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LONG RUN DETERMINANTS OF CEREAL PRODUCTION IN ETHIOPIA: DOES CO_2 EMISSION MATTER?

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Abstract

The study employed vector error correction model to examine the long run relationship between climate change and cereal production using time series data (1962-2014) in Ethiopia. The cointegrating equation shows that the parameters included in the model are jointly significant at 1% significant level. The study revealed that a *10% percent increase in* CO_2 *emission would have 2.75 % cereal production loss in the country. However, land and fertilizer were found to have positive and significant long-term impact on cereal production in the country. The forecasted cereal production - using contingent equation – shows that cereal production is expected to grow annually by 2.8%, on average, for the next 10 years. As a concluding remark, efforts towards reducing* CO_2 *should be strengthened to further enhance the cereal production growth in the country. Moreover, providing fertilizer for the farmers with a reasonable price on due time is decisive to benefit from intensive agriculture.*

Key Words: *Cereal crops,* CO_2 *emission, climate change, Ethiopia, vector error correction model.*
Jel Codes: Q18

1. Introduction

Intergovernmental Panel on Climate Change (IPCC) defines climate change as a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, due to natural variability or as a result of human activity (IPCC, 2007). Carbon dioxide (CO_2) – which is amongst the major greenhouse gases – is considered as a driving factor of climate change (Pervez, Ghulam & Khan, 2015) mainly because the rise in the concentration of CO_2 in the atmosphere is likely to cause an increase in temperature (Neenu, Biswas & Rao, 2013). And this is among the most important problems facing the world agriculture.

However, there has been a tendency in the climate economics literature in recent years (IPCC 2007; Khan, Kumar, Hussain & Kalra, 2009) to downplay this risk, and even to argue that a couple of degree celsius (°C) warming might benefit world agriculture (Cline 2008). Scientifically, the direct effect of CO_2 positively benefits plants in two ways (Pervez, et al., 2015). First, it increases the photosynthesis process in plants – termed as carbon dioxide fertilization effect (Khan, et al. 2009). Second, increased level of CO_2 in the atmosphere decreases the transpiration by partially closing of stomata and hence declines the water loss by plants. Both aspects enhance the water use efficiency of plants causing increased growth. But researchers in the other group (e.g. ICPP, 2007; Neenu, et al. 2013) showed that the impact of climate change is different for different geographic areas. Specifically, the increase in temperature, which could happen due to increasing CO_2 concentration, has a negative impact in tropical and subtropical regions but positive in temperate regions. Hence, this research was motivated to study the net effect of CO_2 emission on cereal production of Ethiopia – a country which lies wholly in tropics – with a prior negative premise.

Ethiopian economy is heavily dependent on agriculture. And, despite all the challenges, the growth of agricultural sector in Ethiopia has been witnessed in the last decade (IFDC, 2012; World Bank, 2014). Different researchers associate the sources of agricultural growth to different factors, such as land and labor expansion (Fantu, Guush & Alemayehu, 2015), total road network (Worku, 2011), and area under irrigation, usage of manure and access to improved variety (Gutu, Bezabih & Menistu, 2012). However, research on estimating the economic impacts of CO_2 emissions are limited (Dawit, et al., 2016). Most importantly, the fact that the agriculture is dominantly rain-fed makes the possible consequence of climate change worse. Moreover, even though there are studies (e.g. Dawit, et al. 2016; Joshua, Esin, & Kamal, 2016; Tonkaz, Dogan & Kocyigit, 2010) done on identifying the (long term and short term) causes of agricultural production both in Ethiopia and elsewhere, the long run effect of CO_2 emission on production and productivity is less studied.

