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ECONOMETRIC INVESTIGATION OF SHORT-RUN AND LONG-RUN RELATIONSHIPS BETWEEN GDP AND AGRICULTURAL GDP OF BANGLADESH

Md. Humayun Kabir*

ABSTRACT

The study is an attempt to investigate long-run and short-run relationships between gross domestic product (GDP) and agricultural GDP of Bangladesh applying the Vector Error Correction Model (VECM). The data published by the BBS for the period 1972-73 to 2015-16 was used. As preconditions of VECM, the stationarity of the time series data and co-integration of the variables were tested. The GDP and agricultural GDP in logarithm forms were found integrated of the order one (d=1) and co-integration of rank one (r=1).The coefficient (beta) of estimated long-run equilibrium equation was positive and significant implying a long-run equilibrium relationship between GDP and agricultural GDP. A positive and significant time trend was also observed in the co-integrating equation. Both coefficients (alpha) of the error correction terms (ECTs) in the VECM, which indicate the rates of short-run adjustments towards the long-run equilibrium, were negative and significant confirming consistency with the theory. Since both ECTs were negative and significant, there was a long-run bi-directional causality running from agricultural GDP to GDP and vice-versa. Responding to a positive shock in agricultural GDP, the GDP gradually increases while due to shock in GDP, the agricultural GDP decreases in the initial stage and increases gradually thereafter. Various post-estimation specification tests were performed and the estimated parameters of the model were found consistent and efficient.

Key Words: GDP, Agricultural GDP, VECM, Bangladesh

I. INTRODUCTION

A country, when lies in its initial stage of development, agriculture sector is considered as the prime driving force of development rather than other existing sector within the economy (Rahman and Hossain, 2014). While not critical to economic growth in industrialized countries, agricultural growth is considered an essential factor for the middle-income countries to boost economic growth and for the emerging countries to initiate the take-off from agrarian societies (Moon and Lee, 2010). The agricultural sector is often advocated as a vital tool and crucial sector for generating economic growth and fighting poverty (World Bank, 2008). Agriculture is the mainstay of the LDC economies, underpinning their food security, export earnings and rural development (FAO, 2002). The role of agriculture becomes even more important when we consider the critical role that agriculture plays in alleviating poverty, hunger, and malnutrition in developing countries (FAO, 2008). In developing countries, where the agricultural sector accounts for a large share of the workforce and accounts for roughly 25% of the value added in the economy, growth in agricultural productivity causes significant aggregate effects and influence the general economic growth within a country (Gollin, 2010). Agriculture and related agribusiness activities are being increasingly organized in global value chains. Supply chains link production, processing, and distribution centres, often driven by direct foreign investments in the food and retail sectors of developing countries (ADB, 2013).

***Corresponding author:** *Deputy Chief, Ministry of Labour and Employment, Bangladesh Secretariat, Dhaka, Bangladesh, E-mail: kabirmh70@gmail.com.*

Growth in Bangladesh agriculture has accelerated from less than 2.0% per year during the first two decades after independence to around 3.0% during the last decade from 2000 to 2010 (GOB,2015). However, the most prominent stylized fact of modern development is a secular decline in the share of agriculture in both output and gross domestic product (GDP), with the consequent increase in the combined shares of industry and services (ADB, 2013). In keeping with the global scenario the share of agriculture in Bangladesh's GDP has declined from about 50% in 1972-73 to 15.35 % in 2015-16 (BBS, 1993; BBS, 2017). This trend is part of the qualitative transformation process of Bangladesh's economy. While there has been an accompanying declining trend in agricultural employment along with rising wages, almost half of the national work force continues to be employed directly or indirectly in the agriculture sector (GOB, 2015).

Positive significant contribution of agriculture is found to overall and nonfarm output growth in Bangladesh. There is also the evidence of agricultural growth causing outputs in other sectors. Agriculture has significant positive spillover effects. Notwithstanding the spillover effects, an agriculture-focused growth strategy will enhance the sector's ability to sustain a decent income growth for rural population thereby triggering immediate anti-poverty effects while ensuring a huge market for products and services for local industries. Given its linkages, agricultural growth can boost economic activities in the sectors (Razzaque and Raihan, 2012).

Extensive irrigation, high-yielding crop varieties, more efficient markets, and mechanization, enabled by policy reforms and investments in agriculture research, human capital, and roads have driven agriculture sector's growth in Bangladesh. Agriculture is a major source of rural jobs in the country. Over 87 percent rural people derive at least some income from agriculture. However, two thirds of rural households rely on both farm and non-farm incomes. Pro-poor agriculture growth has stimulated the non-farm economy in Bangladesh. A 10 percent rise in farm incomes generates a 6 percent rise in non-farm incomes (WB, 2016).

Agriculture plays a key role in economic growth. A girth of studies across the globe has examined the relationship between agriculture and overall economic development of developed and developing countries using time series data. Some studies found significant impact of agricultural growth on economic development and vice-versa while some found only unidirectional linkage. The number of studies in this field is scanty in Bangladesh. The studies conducted in the Bangladesh context by Rahman, and Hossain (2014) and Alam and Wadud (2017) can be particularly mentioned here, a summary of which is presented below.

Author	Sectors	Methodology	Findings
Rahman and Hossain (2014)	*Agriculture and GDP(Economic growth)*	Co-integration, VAR Causality Period: 1973-74 to 2010-11	Non-stationary. One co-integrating vector. Uni-directional causality running from Agriculture to economic growth.
Alam and Wadud (2017)	Crop, Forestry, Livestock, Fisheries, Total agricultural, GDP (economic growth)	Co-integration, VECM Causality, Period:1973-74 to 2012-13	Non-stationary. One co-integrating vector.Bi-directional causality between agricultural and GDP.

