0.108564)	(0.02743)	(0.05502)
	[-1. 857206]	[0.48806]	[-2.23321]
D(LLR(-1))	-0.162598	-0.191439	-0.234323
	(0.53058)	(0.12730)	(0.25534)
	[-0.30645]	[-1.50386]	[-0.91770]
D(LME(-1))	-0.022891	-0.013599	-0.124475
	(0.31434)	(0.07542)	(0.15128)
	[-0.07282]	[-0.18031]	[-0.82284]
C	0.044204	0.019423	0.033087
	(0.06419)	(0.01540)	(0.03089)
	[0.68865]	[1.26122]	[1.07111]
D_LER	0.056511	-0.800585	3.241934
	(5.03619)	(1.20830)	(2.42362)
	[0.01122]	[-0.66257]	[1.33764]

* Significant at the 0.05 level

The results of the fitted VEC model show that the volumes of live animal and meat exports were significantly affected by their own past (lagged) volume of export in the short-run. For a one percent increase in one-time lagged volume of live animal and meat export, the respective current volumes of export decreased by 0.20 and 0.12 percent in the short-run, respectively. Furthermore, the vector error correction model showed that 3.7% of the short-run disequilibrium in the volume of leather export is adjusted within one quarter, while the remaining shocks are adjusted in subsequent quarters. The results revealed no significant feedback effects across Ethiopian livestock and livestock products export in the short-run.

3.5 Structural analysis

Variance decomposition is used to assess the proportion of the fluctuation in a series explained by its own shocks as well as shocks from other variables. The results of the variance decomposition for live animals export are presented in Table 5.

Table 5: Variance decomposition of LLA

Variance Decomposition of LLA:

Period	S.E.	LLA	LLR	LME
1	0.835363	100.0000	0.000000	0.000000
2	1.105118	92.88874	3.624653	3.486603
3	1.259070	88.09384	5.049786	6.856373
4	1.347530	85.30358	5.599132	9.097284
5	1.397888	83.72305	5.835364	10.44158
6	1.426325	82.83517	5.947145	11.21769
7	1.442299	82.33809	6.003622	11.65829
8	1.451243	82.06030	6.033349	11.90636
9	1.456240	81.90521	6.049381	12.04541
10	1.459029	81.81868	6.058150	12.12317

At the first horizon, the variation in live animals export was explained by its own shock only. In the second quarter, shock to the volume of live animals export accounted for 92.9% of the fluctuation in live animals export (own shock) and the remaining 3.6 and 3.5 percent were explained by the volume of leather and meat exports, respectively. At long horizons, leather and meat exports account for almost a fifth of the variance.

4. Conclusion

In this empirical work, an attempt was made to apply multivariate time series analysis to model the cointegration of Ethiopian livestock and livestock products export based on quarterly data from 2002 to 2017. The data were tested for seasonality and results revealed that all of the series were not affected by periodicity. Moreover, unit root tests showed that all four series were non-stationary in level, but stationary after first differencing. Cointegration tests revealed that there exists a long-run association between the volumes of Ethiopian live animals, leather and meat exports.

The fitted long-run equation indicated that the volume of live animals export had a positive long-run relationship with the volume of meat export: for a one percent increase in the volume of meat export, the volume of live animals export increased by 3.9 percent, in the long-run. One naturally expects an inverse relationship between the two. But the finding that the two series drift upward together may support the fact that the Ethiopian livestock resource is underutilized.

From the fitted short-run models, 3.7% of the short-run disequilibria in the volume of leather export were adjusted each quarter. The results also revealed that the volumes of live animals and meat export were significantly affected by their own lagged values in the short-run. However, we found no significant feedback effects across Ethiopian livestock and livestock products (meat and leather) export in the short-run. This probably is an indication of lack of coordination and linkages among meat processing & export industries (export abattoirs) and firms involved in leather products export.

Reference

1. Central Statistical Agency (CSA). (2015/16). Agricultural Sample Survey: Report on Livestock and Livestock Characteristics. http://www.statsethiopia.gov.et/wp-content/uploads/2019/06/Agricultural-Sample-Survey-Livestock-Poultry-and-Beehives-2015.pdf

2. Dickey, DA. and Fuller WA. (1979). Distribution of the Estimators for Autoregressive Time Series with a Unit-root. *Journal of the American Statistical Association*, 74:427-431.

3. Engle, RF. and Granger, CWJ. (1987). Cointegration and Error Correction: Representation, Estimation and Testing, *Econometrica*, 55:251-276.

4. Eyob Eshetu and Zewudu Abraham. (2016). Review on Live Animal and Meat Export Marketing System in Ethiopia: Challenges and Opportunities. *Journal of Scientific and Innovative Research*, 5(2): 59-64.

5. Gebregziabher Girmay and Sileshi Yeserah. (2019). The Impact of Live Animal Export on Meat and Meat Products Export in Ethiopia, *International Journal of Research - Granthaalayah*, 7(9):162-171.

6. Johansen, S. (1991). Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models. *Econometrica*, 59:1551-1580.

7. Lütkepohl, H. (1991). Introduction to Multiple Time Series Analysis. Springer-Verlag, Berlin.

8. Mesele Asegede, Abrha Bsrat, Yohannes Hagos and Getachew Gugsa. (2015). Livestock Market Value Chain Assessment in Selected Sites of Tigray, North Ethiopia: Challenges and Opportunities for Enhancing Animal Product Export. *Global Veterinaria*, 14(1):48-55.

9. National Bank of Ethiopia (NBE). (2018). Annual Report on the Ethiopian Economy. https://nbebank.com/wp-content/uploads/pdf/annualbulletin/Annual%20Report%202018-19.pdf

10. Workneh Ayalew. (2006). Getting the Incentives Right: Concerns Associated with Expansion of Cattle Export Markets in Ethiopia. *Ethiopian Journal of Animal Production*, 6(2):99-103.