The purpose of this research is two-fold. First, the study examines the net effect of CO_2 emission on total cereal production in Ethiopia. Second, it also attempts to identify the long-run determinants of cereal production in the country. The current study gives special attention to cereal production mainly for two reasons. (i) despite the production potential in the country, Ethiopia has imported 900 thousand metric ton of wheat annually for the last three consecutive years – to fill the demand and supply gap in the domestic market (Abu, 2015). (ii) cereals account 87% of the total crop production in the country (CSA, 2015). Hence, improving cereal production will have an immense impact in terms of enhancing the agricultural productivity in general and total grain supply in particular.

The remaining section of the paper develops as follows. The next section explains the data and data source. Section three illustrates estimation strategy and section four discuss results of the study. Section five concludes with policy implications.

2. Data and Descriptive Statistics

The study primarily uses a time series data (1962 to 2014) from the online available World Bank database. However, Ethiopian Central Statistic Authority (CSA) and published journals are also consulted.

Total cereal production is measured in thousands of metric tons. The average cereal production, for the study period, is 7893.8 thousand of metric ton. As presented in Appendix 1, the production shows radical increment starting from 2000. In 2014, the total cereal production in the country was 23,607 thousand metric ton. Land allocated for cereal production was relatively lower from late 1970 to 1990 but has shown an increasing trend – with yearly fluctuations – after 2000 (Appendix 2). On average, a total of nearly 6.4 million hectares of land was allocated for cereal production in the country. The fertilizer consumption in the country has increased from 1200 metric ton in 1961 to 326,583 metric ton in 2013. And the average consumption of fertilizer, for the study period, is 131,112 metric ton.

In this study, CO_2 emission refers to those stemming from the burning of fossil fuels and the manufacture of cement. And the carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring (World Bank, 2015). There has been an increasing trend in the total amount of CO_2 emitted every year, compared to less than 400 kiloton emission level in the beginning to the study period (Appendix 1). The result shows that, over the study period, on average, there is an emission of 2830.5 kiloton of CO_2 annually.

Table 1. Definition and Summary of Variables

Variables	Unit	Observation	Mean	Std. Dev.
Cereal Production	1000 metric ton	54	7893.8	4869.1
Land	1000 Hectare	54	6452.6	1779.9
Fertilizer	Metric ton	53	131112.2	160987.2
CO_2 emission	Kilo ton (Kt)	52	2830.5	1940.00

Source: Own computation from World Bank data (1962-2014)

3. Estimation Strategy

The main interest of this study is to examine the impact of CO_2 emission on total cereal production. Considering the lack of consistent long years of time series data on some of the agricultural inputs (e.g. seed and labor) the study used fertilizer and land together with CO_2 emission as major determinants of cereal production in Ethiopia.

Hence, the conventional Cobb Douglas production function can be specified as:

$$LnY_t = \beta_o + \beta_1 LnL_t + \beta_2 LnF_t + \beta_3 LnCO_{2\ t} + e_t. \qquad (1)$$

where *Ln* denotes to natural log, *Y* refers to total cereal production in thousands of metric ton; *L* is area of land allocated for cereal production measured in thousands of hectares; *F* is total fertilizer used in metric ton; CO_2 is total carbon dioxide emission measured in Kt; $\beta_0,$ β_1, β_2 and β_3 are parameters to be estimated; t indexes year and e is an error term.

The standard regression techniques, such as ordinary least squares (OLS), require the variables to be covariance stationary. A variable is covariance stationary if its mean and all its autocovariances are finite and do not change over time. Instead of being covariance stationary, many economic time series variables are not stationary at levels (StataCorp., 2013b). And if all variables are not stationary at levels, an alternative estimation method should be used.

To solve the possible problem of misspecification, if any, an error correction model called Vector Error Correction (VEC) is employed. Following Engle and Granger (1987) the error correction model can be specified as:

$$\Delta LnY_t = \beta o + \sum_{i=1}^{mi} \beta_{1i} \Delta LnY_{t-1} + \sum_{i=0}^{mi} \beta_{2i} \Delta LnL_{t-i} + \sum_{i=0}^{mi} \beta_{3i} \Delta LnF_{t-i} + \sum_{i=0}^{mi} \beta_{4i} \Delta LnCO_{2\ t-i} + \delta\varepsilon_{t-1} + \eta_t \qquad (2)$$

where *βs* are parameters to be estimated, Δ represents the change (e.g. $Y_t - Y_{t-1}$), *m* is the number of lags, *δ* is the speed of adjustment parameter, ε_{t-1} is one-period lag error correction term; *η* refers to an error term with zero mean.