The application of Vector Autoregressive (VAR) model by Rahman and Hossain (2014) was a misspecification of the model because in case of co-integrating relationship the Vector Error Correction Model (VECM) is appropriate. On the other hand, Alam and Wadud (2017) applied the VECM only to test the causality but short-run and long-run relationships between GDP and agricultural GDP were not analysed. The study is an attempt to fill up this gap.

The primary purpose of this study is to investigate the impact of agricultural sector on the national economic development of Bangladesh. The specific objectives are: (I) To investigate long-run and short-run relationships between real GDP and real agricultural GDP of Bangladesh; and (II) To test consistency and efficiency of the parameter estimates.

Following the introduction section, containing objective of the study and literature review, the next sections of the article are focused on the data description and research methodology, discussion of findings and interpretation of results, and conclusion and policy implications.

II. METHODOLOGY

Data Source and Description

The article is based on time series data of real gross domestic product (GDP) and real agricultural GDP for the period from 1972-73 to 2015-16 fiscal years (July to June) published by the Bangladesh Bureau of Statistics (BBS). The data covered for the base years of 2005-06, 1995-96 and 1984-85. Due to incompatibility, the data of real GDP and real agricultural GDP for the period from 1972-73 to 1994-95 were generated through back calculation using available latest constant growth rates of GDP and agricultural GDP. The minor variations that are observed in constant growth rates due to changes in base year were ignored assuming that it will not distort the attributes of the data and the inference to be generated from the analysis. In fact, the historical constant GDP growth rates are widely used by the economists and policy makers in interpreting economic development of a country. The data of real GDP and real agricultural GDP respectively are used as proxies to economic and agricultural development of Bangladesh. The data used for the study is presented in **Appendix 1.**

During the period 1972-73 to 2015-16, the average annual real GDP was Taka 3,469.16 billion with minimum of Taka 1,226.08 billion and maximum of Taka 8,835.39 billion, the standard deviation being Taka 2,106.39 billion. On the other hand, the recorded average annual real agricultural GDP was Taka 672.24 billion with minimum of Taka 358.59 billion, maximum of Taka 1,301.78 billion and standard deviation of Taka 281.18 billion. Due to the high standard deviations natural logarithm forms of data were used for analysis. The historical trends of real GDP and real agricultural GDP in logarithm forms are presented in **Figure 1**.

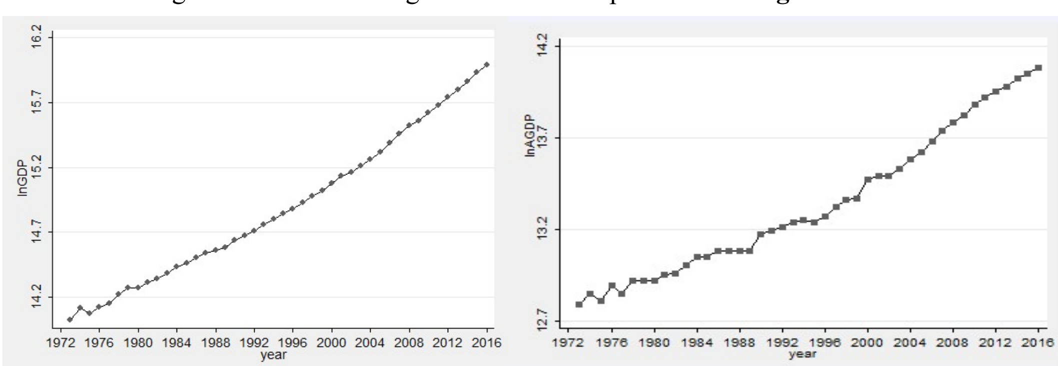


Figure 1: Trends of real GDP and real agricultural GDP (in logarithm forms) of Bangladesh, 1972-73 to 2015-16

Analytical Techniques

This time series analysis technique is applied in this study to investigate the contribution of agricultural sector to the economic growth of Bangladesh. The analytical methods deal with test of degree of stationary, test of co-integration, estimation of vector error correction model **(**VECM**)** for short-run and long-run relationships between the variables and validation. The analysis was performed with the help of STATA 13.0 software.

Testing integration/unit root/stationary

Although the time series data is generally non-stationary the model requires time series that is stationary. There are several procedures to investigate stationary of any given time series. In this study the two most commonly applied tests, the Augmented Dickey-Fuller (Dickey and Fuller, 1981) test and the Phillips-Peron (Phillips and Peron, 1988) test are used.

Augmented Dickey Fuller (ADF) Test: The ADF test is performed based on the following models:

Model-1: With constant only

$$\Delta Y_t = b_0 + b_1 Y_{t-1} + \sum_{i=1}^{p} b_2 \Delta Y_{t-1} + e_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Model-2: With constant and time trend effect

$$\Delta Y_t = b_0 + \delta t + b_1 Y_{t-1} + \sum_{i=1}^{p} b_2 \Delta Y_{t-1} + e_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where$\Delta Y_t = Y_t - Y_{t-1}$,$Y_t$= Time series (lnGDP / lnAGDP), *t*= Time trend effect, p= optimal number of lags, e_t=disturbance term considered as a white noise error.

If the variable is stationary (no unit root), the ADF test should indicate that $b_1$in both equation is significantly smaller than zero.

Phillips Peron (PP) test: The PP test is based on the following model:

Model-1: With constant only

$$\Delta Y_t = b_0 + b_1 Y_{t-1} + e_t \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Model-2: With constant and time trend effect

$$\Delta Y_t = b_0 + \delta T + b_1 Y_{t-1} + e_t \ldots\ldots\ldots\ldots (4)$$

Where $\Delta Y_t =$ first difference of Y= $(Y_t - Y_{t-1})$,b_0= constant, *T*= Time trend effect, e_t= error term and Y_t= Time series.

