Applied Studies in Agribusiness and Commerce – APSTRACT
Center-Print Publishing House, Debrecen
DOI: 10.19041/APSTRACT/2017/1-2/3

SCIENTIFIC PAPER

COMPARING PARAMETRIC AND SEMIPARAMETRIC ERROR CORRECTION MODELS FOR ESTIMATION OF LONG RUN EQUILIBRIUM BETWEEN EXPORTS AND IMPORTS

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Abstract: *This paper introduces the semiparametric error correction model for estimation of export-import relationship as an alternative to the least squares approach. The intent is to demonstrate how semiparametric error correction model can be used to estimate the relationship between Ghana's export and import within the context of a generalized additive modelling (GAM) framework. The semiparametric results are compared to common parametric specification using the ordinary least squares regression. The results from the semiparametric and parametric error correction models (ECM) indicate that the error correction term and import variable are significant determinants of Ghana's exports. On the basis of Akaike Information Criteria and Generalized Cross-Validation (GCV) scores, it is found that the semiparametric error correction model provides a better fit than the widely used parametric error correction model for modeling Ghana's export-import relationship. The results of the analysis of variance provide further evidence of nonlinearity in Ghana's export and import relationship. In effect, this paper demonstrates the usefulness of semiparametric error correction model in the estimation of export – import relationship.*

Keywords: *Exports, imports, semiparametric, nonlinearity, generalized additive model, ECM*
(JEL code: *C14, C18, C22, F10, F14.*)

INTRODUCTION

Explaining the relationship between exports and imports of countries have been given considerable attention in the literature. Noticeably, some studies (Acquah and Acquah 2015, Al-Khulaifi 2013, Mukhtar and Rasheed 2010, Amoah and Loloh 2009, Uddin 2009) have applied the parametric error correction model (ECM) in estimating export and import relationship. Empirically, these studies find a long run equilibrium relationship existing between export and import. They note that imports and the error correction terms are significant determinants of export.

However, the parametric error correction model which employs the ordinary least squares (OLS) estimation technique imposes restrictions on the data. For example, it assumes a linear relationship between the dependent and independent variables in the model. In effect the parametric ECM does not allow for non-linearity. The specification of a functional form, for the export-import relationship, involves the risk of specifying a functional form, which is not similar to the true relationship between exports and imports. This misspecification may lead to bias in estimation results.

An alternative approach to model the export-import relationship within the ECM framework whilst relaxing the restrictions of the parametric approach is to implement a semi-parametric error correction model (ECM) using the generalized additive modelling (GAM) approach. The GAM allows for the nonlinear relationship between the dependent and independent variables within the error correction framework. In effect, the semi-parametric ECM complements the parametric ECM by relaxing the assumptions of linearity and providing evidence of non-linearity in the export-import relationship.

This paper demonstrates that semi-parametric regression offers an alternative and useful approach to model the export-import relationship within the ECM framework. The paper is outlined as follows. The introduction is followed by the methodology which discusses the Error Correction Model, Parametric Regression (Ordinary Least Squares) and Semi-parametric regression model (Generalized Additive Model), results and discussion and conclusion.

METHODOLOGY

The methodology describes the data and the parametric and semiparametric econometric techniques employed in the study. Econometric techniques such as ordinary least squares and semiparametric regression analysis and the Error Correction model are emphasized.

Error Correction Model (ECM)

A simple error correction model for modelling export and import relationship can be written as

$$\Delta Y_t = \alpha_1 \Delta x_t + \alpha_2 (y-x)_{t-1} + U_t \qquad (y-x)_{t-1}$$
$$U_t \sim N(0,\sigma^2) \qquad [1]$$

Where *y* denotes exports and x denotes imports and $(y-x)_{t-1}$ refers to the error correction term which captures the long run equilibrium relationship between exports and imports. The error correction model above can be represented as a standard regression model as defined in equation 2.

Parametric Regression Model (Ordinary Least Squares Method)

The parametric regression model employs the ordinary least squares (OLS) estimation technique which fits the best straight line to data by minimizing the sum of squares residuals. In effect, the parametric model specifies a linear functional form between the dependent and independent variables. The standard regression model is specified in equation 2.

$$y = \beta_0 + \sum_{j=1}^{p} \beta_j x_j + e \qquad [2]$$

Semiparametric Regression Model (Generalized Additive Modelling Approach)

In order to avoid the necessity of parametric assumptions, the standard regression model specified in equation 2 can be rewritten in the form of an additive model as

$$y = \beta_0 + \sum_{j=1}^{p} f_j(x_j) + e \qquad [3]$$

Where is f_j an arbitrary smooth function. Stone (1986) provides a detailed discussion about the function.

The smooth function f can be estimated using penalized smoothing spline method (penalized maximum likelihood) which was first developed by Wood (Wood, 2000 and 2006). This method is applied because of its efficiency, model selection and inferential capabilities (Wood and Augustin, 2002).

