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A Random Effects Model Analysis of the Factors Contributing to Food Production Worldwide

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Abstract: Food is the substance eaten or drunk to provide nutrition for the body. Among problems faced in the food production industry are climate changes, lack of land for cultivation, inadequate resources, expensive high technology and also natural disaster. The objective of the study is to find the relevant factors that contribute more to the food production index. The relevant quantitative variables chosen for this study are Livestock Production Index, Agricultural Machinery, Land under Cereal Production and Food Export. On the other hand, Food and Agricultural Organization (FAO) membership and Tropical Climate have been used as the qualitative variables. Using Random Effects Model under Panel Data Analysis; the results indicate strong significant relationship of Livestock Production Index, Agricultural Machinery and Land under Cereal Production towards food production. It is to be concluded that most of the variables used in the study including time are significant in explaining the food production worldwide. For future studies more independent variables should be added such as employment in the agriculture sector, technology, fertilizer production, water sources, population rate and World Trade Organization (WTO) rules and regulations.

Key words: Food Production · Agriculture · Random Effects Model · Econometrics · STATA

INTRODUCTION

The right to food is a human right derived from the International Covenant on Economic, Social and Cultural Rights (ICESCR) made out in 1966 and came into force in 1976, recognizing the “right” to an adequate standard of living, including adequate food. Today, most of the food consumed by the world population is supplied by the food production industry operated by multinational corporations using intensive farming and industrial agricultural methods. It is estimated that by the year 2000, the global population will be 25% higher than that of the mid 1980s. It is also estimated that 90% of this population increase will be in developing countries. Thus, there will be an increased demand for food and agricultural products for this increased population. This also means that the use of modern agricultural machine and technology will be employed to food production [1]. Managing food production systems on a sustainable basis is one of the most critical challenges for the future of humanity, for people cannot survive without food [2]. A research by [3] discuss the effect of the outsourcing decision of different levels on perceived logistics service performance, including the moderating role that the supply chain complexity may play in a proposed relationship. In pre industrialization agriculture, production depended entirely on natural soil fertility and climatic conditions. However, the European industrial revolution in the 17th century that spread all over the world brought in new technologies for improving crop and animal agriculture [4]. Based on research [5], livestock production is undertaken in a multitude of ways across the planet, providing a large variety of goods and services and using different animal species and different sets of resources, in a wide spectrum of agro-ecological and socio-economic conditions. With a continually rising global demand for food, feed and fuel, it will become increasingly important to identify and promote policy and institutional mechanisms besides the agricultural and environmental systems already in place [6].

A study by [7] found that a concrete policy to provide sufficient tractors would help to increase agricultural productivity without replacing human labour and draught animal power. The need to increase

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agricultural production will have profound and lasting impacts on the sectors providing inputs to agriculture. One of these key sectors is the agricultural machinery industry. A study [8] made in Ethiopia, suggested that the facts about land use at the national level have potentially imposed limits on an increase in areas sown as a major source of increase in production of cereal. Many tropical developing countries are facing major challenges in successfully implementing national development goals and achieving global targets and yet they now have to deal with climate change which is another layer of constraint besides other global environmental change issues which are already limiting national development.

Culture also plays a role in the design and management of food production systems. How food production systems are designed, managed and redesigned throughout the world depends on a myriad of social and ecological factors, such as soil type, climate, water availability, pest control, genetic advances, economic incentives driven by market forces and policy and cultural influences including tastes, traditional practices and urbanization [9]. The need to raise food production should not be limited to the current status. Instead, further increases in agricultural production and productivity will be essential to meet further increases in the ever-growing future demand [10].

There are also other several factors contribute for the food production. Referred to article, [11] Small and Medium Enterprises (SMEs) have been recognized as one of the most important contributors for the economic development of many countries. Domestic livestock have played a role in human societies and evolution for the past ten thousand years, providing important sources of protein, fertilizer, fuel, traction and transport [12-13]. The future and viability of the small farms under climate change impacts and the implications for food production, the environment and the livelihood of smallholding families remain as issues of great concern both for research and policy development [14].

Therefore, the objective of this paper is to analyze the relationship between selected variables such as livestock production index, agriculture machinery and land under cereal and food export with a food production index. In addition, tropical countries and membership of FAO have been added as qualitative variables to capture the composite effect on food production.