If a variable is non-stationary at level but stationary at first difference the variable is said to integrated of order 1, *I(1)*.

Johansen co-integration test:

A time series may be individually non-stationary but a linear combination between two or more time series can be stationary which is confirmed through co-integration test. There exists an equilibrium or long run relationship between the time series if all the variables are integrated of the same order (Engle and Granger, 1987).Once the integration of same order is established, the existence of long run co-integration relationship of the chosen time series can be examined. Co-integration tests recommended by Engle and Granger (1987), Johansen (1988) and, Johansen and Juselius (1990) etc. are used to empirically confirm the presence of potential long run equilibrium relationship between two variables. In this study the Johansen's technique was used in order to establish how many co-integration equations exist between the variables, lnGDP and lnAGDP. Johansen method indicates the maximum likelihood procedure to identify existence of co-integrating vectors for chosen non-stationary time series data. The Johansen methods allow us to determine the number of co-integrating vector(s). Appropriate lag lengths are selected according to the different Information Criterion method.

There are two different likelihood ratio tests proposed by the Johansen namely, Trace Test and Maximum Eigen Value Test.

Trace Test, $$\lambda_{trace} = -T \sum_{i=r+1}^{k} \ln(1-\lambda_i) \ldots\ldots\ldots\ldots\ldots\ldots. \ldots\ldots (5)$$

Maximum Eigen Value Test, $\lambda_{max} = -T \ln(1-\lambda_{r+1}) \ldots (6)$

Where T= number of observations and λ_i= estimated values of characteristic roots ranked from largest to smallest. The trace test (λ_{trace}) examines the null hypothesis of no co-integrating vector (r= 0) against a general alternative of one or more co-integrating vectors (r≥1)while the Maximum Eigen value test (λ_{max})examines the null of *r* co-integrating vector(s) against the specific alternative of r + 1 co-integrating vector(s).

Vector Error Correction Model (VECM)

If two or more variables are I(0) (stationary at level), the standard case is to perform VAR at level. If two or more variables are individually integrated of same order of d, I(d), (non-stationary at level but stationary after taking d^{th} difference) with d ≥ 1 there might be two distinct cases- either the Vector Autoregressive (VAR) model or the Vector Error Correction Model (VECM) may be appropriate. (i) If the variables are co-integrated (r≥1), the error correction term (ECT) has to be included in the VAR and the model becomes a Vector error correction model (VECM) which is a restricted VAR. Since VECM automatically converts all variables into first difference within the system, the non-stationary level data is used. (ii) If the variables are not co-integrated (r=0), the variables have first to be differenced d times and VAR should be performed with the differenced dataset. Fitting the VAR model with non-stationary, I(d) and co-integrated (r≥1) variables may lead to misspecification of the model. In this case, the VECM will be appropriate which captures both the short run and long run relationships between the variables. It also provides scope to analyze how they adjust towards a long-run equilibrium. The ECT needs to be negative and statistically different from zero. It shows the speed of adjustment of the variable toward their long run values. If two variables $\mathbf{X}_t$ and $\mathbf{Y}_t$ are co-integrated of order one, I(1) the VECM for the two variables might look like

$$\Delta Y_t = \beta_{y0} + \lambda_y(\mathrm{Y}_{t-1} - \alpha_0 - \alpha_1 X_{t-1}) \sum_{i=1}^{p} \beta_{yi}\mathrm{Y}_{t-i} + \sum_{i=1}^{p} \gamma_{yi}\mathrm{X}_{t-i} + e_{yt}$$

$$\Delta X_t = \beta_{x0} + \lambda_x(\mathrm{Y}_{t-1} - \alpha_0 - \alpha_1 X_{t-1}) \sum_{i=1}^{p} \beta_{xi}\mathrm{X}_{t-i} + \sum_{i=1}^{p} \gamma_{xi}\mathrm{Y}_{t-i} + e_{xt}$$

Where

Y=Time Series (lnGDP), X=lnAGDP), ECT = $\mathrm{Y}_{t-1} - \alpha_0 - \alpha_1 X_{t-1}$,$Y_t = \alpha_0 + \alpha_1 X_{t-1}$is the long-run co-integrating relationship between the two variables, *p* = optimal lag length of Y_t and X_t, and $\lambda_y$and $\lambda_x$are the error-correction parameters that measure how Y and X react to deviations from long-run equilibrium. There may be time trend effects (*T*) in the model reflected in the long-run co-integrating relationship.

III. RESULTS AND DISCUSSION

Empirical Results

This section deals with the descriptive statistics of the variables, preliminary analysis to check stationary of the data and empirical tests. The time series plots, correlogram plots, Augmented Dickey Fuller (ADF) test and Phillips-Perron test were used to check for stationary of variables in the dataset. In addition, the Johansen Co-integration test was performed to determine the appropriate time series model for analysis. The VECM is specified and performed to explore short run and long run relationships of the variables. The results of the tests performed are presented and interpreted in this section.

Testing integration/unit root/stationarity

Usually most economic variables are non-stationary. Granger and Newbold (1974) noted that the regression results from the VECM models using non-stationary variables will be spurious. It is, therefore, important to test for stationarity before generalizing any relationship. There are several methods for testing stationarity. Plotting time series data is the simplest method for checking stationary of the variables in the dataset. Trends (**Figure 1)** in the movements of lnGDP and lnAGDP indicate possibilities of their non-stationary attribute. The correlograms further suggested non-stationary of the variables since they decayed slowly demonstrating existence of trends overtime. For empirical evidence of non-stationary attribute of the variables, the Augmented Dickey Fuller and Philips Perron tests were performed. The results of the tests presented in **Tables 1 and 2** indicate that the two variables are non-stationary in their levels of natural logarithm form.