Suppose we represent $f_j(x) = \sum_i \beta_i \phi_i(x)$ for a family of spline basis functions. A penalty $f\left[f_j''(x)\right]^2$ which can be written in the form $\beta_j^T S_j \beta_j$, for a suitable matrix S_j that depends on the choice of basis.

Then maximize $\log L(\beta) - \sum_j \lambda_j \beta_j^T S_j \beta_j$, where $L(\beta)$ is likelihood with respect to β and the $\lambda_j s$ control the amount of smoothing for each variable.

The current study is interested in comparing semiparametric and parametric error correction models in estimation of export-import relationship. The study therefore uses the co-integrated export and import data on Ghana used by Acquah and Acquah (2015) and downloaded from the World Trade Organization. The total merchandise annual imports and exports data (measured in USD) are for the period of 1948 to 2012. Acquah and Acquah (2015) established for this time series data set, that the exports and imports are co-integrated and imports granger causes the exports. Consequently in this study, the dependent variable is export and the independent variables are import and the error correction term.

DATA ANALYSIS

The parametric and semiparametric regression analysis were applied in the study. The R programming language was used to analyse the data. The error correction model was estimated using the ordinary least squares approach and semiparametric generalized additive model. The generalized additive model was estimated using the penalized smoothing spline method of the mgcv package in R.

Graphical approach was applied to explain the fitted generalized additive model. The nature of the non-linearity between the imports and exports relationship is graphically revealed. Model selection techniques were used to provide the basis for comparing and choosing between the fitted parametric and semi-parametric error correction models.

RESULTS

Table 1 presents the results of parametric error correction model. There is a significant and positive relationship between import as an independent variable and export as the dependent variable. There is also a significant and negative relationship between the Error Correction Term (ECT) as independent variable and export as the dependent variable. In summary, the results show that the import and the error correction term are significant determinants of export. The import and error correction terms have estimated coefficients of 0.56276 and -0.32257 respectively. The adjusted R^2, AIC and GCV scores for the parametric error correction model are 0.409, 0 -45.48056 and 0.027946 respectively.

Table 1: Parametric ECM Estimates

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.01787	0.02150	0.831	0.40916
Diff(Im)	0.56276	0.08551	6.581	1.21e-08***
Lag(ECT)	-0.32257	0.10071	-3.203	0.00216**

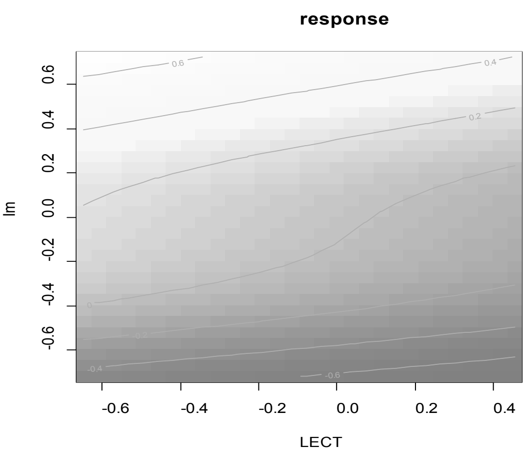
R-sq.(adj)	Deviance explained	GCV	AIC	Scale est.	n
0.409	42.7%	0.027946	-45.48056	0.026636	64

*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

Table 2 presents the results of the semi-parametric generalized additive model error correction analysis. Similarly, there is a significant and negative relationship between error correction term as an independent variable and export as the dependent variable. Notably, the import and the error correction term are significant determinants of export. The error correction term has an estimated coefficient of

-0.25339. The adjusted R2, AIC and GCV scores for the semi-parametric error correction model are 0.479, -51.13979 and 0.025731 respectively. The graph shows lag of ECT (LECT) on horizontal (x) axis and Import (Im) on vertical (y) axis. The response (export) scale is given by the contours, with lighter colour indicating higher values. From Figure 1, very low import levels are associated with contours with darker colours whilst higher levels of import are associated with contours with lighter colours. In effect, low levels of import are associated with poor overall response in export, whilst high import levels are associated with high response in export.

Figure 1: A Contour Plot of Import (lm) and Error Correction Term (LECT) against Response



The p-value of 0.01929 derived from the analysis of variance suggests that incorporating non-linear effects has improved the model. In effect, the analysis of variance provides support in favour of the semi-parametric ECM against the parametric ECM.

DISCUSSION

In the parametric error correction model estimation, the significant and positive relationship between import as an independent variable and export as the dependent variable suggests that, an increase in import will lead to an increase in the export. In the short run, 1% increase in import significantly results to 0.56% increase in export. There is also a significant and negative relationship between the Error Correction Term as an independent variable and export as the dependent variable. In the long run, 32% of the disequilibrium in the export and import in the previous time period is eliminated in the subsequent time period. In summary, the results show that the import and the error correction term are significant determinants of export. Similarly, Uddin (2009) and Al-Khulaifi (2013) find that imports and the error correction term were significant determinants of exports.