The long run equation can be extracted from the error correction model, as the error correction term is the OLS residual serious of the long run cointegration equation:

$$LnY_t = \gamma_o + \gamma_1 LnL_t + \gamma_2 LnF_t + \gamma_3 LnCO_{2\ t} + \rho_t \qquad (3)$$

where, $\gamma_0, \gamma_1, \gamma_2,$ and γ_3 are parameters to be estimated; ρ is the disturbance term with expected value of zero and others are as defined earlier.

4. Result and Discussion

Result of the conventional production function, presented in table 2, shows that land and fertilizer are the determinants of cereal production in Ethiopia. But CO_2 emission doesn't have a detectable effect on the total cereal production. The model output revealed that the variables explain more than 85% of the variation in cereal production.

Table 2. Estimated production function using OLS

Variables(log)	Coefficient	Std. Err.	t value
Land	0.878	0.108	8.12***
Fertilizer	0.112	0.036	3.13***
CO_2 emission	0.053	0.087	0.548
Constant	-0.495	0.797	0.537
Number of observations	51		
Adj. R^2	85.15		

Note: *** refers to 1% significance level.

However, this result has a strong prior assumption – all variables considered in the model are stationary at level. Hence, it is important to test the stationarity of the variables to argue that results using the ordinary least square regression are robust. Graphing the variables over time can help to observe the trend of the variables as an indication of stationarity. As shown in figure 1, cereal production at level (the figure on the left) was not stationary. But after differencing (the figure on the right) the variable was nearly stationary.

Figure 1. Trends of level and differenced cereal production in Ethiopia (1962-2014)

Despite the graphical representation, all the variables considered in the model are tested against stationarity using Augmented Dickey-Fuller (ADF) test – the common method of testing unit root – with a constant and trend. The decision criterion of testing stationarity is to compare the test statistics with the conventional level of critical values. And if the value of test statistics in absolute value is greater than 5% critical value, the null hypothesis of no stationarity will be rejected – implying that the variable is stationary.

Table 3. Stationarity Test of Variables

Variable (log)	Level		First difference		Order of integration
	test statistic	5% critical value	test statistic	5% critical value	
Cereal Production	-1.566	-3.497	-7.34***	-3.498	I (1)
Land	-1.58	-3.497	-8.04***	-3.498	I (1)
Fertilizer	-2.13	-3.498	-7.52***	-3.499	I (1)
CO_2 emission	-2.77	-3.499	-7.30***	-3.50	I (1)

Note: *** refers to 1% significance level.

Stationary test, presented in table 3, shows that all variables are not stationary at levels, implying that one cannot use ordinary least square estimation method. Hence, the study employs VEC model which account for non-stationarity at level. The most common methods to transform the variables to meet stationarity condition include differentiating, detrending and transforming to the log form. For this research combination of log transformation and differencing methods are used to change the variables into their stationary form. The VEC model requires all variables to be non-stationary at level but stationary at first difference. Accordingly, the unit root test done using ADF proves that it is appropriate to use VEC model in this study.

The next step in estimating the long-run relationship is, to determine the lag length. Gonzalo (1994) indicate that under specifying the number of lags in a VEC models can significantly increase the finite sample bias in the parameter estimates and leads to serial correlation. Hence, I estimate the lag using different selection criteria (Table 4).