Table 1: Results of ADF test for unit root or non-stationarity

ADF Model	Variable	Series in Level		Series in First Difference		Order of Integration
		Test Statistic	P-value	Test Statistic	p-value	
Without trend	lnGDP	4.188 [3]	1.0000	-3.441***[1]	0.0096	I(1)
	lnAGDP	2.242 [3]	0.9989	-4.520***[1]	0.0002	I(1)
With Trend	lnGDP	1.081 [3]	1.0000	-4.506 ***[2]	0.0015	I(1)
	lnAGDP	-1.310[3]	0.8853	-4.371 ***[2]	0.0024	I(1)

(H_0 = There is a unit root in the series at level or the series is non-stationary)
*** indicates significant at 1% level. Figures in [--] indicate lag length.

To derive stationary variables, it is customary to take first difference of the variables. The **Tables 1 and 2** present the results of ADF test and Phillips-Perron test of unit root test for first difference of lnGDP and lnAGDP with and without trend. The results show that lnGDP and lnAGDP are stationary after first difference. The correlograms of the first differenced variables also revealed stationarity of the variables. The time series plots of first differenced data **(Figure 2)** exhibit that the data are trend stationary.

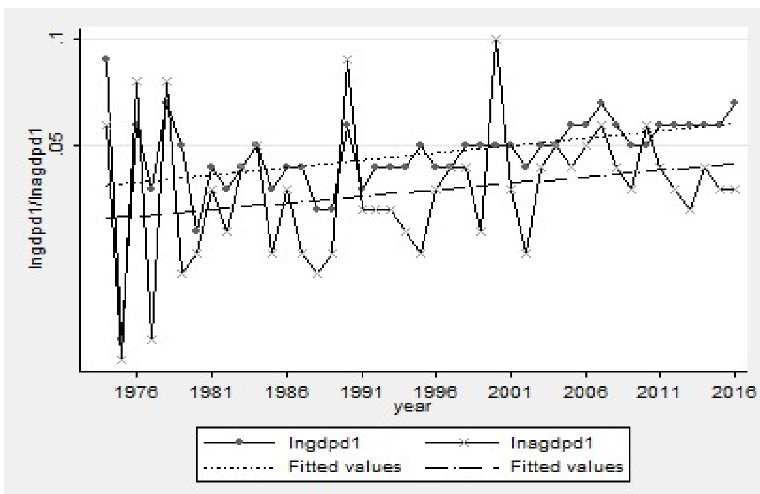


Figure 2: Time series plots of lnGDP and lnAGDP in first difference

Table 2: Results of the Phillips-Perron test for unit root or non-stationary

PP Test Method	Variable	Series in Level		Series in First Difference		Order of Integration
		Test Statistic	P-value	Test Statistic	P-value	
Without trend	lnGDP	5.365[3]	1.0000	-7.607 ***[3]	0.0000	I(1)
	lnAGDP	2.301[3]	0.9990	-8.911***[3]	0.0000	I(1)
With Trend	lnGDP	0.677[3]	0.9970	-11.801***[3]	0.0000	I(1)
	lnAGDP	-1.065[3]	0.9346	-10.871***[3]	0.0000	I(1)

(H_0 = There series at level has a unit root/the series is non-stationary)
*** indicates significant at 1% level. Figures in [--] indicate lag length.

The results of unit root tests confirm that the lnGDP and lnAGDP series are integrated of the order 1, I(1).Thus co- integration tests can be applied for the variables.

Testing co-integration

Since the variables lnGDP and lnAGDP are integrated of the same order, I(1), their long run relationships are studied. From the time series plots it is evident that the lnGDP and lnAGDP move together which apparently indicates existence of co-integration among the variables. The main objective of co-integration analysis is to determine the co-integration rank of the model. In this study the Johansen's technique was used in order to establish the number of co-integration equation(s) exist between variables lnGDP and lnAGDP. The Johansen's technique with different trend options and lag lengths were tested. The results with restricted trend in 4l ags are presented in **Table 3**. As a thump rule first non-rejection of the null hypothesis is taken as an estimate of ***r***.

Table 3: Results of Johansen co-integration test for lnGDP and lnAGDP series

Co-integration rank		Value of statistic	5% critical value	1% critical value	Decision
H_0	H_1				
Trace statistic					
r = 0	r ≤ 1	31.2643 ***	25.32	30.45	H_0 rejected at 1% level
r =1	r ≤2	8.7084	12.25	16.26	H_0 accepted at 1% level
Max-Eigen statistic					
r = 0	r =1	22.5559**	18.96	23.65	H_0 rejected at 1% level
r = 1	r =2	8.7084	12.52	16.26	H_0 accepted at 1% level

*** and ** denotes rejections of the null hypothesis at 1% and 5% levels of significance respectively.

The Lambda trace statistic shows that at r=0 the estimated value 31.26 is greater than the critical value of 30.45 at 1% level indicating rejection of null hypothesis that there is no co-integration equation. At r=1 the estimated value of Lambda trace statistic 8.71 is less than its critical value of 16.26 at 1% level which means that we cannot reject that only one co-integration equation exits. Maximum Eigen-value statistic also confirms that there is only one co-integrated equation. Therefore, it is confirmed that the variables are co-integrated with the rank of one, (r=1) and the VECM is the appropriate model with the dataset, lnGDP and lnAGDP. Alama and Wadud (2017and Rahman and Hossain (2014) also observed one co-integration vector among real GDP and real AGDP.

Vector Error Correction Model

Since the variables lnGDP and lnAGDP were co-integration with rank of one, (r=1) the VECM was constructed. While running VECM the non-stationary level data was used as VECM automatically converts all variables into first difference within the system. The VECM with different trend options and lag lengths were tested. It was observed that only the VECM with restricted trend at lag 6 produced consistent and efficient results.