In the semi-parametric generalized additive error correction model, the significant and negative relationship between error correction term as an independent variable and export as the dependent variable suggest that in the long run, 25 % of the disequilibrium in the export and import in the previous time period is eliminated in the subsequent time period. Furthermore, the results show that the import is a significant determinant of export and nonlinearly related to the export. From Figure 1, very low import levels are associated with contours with darker colours whilst higher levels of import are associated with contours with lighter colours. This suggests that, low levels of import are associated

Table 2: Semi-parametric ECM Estimates

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.06184	0.01916	3.227	0.00205 **
Lag(ECT)	-0.25339	0.10109	-2.507	0.01499*
	edf	Ref.df	F	p-value
s(Diff(Im))	3.592	4.463	12.78	2.44e-08***

R-sq.(adj)	Deviance explained	GCV	AIC	Scale est.	n
0.479	51.7%	0.025731	-51.13979	0.023482	64

*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

Table 3: Analysis of Variance

Model	Resid. Df	Resid. Dev	Df	Deviance	Pr(>Chi)
Parametric ECM	61.000	1.6248			
Nonparametric GAM ECM	57.537	1.3716	3.4633	0.25323	0.01929*

*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

with poor overall response in export, whilst high import levels are associated with high response in export. And middling on import leads to a steady moderate response in export. Similarly, Acquah and Acquah (2015) and Amoah and Loloh (2009) using a linear error correction model find imports and the error correction term as significant determinants of exports. Notably, we allow for nonlinear relationship between exports and imports but a linear relationship between exports and the error correction term. This is because when the ECT enters the model nonlinearly and non-parametrically as illustrated in Table 3 in the appendix, its effective degrees of freedom (edf) obtains a value of 1. The effective degrees of freedom with a value of 1 suggests that the ECT has essentially been reduced to a simple linear effect. Consequently, the ECT is allowed to enter the model linearly as illustrated in Table 2.

On the basis of statistical significance, both the semiparametric ECM and the parametric ECM find the import and the error correction term as significant determinants of export. Thus, we come to the same conclusion as in the linear model regarding the statistical significance of individual effects. On the basis of model comparison measures, the semi-parametric generalized additive error correction model outperforms the parametric error correction model. Model selection methods such as the Akaike Information Criteria (AIC) and the Generalized Cross Validation (GCV) scores were computed for the models. Notably, for AIC and GCV, models with lower scores are preferred. The AIC and GCV scores of -51.13979 and 0.025731 for semi-parametric generalized additive error correction model were lower than -45.48056 and 0.027946 for the parametric error correction model. Thus, on the basis of the AIC and GCV scores the fitted semiparametric Error Correction Model tends to be superior and provides a better model fit when compared with the parametric ECM. Furthermore, the adjusted R2 suggests that the semiparametric ECM accounts for much of the variance in the exports than the parametric ECM. The analysis of variance test also provides a basis for comparing the competing models. The analysis of variance test suggests that incorporating non-linear effects has improved the model considerably. The results of the study suggest evidence of non-linearity in the export-import relationship for Ghana. This is a departure from previous studies which emphasized the use of a linear model (ECM) in estimating import-export relationships (Acquah and Acquah 2015, Al-Khulaifi 2013, Mukhtar and Rasheed 2010, Amoah and Loloh 2009, Uddin 2009). Similarly, Bachmeier and Li (2002) estimated a semiparametric error correction model (ECM) using US interest rate data and find the semiparametric ECM to be superior to the parametric ECM, suggesting evidence of nonlinearities in the term structure.

CONCLUSION

This paper proposes a semi-parametric error correction modelling technique for estimating export and import relationship as an alternative to the parametric ordinary least squares estimation approach. A comparison of the result from the error correction model using the least squares method and the semi-parametric regression approach indicate that the results obtained in the alternative methods are similar.

On the basis of statistical significance, both import and the error correction term are significant determinants of exports in the semi-parametric and parametric ECM. In effect, the semiparametric ECM yields meaningful results which are reasonable and consistent with the results derived from the parametric ECM. The analysis of variance test suggests that incorporating non-linear effects has improved the model considerably. In effect, the results of the study suggest evidence of non-linearity in the export-import relationship for Ghana. Furthermore, the analysis of the Ghana's export-import relationship shows that the semiparametric ECM proves to be superior to the widely used parametric ECM on the basis of Akaike Information Criteria and the GCV scores. In summary, this paper has demonstrated that the semi-parametric error correction model offers an alternative and a useful approach to modelling import - export relationships.

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APPENDIX

Table 3: Semi-parametric ECM Estimates

	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	0.06332	0.01915	3.305	0.00162 **
	edf	Ref.df	F	p-value
s(Diff(Im))	3.592	4.463	12.778	2.44e-08***
s(Lag(ECT))	1.000	1.000	6.283	0.0149 *

R-sq.(adj)	**Deviance explained**	**GCV**	**AIC**	**Scale est.**	**n**
0.479	51.7%	0.025731	-51.13979	0.023482	64

Signif. codes: 0 '' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1***