Table 4. Lag Selection Criteria

Lag length	Cereal Production			
	LR	AIC	HQIC	SBIC
0	NA	2.63	2.69	2.79
1	327.41	-3.64*	-3.34*	-2.86*
2	10.12	-3.18	-2.64	-1.76
3	28.73	-3.11	-2.34	-1.06
4	35.77*	-3.19	-2.18	-0.51

Notes: *shows the optimum lag chosen by the criteria; LR refers to log likelihood; AIC = Akaike information criterion; SIC = Schwarz information criterion; HQIC = Hannan-Quin information criterion.

The SBIC and HQIC methods measure the discrepancy between the given model and the true model, which of course, has to be minimized. And they have a theoretical advantage over other criteria of lag selection (StataCorp., 2013b). Three out of four lag selection criteria recommend using one lag in estimating the level of cointegration in VEC model. Hence, for this study lag order of one is used to estimate the cointegrating model.

The fact that the time series variables under consideration are non-stationary at level implies that the regression result using these variables in the classical framework leads to spurious regression unless their linear combination produces a stationary residual (Gujarati, 2004). Hence, a Johansen test of cointegration is applied to test for potential long term relationship amongst the variables. Test of cointegration – presented in table 5 – confirmed that the variables are cointegrated.

Table 5. Johansen Multivariate Test of Cointegration

Maximum Rank (r)	**Null Hypothesis**	**Parameters**	**Trace stat. (5% Critical Value)**	**Max stat. (5% Critical Value)**
0	Ho: r = 0	4	59.27** (47.2)	40.17(27.07) **
1	Ho: r ≤ 1	11	19.09 (29.68)	11.45 (20.97
2	Ho: r ≤ 2	16	7.64 (15.4)	7.63 (14.07)
3	Ho: r ≤ 3	9	0.01(3.76)	0.01 (3.76)
4	Ho: r ≤ 4	0	-	-

Note: ** The statistics value is less than the 5% critical value and hence reject Ho.

There are two test statistics in Johansen test of cointegration, trace statistics and max statistics. The decision rule for both statistics is that when these statistics values are greater than the 5% critical value, the null hypothesis saying there is at least r level of cointegration, starting from r = 0 of no cointegration, will be rejected. Accordingly, result from both statistics rejects the null hypothesis of no cointegration, confirming the optimum maximum rank to be one.

Table 6. Summary Result of VEC Models

Dependent Variable (Δ Ln)	**Constant**	**ECT_1**	**R^2**	**Chi^2**
Cereal Production	0.054***	-0.50***	0.54	56.98***
Land	0.007	0.03	0.01	0.61
Fertilizer	0.11**	0.35	0.19	11.34***
CO_2 emission	0.07**	-0.15	0.13	6.87**

Note: *** and ** refers to 1% and 5% significance level respectively.

Table 6 presents the summary of VEC models which take each variable – both the dependent and explanatory variables in equation 1 – as a dependent variable to estimate independent regression outputs. The VEC model allows the long-run behavior of the endogenous variables to converge to their long-run equilibrium while allowing a wide range of short-run dynamics (Mukhtar & Resheed, 2010). In confirmation with this, the coefficient of the error correction term (ECT_1) of cereal production do have the expected negative sign and it is significant at 1% significance level. Hence, for this model in the short run, cereal production is adjusted by 50% of the past year deviation from equilibrium. This confirms the stability of the model.

The Johansen test of cointegration confirms that there is a long-term relationship between variables, hence the estimation of the determinants of cereal production, cannot be estimated using the conventional OLS method rather an error correcting model. Accordingly, VEC model results of the long run relationship between cereal production and exogenous (land, fertilizer and CO_2 emission) variables is presented in table 7 below. The values in table (7) are subject to the Johansen normalization restriction, in a sense the coefficients which are very close to zero and one are constrained to be zero and one respectively, for normalization which will yield the same maximized log likelihood (StataCorp., 2013b). The cointegration equation indicates that the three parameters included in the model are jointly significant at 1% significant level, with Chi^2 value of 321.21. Moreover, post-estimation tests (Appendix 3) confirmed that there is no enough evidence at 5% significance level to reject the null that claims no autocorrelation and errors are normally distributed. Hence, generally, the output and tests indicate that the model fits well and results are robust.