Lag length selection

In time series analysis selection of an appropriate lag length is crucial to avoid misspecification of the model. Various methods are used for selecting optimal lag length. The commonly used criteria are Sequential Modified Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Bayesian Information Criterion (SBIC) and Hannan-Quinn Information

Criterion (HQIC). The results for lag length selection using the above-mentioned criteria are presented in **Table 4**.

Table 4: Lag order selection by different criteria

lags	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	55.330	-	-	-	.000192	-2.883	-2.852	-2.79585
1	217.545	324.42	4	0.000	3.7e-08	-11.435	**-11.343***	**-11.174***
2	**-11.174***	8.2934	4	0.081	**3.7e-08***	**-11.443***	-11.289	-11.007
3	223.046	2.7089	4	0.608	4.3e-08	-11.299	-11.085	-10.690
4	225.437	4.7819	4	0.310	4.7e-08	-11.213	-10.936	-10.429
5	229.149	7.4234	4	0.115	4.9e-08	-11.197	-10.859	-10.239
6	233.948	**9.5983***	4	0.048	4.8e-08	-11.240	-10.841	-10.108
7	238.623	9.3505	4	0.053	4.8e-08	-11.277	-10.816	-9.971

The FPE and AIC selects lags 2 while HQIC and SBIC selects lag 1. The lag length recommended by LR information criterion is 6. Since the conflicting lag length were recommended by different information criteria, diagnostic check for different lag length were carried out applying Lagrange-Multiplier (LM) Test. The results of LM tests presented in **Table 5** revealed that there were auto-correlations at lag order for 1-5 lags while for lag 6 as recommended by LR there was no auto-correlation up to 36 lags. Therefore, optimal lag length of 6 was selected for VECM.

Table 5: Diagnostic Check for Different Lag Lengths used

lag	VECM (1 lag)		VECM (2 lags)		VECM (2 lags)		VECM (4 lags)		VECM (5 lags)		VECM (6 lags)	
	LM-Stat	P-values	LM-Stat	P-values	LM-Stat	P-values	LM-Stat	P-values	LM-Stat	P-values	LM-Stat	P-values
1	2.245	0.691	18.181	**0.001**	3.025	0.554	1.004	0.909	10.794	**0.029**	2.710	0.607
2	3.604	0.462	3.964	0.411	3.591	0.464	1.257	0.868	4.084	0.394	2.799	0.592
3	0.664	0.956	4.678	0.322	0.406	0.982	11.385	**0.023**	5.934	0.204	6.489	0.165
4	3.096	0.542	4.033	0.402	3.304	0.508	4.169	0.383	4.329	0.363	2.303	0.680
5	9.586	**0.048**	7.929	**0.094**	9.944	**0.041**	10.353	**0.035**	8.854	**0.065**	1.828	0.767
6	3.249	0.517	1.297	0.862	3.211	0.523	1.565	0.815	3.426	0.489	4.112	0.391

Results of Vector Error Correction Model

Different options of VECM were examined and it was found that the VECM with restricted trend at lag 6 provided consistent and efficient estimates. The restricted trend is applied with dataset when the trends in the levels of the data are linear but not quadratic. This specification allows the co-integrating equations to be trend stationary. It is observed from time series plots (**Figure 1, Figure 2**) that the trends in real GDP and real agricultural GDP is linear not quadratic. The results of VECM are reported in **Tables 6** and **7** respectively present long-run relationships between lnGDP and ln AGDP and, short-run adjustment parameters and short-run coefficients.

Table 6: Co-integrating equation - Johansen normalization restriction imposed

beta		Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
_ce1	lnGDP	1	-	-	-	-	-
	lnAGDP	**-1.031*****	0.173	-5.968	0.000	-1.370	-0.693
	_trend	-0.021	0.005	-4.579	0.000	-0.030	-0.012
	_cons	-1.060	-	-	-	-	-

Long-run Relationship: The co-integrating equation based on beta (β) parameter of estimated VECM represents long-run stable relationship between variable of the system. Based on the findings as presented in **Table 6** the co-integrating equation between lnGDP and lnAGDP of Bangladesh during 1972-73 to 2015-16 normalized with a coefficient of unity on lnGDP is given below:

$$lnGDP = 1.0605 + 0.0209T + 1.03134\, lnAGDP$$

The estimated coefficient of lnAGDP is positive and significant at 1% level. This implies that there is a long-run equilibrium relationship between GDP and agricultural GDP and a 1% increase in real agricultural GDP will lead to increase the real GDP by 1.03%. The rate of increase in real GDP is greater than that of real agricultural GDP which demonstrates that there are strong forward and backward linkage effects of agricultural growth on the GDP growth in Bangladesh. It is relevant to mention that Razzaque and Raihan (2012) observed significant spiller over effects of agriculture on other sectors of the economy. A positive and significant time trend is also observed in the co-integrating equation.

Short-run Relationship: The error correction terms (ECT) in VECM report the rate of short-run adjustment of the variables of lnGDP and lnAGDP. The parameters of the individual adjustment of the variables in the short run towards the long-run equilibrium are shown in **Table 7**. The value of the coefficients alpha (α) of ECTs for lnGDP and lnAGDP is -0.1981 and -0.2429 respectively. Both coefficients of ECTs are negative which is consistent with theory. The significant value of the coefficient of ECT indicates that the rate of adjustment of previous disequilibrium of lnGDP to its long-run equilibrium is 19.81% per annum by the joint contribution of lnAGDP and lnGDP. On the other hand, the rate of adjustment of previous disequilibrium of lnAGDP to its long-run equilibrium is 24.29% per annum by the joint contribution of lnGDP and lnAGDP. Since both ECTs are negative and significant, there is a long-run bi-directional causality running from lnAGDP to lnGDP and vice-versa. Similar finding was observed by Alama and Wadud (2017 while Rahman and Hossain (2014) reported uni-directional causality running from agriculture to economic growth. The obtained estimates of short-run parameters of the lagged variables are not very informative since those are not significant.