Methodology

The Model: The model uses the panel/pooled data set of six (6) independent variables and one (1) dependent variable over a seven (7) year period from year 1999 to 2005. This study used a single equation of log-log model. As a result, the estimated coefficient can be interpreted as elasticity. Variables ln(*LIVESTOCK*), ln(*AGCMACH*), ln(*LANDUC*) and ln(*FOODEX*) are entered as quantitative variables. While (*D-FAO*) and (*D-TROPICACLI*) are treated as qualitative variables.

The log-log model is as follows:

$$\ln(FOODIN_{i,t}) = \alpha + \beta_1\ln(LIVESTOCK_{i,t}) + \beta_2\ln(AGCMACH_{i,t}) + \beta_3\ln(LANDUC_{i,t}) + \beta_4\ln(FOODEX_{i,t}) + \beta_5(D\text{-}FAO_{i,t}) + \beta_6(D\text{-}TROPICACLI_{i,t}) + u_{i,t} \quad \text{(Equation 1)}$$

Hypothesis: In the above specification, variables such as *LIVESTOCK, AGCMACH, LANDUC* and *FOODEX* estimated parameters are expected to have a positive sign. Countries that joined FAO are expected to contribute more for food production. Countries that are located at areas of tropical climate also affect the production of food.

Data Retrieval:

FOODIN - Food Production (DV): The demand for food product is shown by the food production index. The data is retrieved from World Bank: World Development Indicator 2010. The sample consists of 206 countries which come from different socio political and economic backgrounds. It is valued in index=100.

LIVESTOCK - Livestock (IV_1): The data on livestock production index is retrieved from World Bank: World Development Indicator 2010. It is valued in index=100.

AGCMACH- Agricultural Machinery (IV_2): The data for agricultural machinery is retrieved from World Bank: World Development Indicator 2010. It is valued in unit.

LANDUC - Land under cereal production (IV_3): The data for land under cereal is retrieved from World Bank: World Development Indicator 2010. It is valued in hectares.

FOODEX - Food export (IV_4): The data on food export is retrieved from World Bank: World Development Indicator 2010. It is valued in percentage (%).

D-FAO - FAO Membership (IV_5): This defines FAO membership. It is a specialized agency of the United Nations that leads international efforts to defeat hunger. Value 1 is given for countries that joined FAO as members and 0 for countries that did not join FAO.

D-TROPICACLI - Tropical climate (IV_6): Tropical climate is one of the factors that contribute a lot in food production. Value 1 is given for countries that are located at the tropical climate area and 0 for countries located at non-tropical climate area.

Data Processing: The raw data was inserted into the Microsoft Excel software to be modified due to model restrictions. All the data inserted are on a yearly basis. All the data, then, including the dependent variable were converted into a natural log value (log10) before being processed using Stata 10.1 software. Breusch and Pagan Lagrangian Multiplier test had been conducted to choose between the Pooled Ordinary Least Squares (POLS) method or Random Effects Model (REM) method. In addition, the Hausman Fixed test was also employed in order to determine the choice between Random Effects Model (REM) and Fixed Effects Model (FEM) for further analysis. From the tests conducted, the relationship between food production on one hand and the independent variables on the other is estimated using panel data analysis (REM).

RESULTS AND DISCUSSION

The descriptive statistics related to the stock index and macroeconomic variables are presented in the following Table 1. These statistics are; maximum, minimum, mean, variance, standard deviation and coefficient of variations.

The Breusch and Pagan Lagrangian multiplier test is conducted to test whether to employ pooled OLS or panel data method. With a null hypothesis pooled regression, the following results were obtained as shown in Table 2.

Based on the Chi^2 and p-value, it is apparent that the model is significant at 1% significance level, thus supporting the motion to reject the null hypothesis. Panel data (random effect) estimation will be conducted as the preferred option.

In the next step, a Hausman Fixed test is performed to recognize the appropriateness of employing either REM or FEM. The result, as illustrated in Table 3, shows that the model succeeds in meeting asymptotic assumptions of the test. Since the p value of chi2 is significant at the 1% significance level, the null hypothesis is rejected, which means that the differences between the FEM and REM coefficients are systematic. This shows that the coefficients for FEM are efficient. Therefore the FEM-Two Way Estimation is performed due to the significant p-value in the Hausman Fixed test.