Table 7. Cointegrating Equation of Long Term Determinants of Cereal Production

Beta (log)	**Coeff.**	**Std. Err**	**P Value**
Cereal production	1		
Land	-1.304	0.118	0.000***
Fertilizer	-0.247	0.039	0.000***
CO_2 emission	0.275	0.094	0.003***
Constant	3.173		
Chi^2 value	321.21		0.000***
Parameters	3		
Observations (years)	52		

Note: *** refers to 1% significance level.

More formally, the long run cointegration equation can be written as:

$$\mathrm{Pr}oduction = -3.173 + 1.304Land + +0.247Fertilizer - 0.275CO_2$$

Table 7 presents the main results of this study. CO_2 emission – which is the main aggravating factor of climate change – has a negative and significant impact on cereal production in Ethiopia. Specifically, increase in the total CO_2 emission by 10 percentage points is associated with 2.75% decline in the total cereal production in the country. This result is in line with Joshua et al. (2016), Amponsah, Glory, and Samuel (2015) and Dawit et al. (2016) but contrary to Tonkaz et.al. (2010). Given the prior premise of the negative impact of climate change on developing countries economy, as stated in IPCC (2007), it was not surprising that its impact on cereal production of Ethiopia is negative.

Agriculture is the most vulnerable sector to climate change (Harry, Kaiser, Riha, David & Radha, 1993; Pervez et al. 2015) and unless measures are taken to curb CO_2 emission, agricultural productivity would fall dramatically, especially in developing countries (Clien, 2008). However, Christoph et al. (2015) got a promising result saying aggressive mitigation could eliminate up to 81% of the negative impacts of climate change on biophysical agricultural productivity globally by the end of the century. Hence, the current effort of the Ethiopian government in implementing Climate Resilient Green Economy (CRGE) strategy – which is planned to foster development and sustainability while limiting greenhouse gas emissions by 2030 – should be strengthened.

Both conventional inputs, land and fertilizer, considered in the model were found to have a positive and significant effect on cereal production. As shown in table 7, an increase in land by 10 percentage points is attributed to 13 percentage points increase in total cereal production. Similarly, increasing the fertilizer consumption by 10 percentage points raise the total cereal production by 2.4 percentage points. This result confirms the study done by Fantu et al. (2015) which claims land and labor expansion over time to be important contributing factors for the increasing agricultural production in Ethiopia. However, as the available arable land is becoming increasingly scarce, increase in production will be driven largely by intensification of inputs rather than expansion of land area (IFDC, 2012). This makes fertilizer consumption a key element in increasing agricultural production in general and cereal production in particular.

Finally, after checking all potential econometric problems, cereal production for the period 2014-2023 is forecasted by the predicted contingent equation using STATA version 13. The total cereal production in Ethiopia is expected to increase, on average, annually by 2.8% for the next 10 years. Accordingly, the total cereal production in Ethiopia will be 18,639 thousand metric ton as of 2023.

Table 8. Forecast of Cereal production trend (2014-2023)

Production forecast	Coefficient*	Std. Err.	P value
Year	0.0278***	0.0001	0.000
Constant	-46.61***	1.176	0.000
Adj_R^2	0.99		
Number of Obs.	10		

Note: *** refers to 1% significance level; * OLS estimation using the projected yield as dependent variable.

5. Conclusion and Recommendations

This study was done with the objective of analyzing the determinants of cereal production, with special attention to CO_2 emission, in Ethiopia. The post estimation result showed that the results are robust. The cointegrating equations normalized relative to cereal production show that the three parameters (land, fertilizer and CO_2 emission) included in the model are jointly significant at 1% significant level. The study revealed that CO_2 emission has a negative and significant impact on long-run total cereal production in Ethiopia. But land and fertilizer were found to have positive and significant long-term impact, as expected. Finally, the future cereal production was forecasted by the predicted contingent equation. Accordingly, the total cereal production is expected to increase, on average, by 2.8% annually for the next 10 years. It should be noted that this research ignores the role of technological progress to reduce the negative impact of climate change on agricultural production.