Table 7: Adjustment and Short-run Parameters of VECM

Element		lnGDP				lnAGDP			
		Co-efficient	Standard errors	z-statistics	P-Value	Co-efficient	Standard errors	Z-statistics	P-Value
ECT (L1. _ce1)		-0.1981***	0.049	-4.07	0.000	-0.2429**	0.1131	-2.15	**0.032**
lnGDP	LD	-0.183	0.203	-0.91	0.365	-0.852	0.471	-1.81	0.071
	LD2	**0.117**	0.217	0.54	0.589	**0.641**	0.505	1.27	0.204
	LD3	-0.031	0.184	-0.17	0.866	-0.086	0.428	-0.20	0.842
	LD4	-0.116	0.159	-0.73	0.466	**0.123**	0.371	0.33	0.740
	LD5	**0.234**	0.148	1.58	0.114	**0.533**	0.344	1.55	0.121
lnAGDP	LD	-0.022	0.105	-0.21	0.836	-0.002	0.244	-0.01	0.994
	LD2	-0.231	0.110	-2.10	0.036	-0.448	0.256	-1.75	0.080
	LD3	-0.058	0.103	-0.57	0.572	-0.189	0.238	-0.79	0.428
	LD4	-0.112	0.098	-1.15	0.251	-0.220	0.227	-0.97	0.332
	LD5	-0.216	0.096	-2.26	0.024	-0.687	0.222	-3.09	0.002
Constant		0.008	0.010	0.88	0.376	-0.007	0.022	-0.31	0.756

Table 8: Results of ADF Unit Root or Non-stationarity Test of ce1

ADF Model	Variable	Test Statistic	Lag length	P-value	Critical values		
					1%	5%	10%
With Trend	ce1	-5.001***	3	0.0002	-4.24	-3.540	-3.204

(H_0 = There is a unit root in the series or the series is non-stationary)
*** indicates significant at 1% level.

Post-estimation specification testing
The parameter estimates of any model should be consistent and efficient. To check the consistency and efficiency of the estimated VECM, various diagnostic tests namely VECM residuals stationarity test, Eigen-value stability test, LM test for serial correlation/auto-correlation in the residuals of the estimated VECM and the normality test were performed.

VECM Residuals Stationarity Test: Inference on the parameters in α(alpha)of VECM depends crucially on the stationarity of the co-integrating equations. Therefore, correct specification of the VECM model should be tested. The result of ADF test confirms that the residuals of the co-integrating equation are stationary at 1% level (**Table 8**).

Eigen-value stability Condition: For a stable VECM model, the Eigen-values of the companion matrix of a VECM with K endogenous variables and r co-integrating equations should have (K – r) unit Eigen-values. If the moduli of the remaining r Eigen-values are strictly less than 1 (one) it will ensure correct specification of the number of co-integrating equations and stability of the process. Since here we have two (K) variables and 1(one) co-integrating equation there will be only one unit Eigen-value. From the Eigen-value stability test, it is evident that only one Eigen-value of the companion matrix of the VECM equals to unity and none of the remaining Eigen-values is greater than one. The graph of the Eigen-values (**Figure 3**) shows that none of the remaining Eigen-values appears close to the unit circle. Therefore, the stability check does not indicate that our model is mis-specified.

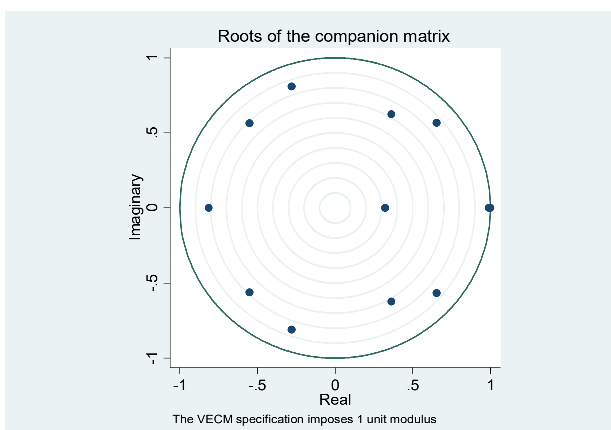


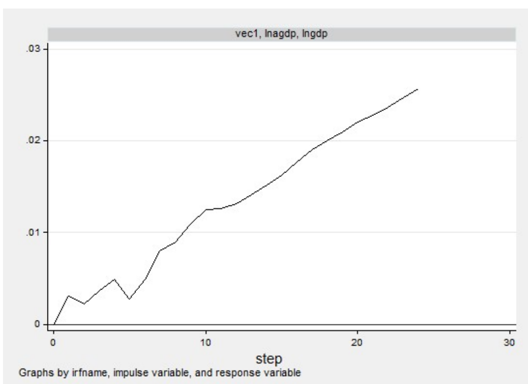
Figure 3: Roots of the companion matrix

Serial correlation LM test: Auto-correlation in the residuals of the estimated VECM was checked by means of LM test which confirms that there is no autocorrelation at lag order up to 36 lags at 1% level. Therefore, the estimated VECM is free from serial correlation at lag order and is well specified.

Normality test: It is assumed that the errors are independently, identically, and normally distributed with zero mean and finite variance. If the errors do not come from a normal distribution but are just independently and identically distributed with zero mean and finite variance, the parameter estimates are still consistent, but they are not efficient. The Jarque-Berat test was performed to the null hypothesis that the errors are normally distributed. The Jarque-Bera statistic was found insignificant at 1%level and the errors were not skewed and kurtotic at 1% level of significance.