Table 1: Descriptive statistics

stats	lnfoodin	lnlive~k	lnagcm~h	lnlanduc	lnfoodex	dfao	dtropi~i
max	5.894403	5.209486	15.33994	18.44442	4.60517	1	1
min	3.401197	3.912023	0	1.609438	0	0	0
mean	4.630997	4.637696	8.367688	12.5386	2.652156	.8543689	.5485437
cv	.0283989	.0220315	.4009359	.2703602	.4596922	.4130046	.9075131
sd	.1315151	.1021754	3.354907	3.389939	1.219176	.3528583	.4978106
variance	.0172962	.0104398	11.2554	11.49169	1.486389	.124509	.2478154

Table 2: Breusch and Pagan Lagrangian Multiplier test for Random Effects

```
lnfoodin[code,t] = Xb + u[code] + e[code,t]

Estimated results:
                 |       Var     sd = sqrt(Var)
        ---------+-----------------------------
        lnfoodin |   .0110308       .1050276
               e |   .0050046        .070743
               u |    .003168       .0562854

Test:   Var(u) = 0
                       chi2(1) =    58.40
                   Prob > chi2 =     0.0000
```

Table 3: Hausman Fixed test

```
             ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed          .          Difference          S.E.
-------------+----------------------------------------------------------------
  lnlivestock |   .5851944     .5888399       -.0036455        .0072042
    lnagcmach |  -.0318036    -.0083696       -.0234339        .0110925
     lnlanduc |   .1796796     .0120081        .1676714        .0162958
     lnfoodex |  -.0018727    -.0012049       -.0006678        .0020319
------------------------------------------------------------------------------
                   b = consistent under Ho and Ha; obtained from xtreg
    B = inconsistent under Ha, efficient under Ho; obtained from xtreg

 Test:  Ho:  difference in coefficients not systematic

              chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                      =      115.14
            Prob>chi2 =      0.0000
```

The result shows that three out of six independent variables are significance as presented in Table 4. Plus, two independent variables have to be dropped due to serious collinearity problem. However, according to research [15], even though FEM can estimate individual and/or time-specific effects from time- and individual-variant variables, contrastingly, it cannot detect the individual-specific effects regarding the individual-variant but time-invariant variables. The model cannot capture time-specific effects for variables which are variant over time but invariant across individuals. Thus, respective time or individual specific effects for the invariant

Table 4: FEM-Two Way Estimation

```
Fixed-effects (within) regression               Number of obs      =       925
Group variable: code                            Number of groups   =       161

R-sq:  within  = 0.4027                         Obs per group: min =         1
       between = 0.0867                                        avg =       5.7
       overall = 0.0677                                        max =         7

                                                F(4,760)           =    128.09
corr(u_i, Xb)  = -0.9863                        Prob > F           =    0.0000
```

lnfoodin	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnlivestock	.5851944	.0302979	19.31	0.000	.5257168	.6446719
lnagcmach	-.0318036	.0113989	-2.79	0.005	-.0541805	-.0094266
lnlanduc	.1796796	.016455	10.92	0.000	.1473769	.2119822
lnfoodex	-.0018727	.0038438	-0.49	0.626	-.0094184	.0056731
dfao	(dropped)					
dtropicacli	(dropped)					
_cons	-.1184221	.2708364	-0.44	0.662	-.6500984	.4132542
sigma u	.52365281					
sigma e	.07074304					
rho	.98207638	(fraction of variance due to u_i)				

F test that all u_i=0: F(160, 760) = 3.67 Prob > F = 0.0000

Table 5: Random Effect GLS regression

```
Random-effects GLS regression                   Number of obs      =       925
Group variable: code                            Number of groups   =       161

R-sq:  within  = 0.3335                         Obs per group: min =         1
       between = 0.4013                                        avg =       5.7
       overall = 0.3512                                        max =         7

Random effects u_i ~ Gaussian                   Wald chi2(7)       =    482.54
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000
```

lnfoodin	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnlivestock	.505707	.0329542	15.35	0.000	.4411179	.5702961
lnagcmach	-.0076967	.0024394	-3.16	0.002	-.0124777	-.0029156
lnlanduc	|.0116176	.0021173	5.49	0.000	.0074679	.0157674
lnfoodex	.0001356	.0031671	0.04	0.966	-.0060719	.0063431
dfao	-.0210742	.0228579	-0.92	0.357	-.065875	.0237265
dtropicacli	-.0107266	.0115783	-0.93	0.354	-.0334196	.0119665
year	.0075608	.0014267	5.30	0.000	.0047645	.010357
_cons	-12.90103	2.789259	-4.63	0.000	-18.36788	-7.434183
sigma_u	.05028058					
sigma_e	.06989872					
rho	.34099646	(fraction of variance due to u_i)				

variables are subsumed under the intercept term. An alternative FEM model expresses the specific effects for time- or individual invariant variables as random variables (error terms) in the equation, instead of expressing the fixed intercept as the unobserved effects in FEM. This is the so-called Random Effects Model (REM).