As concluding remark, the government should strengthen its effort to implement the green economy strategy to reduce possible effect of CO_2 emission on the total grain production and supply in the economy by adopting environment-friendly substitutes of energy sources and implementing command and/or control systems for excess emission of CO_2 by manufacturing firms. Moreover, given that the total available land is limited, efforts towards increasing future cereal production and productivity should benefit from intensive use of inputs (fertilizer). Hence, it is very crucial to plan on the ways to provide fertilizer for the farmers with a reasonable price on due time.

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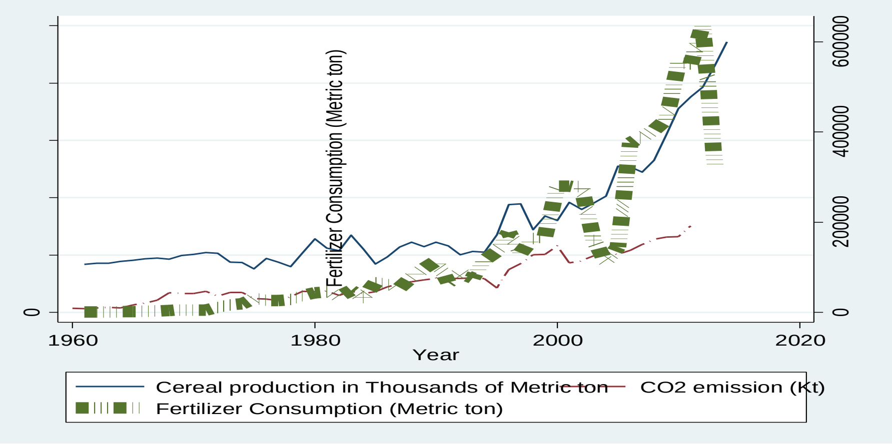
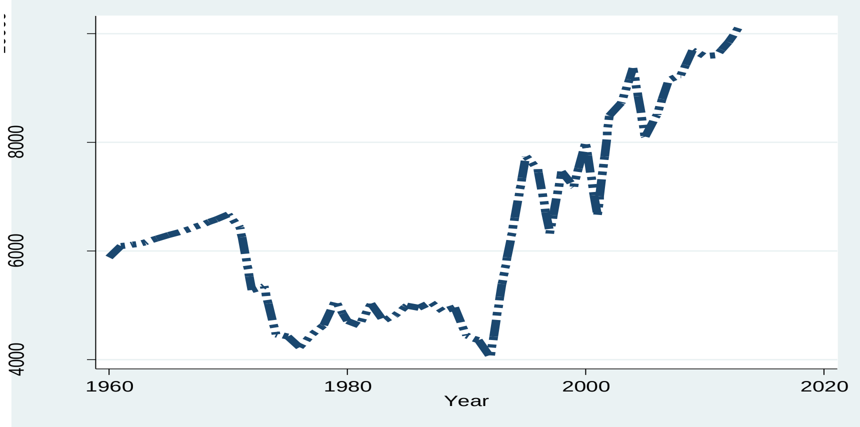
Appendix

Appendix 1 Trend of Cereal Production and CO_2 Emission (1962-2014)



Appendix 2 Land Allocated for Cereal Production in 1000 Hectares (1962- 2014)



Appendix 3 Post Estimation Diagnostics

Description	Chi^2		P value	
LM test of autocorrelation	17.79		0.33	
	11.88		0.75	
Normality Test	Chi^2	P value	Skewness	Kurtosis
J-Bera test	4.317	0.12	-	-
Skewness test	0.28	0.59	-0.18	-
Kurtosis test	4.03	0.04	-	1.57

Source: Own computation (2016