Impulse–response functions (IRFs) for VECMs

Impulse response functions are employed to investigate reaction of variables to each other using same orders of variables due to sensitivity. The I(1) variables modeled in a co-integrating VECM are not mean reverting, and the unit moduli in the companion matrix imply that the effects of some shocks will not die out over time. When the effect of a shock dies out over time, the shock is said to be transitory. When the effect of a shock does not die out over time, the shock is said to be permanent. The results of orthogonalized impulse response function analyses derived from the estimated VECM indicate the response of one standard deviation shock in lnAGDP on the lnGDP of the system and vise-versa (**Figure 4)**.



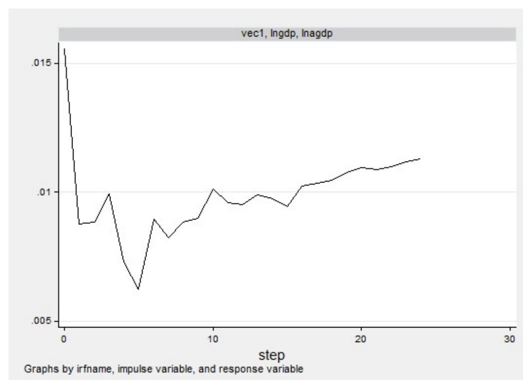


Figure 4: Graphical presentation of impulse response functions (orthogonalized)

The graphs indicate that an orthogonalized shock to the lnAGDP has a permanent effect on the lnGDP while an orthogonalized shock to the lnGDP has a transitory effect on lnAGDP at the initial stage which becomes permanent in the later stage. It is revealed that responding to a positive shock in lnAGDP, the lnGDP gradually increases while due to shock in lnGDP, the lnAGDP decreases in the initial stage and increases gradually thereafter.

Forecasting with VECMs

Co-integrating VECMs are also used to produce forecasts of both the first-differenced variables and the levels of the variables. The variances of the forecast errors in levels of a co-integrating VECM diverge with the forecast horizon (Lutkepohl, 2005). Since all the variables in the model for the first differences are stationary, the forecast errors for the dynamic forecasts of the first differences remain finite. In contrast, the forecast errors for the dynamic forecasts of the levels diverge (grow) to infinity. The dynamic forecasts in the levels of the variables, lnGDP and lnAGDP, are obtained and graphed along with their asymptotic confidence intervals. As expected, the widths of the confidence intervals grow with the forecast horizon (**Figure 5**).

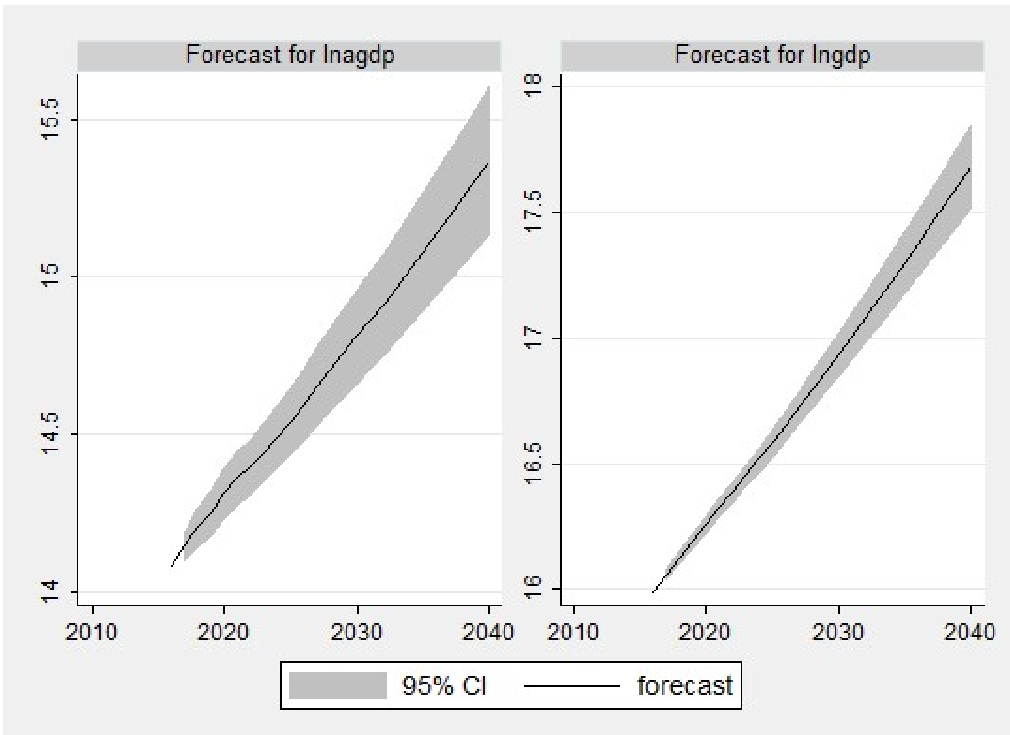


Figure 5: Dynamic forecasts of lnGDP and lnAGDP

IV. CONCLUSIONS AND POLICY IMPLICATIONS

Time series data of real gross domestic product (GDP) and real agricultural GDP for the 1972-73 to 2015-16 was used to investigate the relationship between GDP and agricultural GDP of Bangladesh which are respectively used as proxies for economic development and agricultural development. The Augmented Dicky-Fuller (ADF) test and Phillips-Perron (PP) test revealed that the real GDP and real agricultural GDP were non-stationary. However, both were found co-integrated with the rank of one indicating that VECM is appropriate to investigate existence of long-run and short-run relationships between GDP and agricultural GDP of Bangladesh during the period mentioned above. The coefficient (beta) of estimated long-run equilibrium equation was positive and significant implying a long-run equilibrium relationship between GDP and agricultural GDP. A positive and significant time trend was also observed in the co-integrating equation. Both coefficients (alpha) of the error correction terms (ECTs) in the VECM, which indicate the rates of short-run adjustments towards the long-run equilibrium, were negative and significant confirming consistency with the theory. Since both ECTs were negative and significant, there was a long-run bi-directional causality running from agricultural GDP to GDP and vice-versa. Similar finding was observed by Alama and Wadud (2017 while Rahman and Hossain (2014) reported uni-directional causality running from agriculture to economic growth.