From the regression result in Table 5, time (collectively) has become the seventh independent variable and was taken into consideration for the model. Based on the p-values of the z-test, four independent variables, namely livestock production, agricultural machinery, land under cereal and year is significant at 1%. The results suggest that the livestock production and land under cereal and time are positively related to the dependent variable.

Table 6: GLS-Two Way Estimation (include individual yearly time series)

```
Random-effects GLS regression                   Number of obs      =       925
Group variable: code                            Number of groups   =       161

R-sq:  within  = 0.3409                         Obs per group: min =         1
       between = 0.4143                                        avg =       5.7
       overall = 0.3581                                        max =         7

Random effects u_i ~ Gaussian                   Wald chi2(12)      =    498.33
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000
```

lnfoodin	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnlivestock	.5000938	.0329007	15.20	0.000	.4356095	.564578
lnagcmach	-.0071503	.0023179	-3.08	0.002	-.0116933	-.0026073
lnlanduc	.011327	.0020076	5.64	0.000	.0073921	.0152619
lnfoodex	.0006912	.0031129	0.22	0.824	-.0054099	.0067922
dfao	-.0194064	.0216977	-0.89	0.371	-.061933	.0231202
dtropicacli	-.0100979	.0109553	-0.92	0.357	-.03157	.0113741
yr1	-.0471904	.0104721	-4.51	0.000	-.0677155	-.0266654
yr2	-.0403034	.0100828	-4.00	0.000	-.0600653	-.0205416
yr3	-.0397813	.0099231	-4.01	0.000	-.0592301	-.0203325
yr4	-.0421786	.0096959	-4.35	0.000	-.0611822	-.023175
yr5	-.0325814	.0096289	-3.38	0.001	-.0514536	-.0137091
yr6	-.0054859	.0094251	-0.58	0.561	-.0239587	.0129868
_cons	2.28626	.1556045	14.69	0.000	1.981281	2.59124
sigma_u	.04582431					
sigma_e	.06950957					
rho	.30294788	(fraction of variance due to u_i)				

Meanwhile, the agricultural machinery and food production are indeed, inversely related. It indicates that an increase in agricultural machinery would significantly decrease the food production index. From the results also, the time series is found to be significant, in explaining the food production index and it proves that the relation is unchanged and stable through time. The relationship is in a positive magnitude.

For a more specific time-effect, the study divides the time based on yearly time series and tests each individually and the result is shown in Table 6. Based on the significant p-values of the z-test, during this period (1999-2005), the results suggest that there is a significant impact of the selected independent variables (livestock production, agricultural machinery and land under cereal) and is unchanged and stable when the timing factor is accounted for. This GLS estimation result also suggests that the food production is related to the individual yearly time series since the p-values of the z test are significant from the first year (1999) until the 5th year (2003) and the 6th year (2004) is not significant to the food production, while during the 7th year (2005), it has dropped because of collinearity. Based on the result mentioned above, three out of six independent variables namely the livestock, agricultural machinery and land under cereal are significant with the food production index.

Meanwhile, the others independent variables are not significant towards food production index. It is supported by a study [16], that it is generally recognized that livestock has a potential to make a significant contribution to food security. It has been reported that increasing cereal production through the expansion of cultivated areas also increases the food production in many countries. The significant relationship of agricultural machinery towards food production was proven by research [7]. The study proves that a concrete policy to provide sufficient tractors would help to increase agricultural productivity without replacing human labour and draught animal power.

CONCLUSION

Applying the panel data analysis (REM), the results shows that food production is significantly influenced by all economic variables except for food export, FAO members and tropical countries. The time series factors are found to be statistically significant in influencing the dependent variable, both individually and collectively and it is stable over time. For future studies, researchers should add more independent variables such as employment in the agriculture sector, technology, fertilizer usage, water sources, population rate and World Trade Organization (WTO) rules and regulations.

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