The obtained estimates of short-run parameters of the lagged variables are not very informative since those are not significant. Consistency and efficiency of the model were examined by employing various post-estimation specification tests which confirmed that the model was rightly specified and therefore, the estimated parameters were found suitable for forecasting. The impulse response functions revealed that responding to a positive shock in agricultural GDP, the GDP gradually increases while due to shock in GDP, the agricultural GDP decreases in the initial stage and thereafter increases gradually. The findings confirm that although the share of agriculture in GDP shows gradual decline it played a key role in economic development of Bangladesh during 1972-73 to 2015-16. Considering the sub-sectoral GDP contribution as well as strong forward and backward linkage and spillover effects of agriculture with rest of the sectors of the economy and within the agricultural sub-sectors, Bangladesh needs to adopt conducive policy toward high-value agriculture, including horticulture, livestock, poultry and fisheries supported by human resource development, product innovation and diversification, and quality research and extension services. This would certainly help to foster future growth and further poverty reduction and thereby to contribute smooth transition of Bangladesh towards a middle-income country by 2021 and a developed country by 2041.

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Appendix 1: Real GDP and Real agricultural GDP (Base year 2005-06)

Sl	Period	Annual growth of AGDP	Annual growth of GDP	Real AGDP (Million BDT)	Real GDP (Million BDT)	lnAGDP	lnGDP
1	1972-73			358,585	1,226,086	12.79	14.02
2	1973-74	6.44	9.59	381,678	1,343,667	12.85	14.11
3	1974-75	-4.56	-4.09	364,273	1,288,711	12.81	14.07
4	1975-76	8.39	5.66	394,836	1,361,652	12.89	14.12
5	1976-77	-3.66	2.67	380,385	1,398,008	12.85	14.15
6	1977-78	7.83	7.07	410,169	1,496,848	12.92	14.22
7	1978-79	-0.66	4.8	407,462	1,568,696	12.92	14.27
8	1979-80	0.16	0.82	408,114	1,581,560	12.92	14.27
9	1980-81	3.31	3.74	421,622	1,640,710	12.95	14.31
10	1981-82	1.01	2.69	425,881	1,684,845	12.96	14.34
11	1982-83	3.94	4.05	442,661	1,753,081	13.00	14.38
12	1983-84	4.87	5.41	464,218	1,847,923	13.05	14.43
13	1984-85	0.27	3.04	465,472	1,904,100	13.05	14.46
14	1985-86	3.31	4.34	480,879	1,986,738	13.08	14.50
15	1986-87	0.14	3.64	481,552	2,059,055	13.08	14.54
16	1987-88	-0.57	2.03	478,807	2,100,854	13.08	14.56
17	1988-89	-0.26	2.44	477,562	2,152,115	13.08	14.58
18	1989-90	9.37	5.78	522,310	2,276,507	13.17	14.64
19	1990-91	2.23	3.24	533,957	2,350,266	13.19	14.67
20	1991-92	2.46	4.35	547,093	2,452,502	13.21	14.71
21	1992-93	2.53	4.34	560,934	2,558,941	13.24	14.76
22	1993-94	0.85	4.19	565,702	2,666,161	13.25	14.80
23	1994-95	-0.3	4.61	564,005	2,789,071	13.24	14.84
24	1995-96	3.1	4.47	581,489	2,913,742	13.27	14.88
25	1996-97	-	-	607,765	3,044,565	13.32	14.93
26	1997-98	-	-	631,682	3,202,183	13.36	14.98
27	1998-99	-	-	638,201	3,351,731	13.37	15.02
28	1999-00	-	-	704,696	3,529,149	13.47	15.08
29	2000-01	-	-	724,131	3,708,331	13.49	15.13
30	2001-02	-	-	723,270	3,850,478	13.49	15.16
31	2002-03	-	-	752,084	4,032,974	13.53	15.21
32	2003-04	-	-	789,489	4,244,282	13.58	15.26
33	2004-05	-	-	824,487	4,521,686	13.62	15.32
34	2005-06	-	-	869,847	4,823,370	13.68	15.39
35	2006-07	-	-	928,062	5,163,832	13.74	15.46
36	2007-08	-	-	969,768	5,474,373	13.78	15.52
37	2008-09	-	-	1,003,381	5,750,562	13.82	15.56
38	2009-10	-	-	1,065,108	6,070,972	13.88	15.62
39	2010-11	-	-	1,112,573	6,463,423	13.92	15.68
40	2011-12	-	-	1,146,109	6,884,932	13.95	15.74
41	2012-13	-	-	1,174,360	7,298,965	13.98	15.80
42	2013-14	-	-	1,225,702	7,741,361	14.02	15.86
43	2014-15	-	-	1,266,497	8,248,624	14.05	15.93
44	2015-16	-	-	1,301,785	8,835,389	14.08	15.99

Source: Growth rates: 1973-74 to 1979-80(BBS, 1993), 1980-81 to 1989-90(BBS, 2001) and1990-91 to 1995-96 (BBS, 2001).Real GDP and real agricultural GDP: 1995-96 to 2015-16 (BBS, 2014; BBS, 2017). 1972-73 to 1994-95: Derived by back calculation based on the latest available growth rates.